Gokaraju Rangaraju Institute of Engineering and Technology

(Autonomous)

Department of Civil Engineering

YEAR 2019

Year	Number of Journal Publications			Number of Conference Proceedings	
	SCI	SCOPUS	UGC	SCOPUS	UGC
2019	0	42	0	2	0

JOURNAL PUBLICATIONS:

SCI JOURNALS:

NIL

SCOPUS JOURNALS:

1. **M.S. Britto Jeyakumar,** Y. Kamala Raju (2019), "Characteristics of Paper brick with Inequitable Substitution of Cement", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8 Issue-12S, pp.85-88, ISSN: 2278-3075.

2. Y.Kamala Raju**, M.S.Britto Jeyakumar,** (2019)**,** "Modulus of Elasticity on High Performance Glass Fibre RCC Beams With Partial Replacement of Cement by Silica Fume", International Journal of Innovative Technology and Exploring Engineering (IJITEE),ISSN: 2278-3075, Volume-8 Issue-10, PP No-1545-1550. ISSN: 2278-3075.

3. Swetha G, **Chandana I,** Rakesh M, (2019), **"**Pavement Overlay Design Using Falling Weight Deflectometer", International Journal of Recent Technology and Engineering (IJRTE) ,Volume-X, Issue-X, pp.1-4 ISSN: 2277-3878.

4. **G. V. V Satyanarayana,** K. Yashwanth. (2019), "Inquiry on mechanical properties of M3O grade concrete with partial replacement of copper slag and dolomite powder for fine

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5. **G.V.V.Satyanarayana,** CH.Saikiran ,(2019), " Effect on mechanical properties of M35 grade concrete by partial replacement of fine aggregate with copper slag", International journal of innovative technology and exploring engineering(IJITEE),Volume-8,Issue 12,pp. 3759-3762, ISSN:2278-3075.

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9. **Y.Kamala Raju**, M.S.Britto Jeyakumar , (2019) , "Modulus of Elasticity on High Performance Glass Fibre RCC Beams With Partial Replacement of Cement by Silica Fume", International Journal of Innovative Technology and Exploring Engineering (IJITEE),ISSN: 2278-3075, Volume-8 Issue-10, PP No-1545-1550. ISSN: 2278-3075.

10. **Y. Kamala Raju,** S. VenkatCharyulu, T.Srikanth, (2019), "Influence of support reactions on RCC building frames a computational method", International Journal Of Recent Technology And Engineering ((IJRTE), Volume-8, Issue-3 , pp.4710-4715, ISSN:2277-3878.

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Characteristics of Paperbrick with Inequitable Substitution of Cement

M.S. Britto Jeyakumar, Y. Kamala Raju

Abstract— Paper bricks are key construction materials for buildings in general and for low cost housing in particular. To keep up with sustainable development movements and increasing competitive pressure in the industry, building materials of the upcoming have to be of lesser weight, more force capable and lower cost. The use of recycled materials is also critical for long-term sustainability.

The intention of this paper is to develop lightweight paper brick from waste paper with lowest amount. The paper was hydrating and spin to obtain paper mash slurry after mixing with cement, and cast to shape. Compressive strength and water absorption were found. The results showed that investigational bricks are upper compressive force, water absorption when compared to those of existing masonry blocks. Quick cost estimation indicated that bricks could be made at a lower cost than those available in the market. It is fulfilled that paper bricks as of waste paper possess smart property and high-quality strengths. Sustainable and rate issues are also addressed. The result show the arrangement of paper dissipate and cement provides improved results for produce economical latest bricks.

Keywords : Sustainability, paper waste, paper-pulp slurry,water absorption.

I. INTRODUCTION

Since a big call for has been positioned on constructing material industry particularly inside the ultimate decade, because of the growing population which causes continual storage of building substances, the civil engineer has been challenged to transform industrial wastes to useful building and construction materials

Then with the help of graph, a comparison between Compressive strength, Water absorption and Efflorescence of ordinary bricks and paper bricks was determined. Before manufacturing the bricks, different properties of materials (cement and paper) were verified. After that, bricks were made and sun dried and then with the help of compressive strength machine (CTM), their compressive strength was calculated. The purpose of this study was to use waste paper to produce light weight masonry bricks. At make we have covered a type of paper brick before, but it was used simply as fire starter

Rahul Ralegaonkar and Sachinmandavgane of the Visveavaraya National Institute of Technology in India have come up with a process to make paper bricks designated for creation instead of destruction. It started when they visited a paper recycling plant in 2009. They learned that 15% of the material that went through the plant was piled up into an un sighting sludge and sent to a landfill.

Raleganokar and Mandavgane decided to take some of that sludge back to their lab and play around with it along with students over the summer. They are found when the bricks were made at 90% recycled paper mill waste and 10% cement. The slurry is mechanically mixed pressed into moulds, and left in the sun to dry. The bricks are half the cost of conventional ones, much lighter and could be a suitable to the Indian construction economy, which is 30% deficit in brick masonry (Including rice husk, fly ash,cotton waste etc.)

II. LITERATURE REVIEW

Rahul Ralegaonkar and Sachin mandavgane of the Visveavaraya National Institute of Technology in India have come up with a process to make paper bricks designated for creation instead of destruction. It started when they visited a paper recycling plant in 2009. they learned that 15% of the material that went through the plant was piled up into an un sighting sludge and sent to a landfill.

Physical properties of Paper

At Smithers Pira we are expert in testing the physical properties of paper to specific standard requirements. We specialize in creating bespoke test programmes based on your requirements, such as investigating product failure or weakness. We can also work with you to develop a custom test method, should it be needed.You can browse each section listed on the right to see our full range of tests. We are always happy to talk to you about the suitability of particular tests, so please make contact with the Smithers Pira expert shown if you have questions about the test itself or the support you need for your particular project or issue.

As standard, all of our tests are performed in a controlled laboratory environment. However, we have the capability to combine any of the above testing services at a set temperature or after exposure to freezing temperatures or high humidity.

Physical properties of Cement

Cement is the most important material for Civil Engineering Construction of Buildings, Dames, Bridges, Channels, Culverts, etc. It must be understood that cement is a chemical and reacts when mixed with water. Cement particles develop a type of growth on its surface until it link up with the growth from the neighbouring cement particles. It is this linking which results in progressive stiffening, hardening and strength development.

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The chemical reaction continues in the presence of free water, moisture or humidity present within the mass or outside. The mix becomes harden and stronger with age. This strength development is significant in the first month but it does not continue at a much slower rate for many years is called " HYDRATION " of cement and is accompanied by generation of heat which is called "Heat of hydration"

III. RAW MATERIALS

In the experimental work **raw materials** used as follows :

Cement:

In this have a look at, cement which is used is an normal port land cement. It acts as an awesome binder with paper sludge to supply paper brick. It hardens quickly when mixed with paper sludge and water.

Paper:

Paper used in this research was taken as waste news paper and in this project.

Sample preparation:

In this study, three different mix ratios were used as shown table 1 the water and waste paper mixes were kept constant and the proportion of cement was varied. For each ratio, ten samples were prepared.

The standard brick mould size 190*90*90 mm

IV. EXPERIMENTAL WORK & RESULTS

Methods used to prepare the Paper brick:

The desecrate paper was soaking in water for day.

Fig. 1 In wet condition and in dry condition

Pour the cement into the paper pulp and blend it thoroughly

Now upload the water and mix it at a uniform shade

Pore the mixed proportion into the mould

Fig. 2 shake the blend to take out the air with the facilitate of Vibrator apparatus

Fig. 3Remove the forms (moulds)

Fig. 3Let the Bricks dry for at least one week.

Compressive force of bricks : (I S 3495 : 1992)

A wall or column carrying a compressive load behaves like any other strut, and its load bearing capacity depends on the compressive strength of the materials, the cross sectional area and the geometrical properties as expressed by the slenderness ratio.

1) Compressive testing machine (CTM)

2) Scale for measuring dimension of brick

$$\text{Compressive Strength} = \frac{\text{Maximum load at failure}}{\text{Area of the in mm}}$$

The normal Compressive strength of bricks (IS 3495: 1992) is 35Mpa.

Fig. 4 While doing the Compressive strength in Laboratory:

Formulae for Water absorption:

$$\text{Water absorption} = \frac{M2-M1}{M1}*100$$

The average of result shall be reported.

while hardened, the standard water absorption shall not be extra 20% by weight.

1) NIL: - When there is not perceptible deposit of efflorescence.

2) Slight: - Not more than 10% area of the brick covered with a thin deposit of salt.
3) Moderate: - Covering up to 50% area of the brick.
4) Heavy: - Covering 50% or more area but un accompanied by powdering or flaking of the brick surface.
5) Serious:- When there is a heavy deposit of salts accompanied by powdering and flaking of the exposed surfaces.

While doing Efflorescence in laboratory:

Caluclations For Compressive Strength

$$\text{Compressive Strength} = \frac{\text{Maximum load at failure}}{\text{Area of the in mm}}$$

Size of the brick 220*80*70mm

- For 85% of newspaper crush,15% of cement:
  Load at failure = 60 KN
  Compressive strength = $(60*10^{3)}$ / 220*80
  = 3.41Mpa
- For 80% of newspaper crush, 20% of cement :
  Load at failure = 55 KN
  Compressive strength = $(55*10^{3})$ / 220*80
  =3.13 Mpa
- For 75% of newspaper crush, 25% of cement :
  Load at failure = 65 KN
  Compressive strength = $(65*10^{3})$ / 220*80
  = 3.70 Mpa

Table I: Compressive Strength

Specimen	% Of Cement Add	Compressive Strength in (Mpa)
S1	15%	3.41
S2	20%	3.13
S3	25%	3.70

Calculations For Water Absorption

Formulae for calculating Water absorption = $\frac{M2-M1}{M1}$*100

M1 = The weight of the brick is before pour into the water

M2 =The weight of the brick after taken from the water

For 85% of newspaper crush, 15% of cement
M1 = 810gm M2 = 1100gm
Water absorption = $\frac{1100-810}{810}$*100 = 35.8%

- For 80% newspaper crush, 20% cement
  M1 = 760gm M2 = 1010gm
  Water absorption = $\frac{1010-760}{760}$*100= 32.8%

- For 75% Paper pulp, 25% cement
  M1 = 900 M2 = 1160
  Water absorption = $\frac{1160-900}{900}$*100 = 28.8%

Table- II: Water Absorption Results

Specimen	% Of Cement Add	Water Absorption in (%)
S1	15%	35.8
S2	20%	32.8
S3	25%	28.8

Calculations for Efflorescence

For 85% of newspaper crush, 15% of cement
For more than 10% of area of the brick covered with a thin deposit a thin deposit of salt.

Efflorescence is Slight

For 80% newspaper crush, 20% cement
For surplus 10% of region of the brick covered with a thin deposit a thin deposit of salt.
So, It has Slight Efflorescence
For 75% Paper pulp, 25% cement
For surplus 10% of region of the brick covered with a thin deposit a thin deposit of salt.
So, It has Slight Efflorescence

Table III. Efflorescene results:

case	% Cement include	Efflorescence
S1	15%	Slight
S2	20%	Slight
S3	25%	Slight

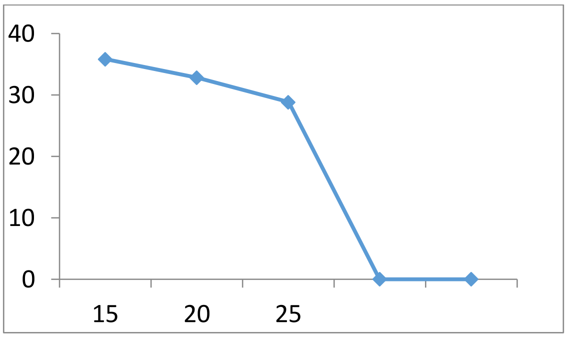

Fig5. Cement in % vs Water absorption in %

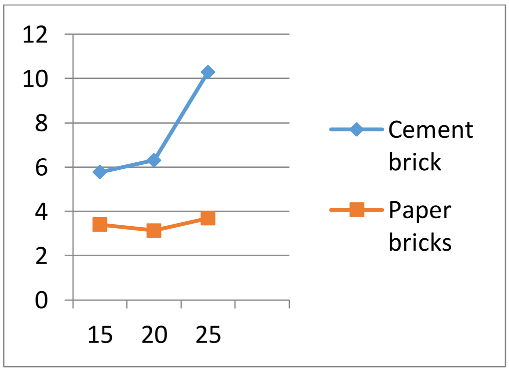

Fig 6. Comparison of Compressive strength between Cement brick and Paper brick

Cement in % vs Compressive Strength in Mpa

Table IV: Test Results

Case	% Of Paper Sludge	% Of Cement
C 1	85%	15%
C 2	80%	20%
C 3	75%	25%

The 190*90*90 mm size bricks were prepared and used as test specimens to determine the compressive strength and water absorption respectively. The specimens were prepared with various percentages of cement and paper sludge.

Table V: Compressive Strength opted :

Case	% Of Cement Add	Compressive Strength in (Mpa)
C 1	15 %	3.41
C 2	20 %	3.13
C 3	25 %	3.70

Table VI: Water Absorption grades

Case	% Of Cement Included	Water Absorption in (%)
C 1	15 %	35.80
C 2	20 %	32. 80
C 3	25 %	28. 80

Table VII: Efflorescence opted

Specimen	% Of Cement Included	Efflorescence
C 1	15 %	Slight
C 2	20 %	Slight
C 3	25 %	Slight

V. CONCLUSIONS

Based on the experimental investigation the subsequent effects were determined.

The superior (%) Of cement substitute in paper brick and compressive energy of the bricks have studied.

Paper bricks extra low-priced the time required to prepare bricks much less in comparison to normal bricks

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AUTHORS PROFILE

Mr. M. S. Britto Jeyakumar, Assistant Professor of Civil Engineering, completed his Master of Engineering (Structural Engineering) from Sathyabama University, Chennai. He has over 1.5 years of academic experience in Gokaraju Rangaraju Institute of Engineering and Technology (GRIET) and 7.5 years of Rajas Engineering College, Tamilnadu. He had 9.5 years of industrial experience at varies industrial organizations. He had earned Bachelors of Engineering (Civil Engineering) Madurai kamaraj university, Tamilnadu. His research interests include Concrete Technology and Design of Concrete Structures, in which he has 3 publications, in various conferences. He is currently Class coordinator, Department of Civil Engineering at Gokaraju Rangaraju Institute of Engineering and Technology (GRIET). He is also a Life Member of ISTE and IASTER.

Er.Y. Kamala Raju, Assistant Professor of Civil Engineering, He recseived his B. E in Civil Engineering from Osmania University in 2007, and M. Tech in Structural Engineering from JNTUK in 2011. Over 10 years of professional experience in Industry, Academic and Research.

MODULUS OF ELASTICITY ON HIGH PERFORMANCE GLASS FIBRE RCC BEAMS WITH PARTIAL REPLACEMENT OF CEMENT BY SILICA FUME

Y.Kamala Raju, M.S.Britto Jeyakumar

Abstract*— *The present paper contains, Seven blends Mix1 to Mix7 are thrown with 0%, 5%, 7.5% and 10% substitution of bond utilizing SF and another arrangement of examples with 0%, 5%, 7.5% and 10% substitution of concrete utilizing SF alongside 0.2% consistent substitution of Glass fiber to contemplate the mechanical property modulus of versatility. The outcome demonstrates that the ideal substitution of silica smoke is 7.5%. On the off chance that the fiber of 0.2% is included the malleable and flexural quality got expanded.

Absolutely seven RC beams 200 x 200 x 750mm size were thrown for assessing the flexural test and restored for 28 days. These beams are tested in loading frame of 1000 kN at 28 days, two point burdens are connected over the beam. The Heap from the start split, diversion, and a definitive burden are noted for each blend and similar examination is accomplished for Burden – redirection (P-Δ), first break - extreme burden, Moment – Curvature (M-φ) and Moment – rotation with Control and HPC blend examples lastly different malleable natures is plotted.

Keywords: optimum replacement of silica fume, Moment – Curvature, Moment – Rotation, modulus of elasticity, flexural behavior.

I. INTRODUCTION

The modulus of flexibility most ordinarily utilized practically speaking is secant modulus. There is no standard technique for deciding the secant modulus. At some point it is estimated at stresses going from 3 to 14MPa and at some point the secant is attracted to point speaking to a feeling of anxiety of 15, 25, 33 or 50 percent of extreme quality. Since the estimation of secant modulus diminishes with increment in stress, the worry at which the secant modulus has been discovered must to consistently be expressed.

Table 1 Maximum Stress Strain Values

Mix	Stress (MPa)	Strain in Microns
Mix1	60.51	2490
Mix2	57.32	3050
Mix3	70.06	3470
Mix4	63.69	3175
Mix5	66.24	3300
Mix6	71.34	3350
Mix7	62.42	3125

II. REVIEW ON LITERATURE

M Newtson Craig (2014) he investigated that the fracture response of RC deep beams and also investigated on the strength and size of beams. RC deep beams and also investigated on the strength and size of beams.

P Kumar Mehta (2004) he studied the RC beams under two point loading conditions.

Zhenhua Wu. (2007) studied that the RC beam for different shear reinforcement patterns

Aruna Munikrishna (2011) mentioned the RC beams under pure torsion. The torsional strength due to the changes in the length of beam and cracks propagation due to various loading conditions were studied and analyzed. He has tested six beams with different length and same reinforcement ratios as per the ACI318-05 code. The author considered multilinear isotropic stress-strain curve for the concrete model.

Table 2 Modulus of Elasticity

Mix	Stress N/mm^2	33% of Ultimate strength N/mm^2	Strain	Young's Modulus N/mm^2
Mix1	60.51	20.17	0.00048	42462.84
Mix2	57.32	19.11	0.00043	44960.65
Mix3	70.06	23.35	0.00045	51899.03
Mix4	63.69	21.23	0.00048	44697.73
Mix5	66.24	22.08	0.00053	42058.43
Mix6	71.34	23.78	0.00053	45293.7
Mix7	62.42	20.81	0.0005	41613.58

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Stress-Strain Behavior

Tests were led to study pressure strain conduct of HPC on chamber examples of size 100x300mm for all the blends in the pressure testing machine of limit 2000kN. These examples were tried under hub pressure and the estimations of pivotal pressure and hub strain were recorded at standard interims. The pressure versus strain bends are appeared for the blends Mix1 to Mix7 in Figs. The most extreme pressure and greatest strain esteems for different blends are given in Table.It is discovered that Mix3 (with 7.5% silica rage) indicates higher quality and extreme strain contrasted with ordinary cement.

Preparation of Beam Specimen

All the reinforced beam specimens were cast at the structural laboratory. The raw materials for concrete mixes already described in the previous section were mixed by a rotary mixer. The wooden mould were prepared and lubricated with oil before the concrete was poured. The reinforcement bars were cut to the required lengths. The longitudinal bars and stirrups were secured to each other at correct spacing by means of binding wires.

A mixing time of 3 to 5 minutes was given to ensure uniform mixing. Wooden moulds were used to cast the beams. The specimens were demoulded after 24 hours and cured for 28 days using gunny bags. After curing period, the beams were kept for 24 hours in a dry state. After drying they were cleaned with a sand paper to remove all grit and dirt. Then all the specimens were prepared by white washing from all sides. White washing was done to facilitate easy detection of crack propagation

Experimental Test Setup for Beam Specimens

A total of seven beams were cast. Out of those seven beams cast, one is conventionally reinforced concrete beam. Remaining six beams were separated into two categories and were cast with concrete, one with the 5%, 7.5% & 10% silica fume replacement and the other with above mentioned replacement of silica fume in addition to the glass fibers. All the beams were tested for flexure under a loading frame of capacity 1000kN. These beams were tested on a effective span of 750mm with simply supported conditions under two point loading. Deflections were measured under the loading point and at the mid span using Linear Variable Differential Transducers (LVDTs). The crack patterns were also recorded at every load increment. All the beams were tested up to failure.

Design of Flexure Beams

Grade of Concrete	M80
Grade of steel	Fe 415
Length of Beam	750mm
Breath of beam	200mm
Depth of Beam	200mm
Loading Method	Two Point Load (Equal Distance (L/3))
End Condition	Simply Supported Beam

We have to design a Beam failures occurs in the mode of flexure

$$\frac{x_u}{d - x_u} = \frac{\varepsilon_{cu}}{\varepsilon_s}$$

$$\frac{x_u}{d} = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_s}$$

$\varepsilon_{cu} = 0.0035$ (IS 456-2000 38.1(b))

$\varepsilon_s = 0.002 + \frac{0.87 f_y}{E_s}$ (IS 456-2000 38.1)

$$\varepsilon_s = 0.002 + \frac{0.87x415}{2x10^5} = 0.00366$$

$$\frac{x_u}{d} = \frac{0.0035}{0.0035 + 0.00366} = 0.479 \approx 0.48$$

$\frac{x_{u,max}}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} bd} = 0.48$ (IS 456-2000 Note 38.1)

Clear cover =20mm

Effective cover= (20+12/2) = 26mm

Effective depth= 200- 31 = 174mm

f_{ck} = 80 N/mm^2

b = 200 mm

$M_{u,\lim} = 0.36 \frac{x_{u,\max}}{d}\left[1 - 0.42\frac{x_{u,\max}}{d}\right] bd^2 f_{ck}$ (IS 456-2000 Annex G 1.1(c))

=33.42 kNm

$A_{st} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} bd^2}}\right] bd$ A_{st}=664 mm^2

Provide $A_{st} = 2x\frac{\pi x 12^2}{4} = 226mm^2$

Moment carrying capacity of under reinforced section

$$M_u = 0.87 f_y A_{st} d\left[1 - \left(\frac{A_{st} f_y}{bd f_{ck}}\right)\right]$$

M_u = 13.24 kNm < $M_{u.lim}$

A_{st} = 314 mm^2

The section is failure mode of flexure.

Increase the shear resistance capacity of the beam.

$$M = \frac{Wl}{3}$$

$$w = \frac{3M}{l}$$

$$w = 3X\frac{13.24}{1.5}$$

w = 26.48 kN

Jack load (2w) = 52.96 kN

Design of shear Resistance:

$$\%ofsteel = \frac{100x226}{100X174} = 1.30\ \%$$

From Table 19,IS 456 -2000,

For fck = 80 N/mm^2 & pt=1.30

Design shear strength of concrete τ_c = 0.75 N/mm^2

From Table 20,

Maximum shear stress $\tau_{c\ max}$ = 4 N/mm^2

$$\frac{v}{bd} = \frac{26.48x10^3}{100X174} = 1.52\ \text{N/mm}^2$$

$\tau_v < \tau_{cmax}$

$V_{us} = (\tau_v - \tau_c)$x bd = (1.52-0.75) x 100x174 = 13.40 kN

IS 456 clause no : 40.4 (a)

$$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$$

A_{sv}= total cross sectional area of stirrup legs

Using 8mm φ (2 legged stirrup)

$$A_{sv} = \frac{2\pi X 8^2}{4} = 101mm^2$$

$$s_v = \frac{0.87 X 415 X 101 X 174}{13.4 X 10^3} = 473 \text{ mm}$$

Provide maximum spacing of shear resistance

As per IS 456 –2000 26.5.1.5

1. Shall not exceed 0.75d for vertical stirrups (131.25mm)
2. Spacing should not exceed 300mm

We choose 8mm φ 2 legged vertical stirrups at a 125mm c/c distance

Beam with stand upto $V_u = V_c + V_s$

$$Vs = \frac{0.87x415x101x174}{125}$$

V_s = 50.76 kN

V_c = 0.75x100x174 = 13.05 kN

$V_u = V_c + V_s$ = 63.81 kN > 26.48 kN

The section is failure mode of flexure.

Beam Test Results

Testing of beam was carried out as per the procedure. The test results for beam tested for Flexure are shown in Tables.

Table 3 Test Results for Flexure Beam

Specimens	% Of SF	Fiber (%)	First Crack Load (kN)	Ultimate load (kN)	Deflection at Ultimate Load (mm)
M1	0	0	26	46	12.46
M2	5	0	28	48	14.65
M3	7.5	0	32	54	17.75
M4	10	0	30	52	16.26
M5	5	0.2	35	52	17.89
M6	7.5	0.2	38	58	21.77
M7	10	0.2	37	54	19.08

Table 4 Displacement Ductility

Beams	Ultimate Displacement Δ_u (mm)	First Yield Displacement Δ_y (mm)	Displacement Ductility $\mu = \Delta_u / \Delta_y$
M1	12.46	3.88	3.21
M2	14.65	4.26	3.44
M3	17.75	5.01	3.54
M4	16.26	4.69	3.47
M5	17.89	5.11	3.50
M6	21.77	5.39	4.04
M7	19.08	4.85	3.93

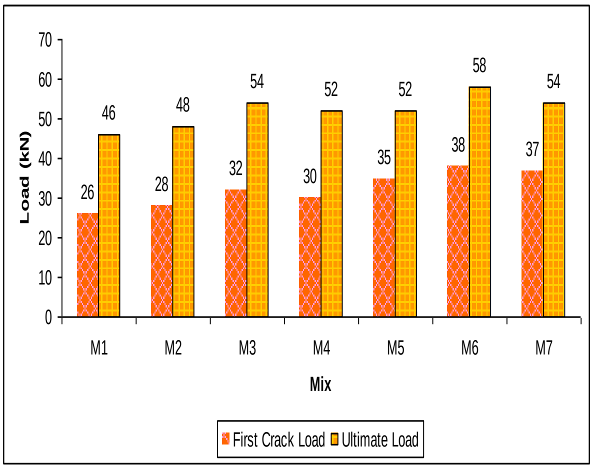

Fig 1.comparison For First Crack Load And Ultimate Load

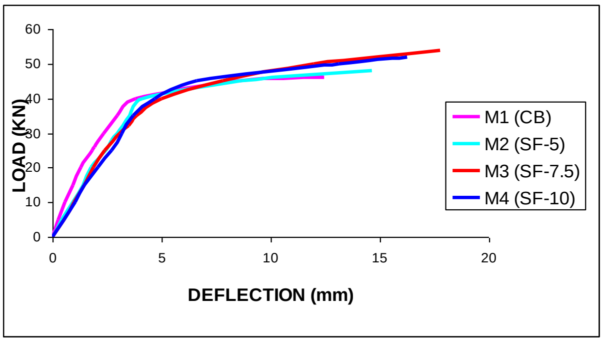

Fig2. Load Vs Def curves for Flexure Beam

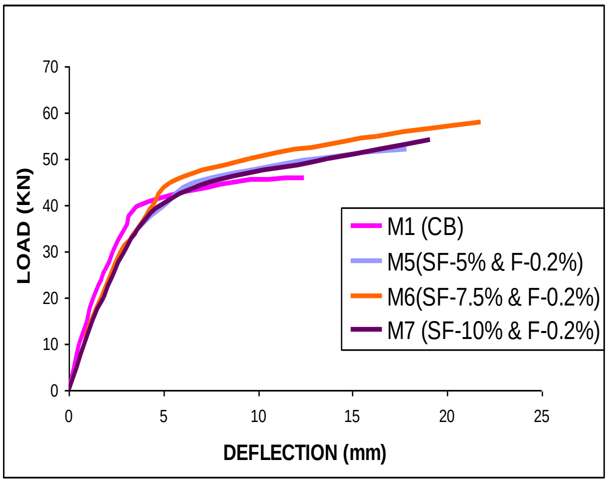

Fig 3. Load Vs Def curves for Flexure Beam (M1, M5, M6, and M7)

Table 5 Curvature Ductility

Beams	Maximum Curvature φ_u (rad/mm) x 10^{-6}	Curvature at First Yield φ_y (rad/mm)x10^{-6}	Curvature Ductility $\mu = \varphi_u / \varphi_y$
M1	152.14	53.68	2.83
M2	155.84	42.68	3.65
M3	167.35	44.11	3.79
M4	160.66	43.82	3.67
M5	167.42	45.34	3.69
M6	196.25	49.29	3.98
M7	181.25	46.89	3.87

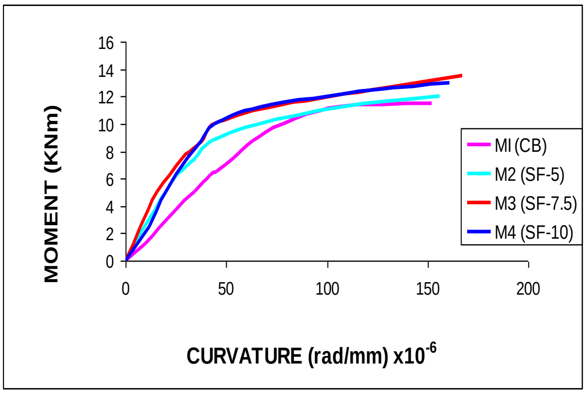

Fig.4. M-φ relationship for Flexure beam (M1, M2, M3, and M4)

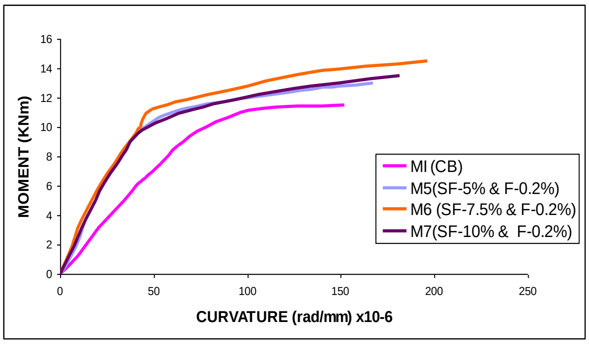

Fig.5 M-φ relationship for Flexure beam

Table 6 Rotation Ductility

Beams	Maximum Rotation θ_u (rad)	First Yield Rotation θ_y (rad)	Rotation Ductility $\mu = \theta_u / \theta_y$
Mix 1	0.0182	0.0055	3.309
Mix 2	0.0215	0.006	3.583
Mix 3	0.0257	0.0067	3.836
Mix 4	0.0237	0.00654	3.624
Mix 5	0.0263	0.0068	3.868
Mix 6	0.0321	0.00796	4.033
Mix 7	0.0282	0.00718	3.928

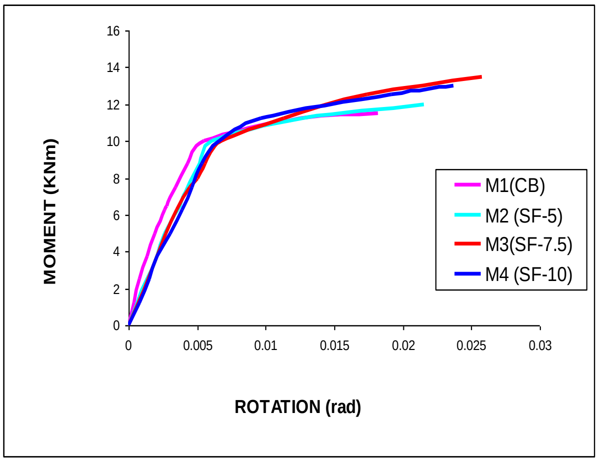

Fig.6. M-θ relationship for Flexure beam (M1, M2, M3 and M4)

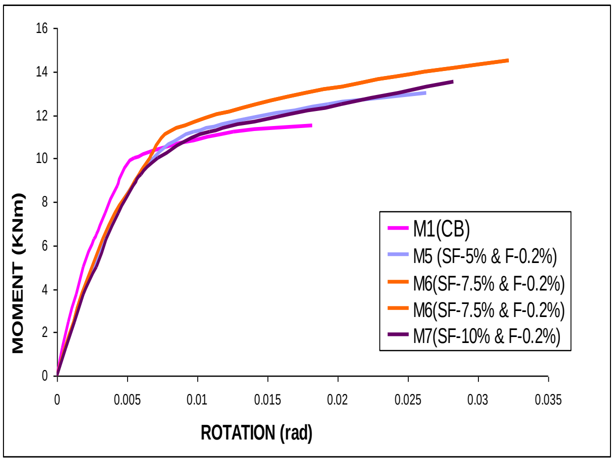

Fig 7. M-θ relationship for Flexure beam (M1, M5, M6 and M7)

III. DISCUSSION OF BEAM TEST RESULTS

Test consequences of pillars under flexure show that, the bar with 7.5% of silica seethe (M6) has the most astounding burden conveying limit of 58 kN. This is about 1.26 occasions higher than that of the control bar (CB).

A definitive burden conveying limit acquired tentatively is more prominent than the worth got hypothetically. The principal break showed up at the jack heap of 26kN for M1 shaft where as the primary split burden was 32 kN for M3 bar which is 23.07% higher than that of the control bar. A definitive heap of M3 shaft is 54kN which is 17% higher than that of a definitive heap of the M1.

From the Occasion Ebb and flow relationship, inside the yielding stage the 5% silica smoke shafts show higher solidness than the control and 7.5% silica smoke pillars. In any case, in the plastic stage, the 7.5% bars (M3) show better malleability conduct contrasted with that of customary and 5% silica smoke supplanted shafts.

The arch pliability, turn malleability and ebb and flow flexibility is incredibly expanded in the bars which contains SF of 7.5% substitution.

The incorporation of fiber expands the heap conveying limit with regards to M6 bar about 26.08% contrasted and the Control example M1 and with the ideal SF substance of 7.5 % the addition is 7.41%.

IV. CONCLUSION

The following conclusions ware made

a. The Mix3 blend which is without fiber give most extreme flexural quality of cement without expansion of fiber (ie) 6.05 MPa which is 11.42% more noteworthy than control blend.

b. The Mix6 blend which is with fiber give most extreme flexural quality of cement without expansion of fiber (ie) 6.70 MPa which is 23.39% more noteworthy than control blend.

c. The consideration of fiber expands the heap conveying limit with regards to M6 shaft about 26.08% contrasted and the Control example M1 and with the ideal SF substance of 7.5 % the augmentation is 7.41%.

d. The introductory break is deferred when contrasted and the pillars without incorporation of strands.

V. SCOPE FOR FURTHER INVESTIGATION

The following are the some of the aspects recommended for further in depth study.

1.Water Cement Ratio can be varied.
2.Durability studies can be extended.
3.Corrosion resistance test can be studied for long term durations.
4.Shear beams can be cast to study the shear behavior of Silica fume and Fiber.
5.Varying Percentage replacement of admixtures,
6.Different Combination of Fiber and dosage of Superplasticizer can be varied.

Various fibers like steel, Synthetic fibers can be mixed and the properties can be studied.

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Pavement Overlay Design Using Falling Weight Deflectometer

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Abstract*: Pavement evaluation is a technique of assessing the condition of a pavement, both structurally and surface characteristics. Pavements which have been subjected to traffic, deform elastically under load which depends on type subgrade soil and its compaction level, pavement thickness and its composition, drainage conditions, pavement surface temperature and wheel load. There are number of different types of pavement deflection testing equipment which are being used all over the world. The most common types are Benkelman Beam Deflection (BBD), Falling Weight Deflectometer (FWD) and Dynamic Cone Penetrometer. BBD test widely used method in which rebound deflection is measured on static loading and there by evaluating strength of the pavement. However with limitations and practical difficulties of BBD, FWD was chosen for the study. The deflections of the pavement are recorded due to the dynamic loading and studied for further strength determination. A 4-lane National Highway has been selected and tested for residual strength and it is designed for overlay as per IRC:115-2014 & IRC:37-2012 using FWD equipment and with the assistance of KGPBACK and IIT PAVE software's. An overlay of 50 mm on one direction and 100 mm on opposite direction was recommended to meet the functional and structural requirement respectively.

***Keywords* : Falling Weight Deflectometer (FWD), Pavement overlay, KGPBACK, IIT PAVE, IRC:115-2014 and IRC:37-2012.**

I. INTRODUCTION

The objective of the study is to evolve structural condition of the pavement using Falling Weight Deflectometer and subsequent analysis is carried out to ascertain the relative performance of the pavement in the perspective of evaluating residual life. The load-deflection data from the FWD was inferred through the analytical techniques by back calculation to estimate the elastic moduli of the pavement layers. Thus calculated moduli was therefore used for the strength evaluation of different layers of pavement and the estimation of strength requirement of pavement. The procedures for the test and evaluation of structural condition of pavements is detailed in IRC- 115:2014.

II. DESIGN METHODOLOGY

Performance of flexible pavements can be evaluated by subjecting the pavement to external loads such that it simulate the traffic loading and recording the response of pavement to such loading by measuring the elastic deflection under such loads. For the reason, the Falling Weight Deflectometer was chosen as per the guidelines in IRC:115_2014. Falling Weight Deflectometer, which is closely simulates the duration and amplitude of the load pulses produced by moving wheel loads. The basic working principle of the impulse loading equipment is to drop a mass on the pavement to produce an impulse load and measure the surface deflections. The mass is dropped on a spring system, which in turn transmits the load to the pavement through a loading plate. The resulting bowl characteristics are observed and used in the back-calculation of pavement material properties.

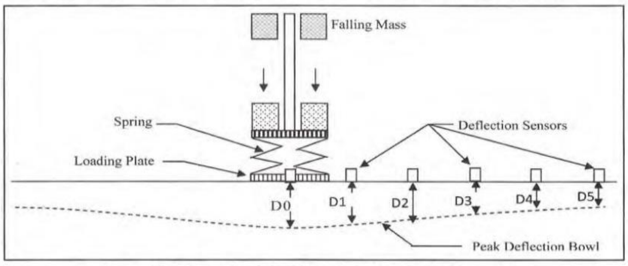

Fig. 1. Working Principle of FWD

The FWD test data was collected from different load drops at each test point primarily consisted of peak load, peak deflections at different radial locations. Unrealistic deflection values and obviously enormous data are removed.

The target peak load was applied on bituminous pavement is 40kN (+/- 4kN), which corresponds to the load on one dual wheel set of an 80kN standard axle load. But in practice applied peak load always may not be exactly 40kN, hence the deflection values measured by geophones should be normalized to equivalent 40kN loading. The normalization of deflections are done linearly.

KGPBACK is the Back calculation technique used to calculate the elastic moduli of existing pavement layers. Normalized surface deflections, along with other inputs such as radial distances at which deflections are measured, layer thicknesses, Poison's ratio values of different layers, target load and loading plate radius, are used to back-calculate the elastic moduli of different layers of the existing pavement. Elasticity moduli values were corrected for temperature and seasonal variation which is further used for the estimation of the design Elastic Moduli (E) values. As per IRC guidelines 15th percentile of E values are considered for the project study.

For areas in India having a tropical climate, the temperature corrections has to

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be applied for the temperatures more than the standard pavement temperature which is 350C. The temperature corrections are applied for the back calculated modulus obtained from of bituminous layer using below mentioned equation.

$$E_{T1} = \lambda E_{T2} \quad (1)$$

Where,

λ is temperature correction factor, is given as

$$(1\text{-}0.238\ln T1)/(1\text{-}0.238\ln T2)$$

E_{T1} is back-calculated modulus (MPa) at temperature T1 (^{0}C)

E_{T2} is back-calculated modulus (MPa) at temperature T2 (^{0}C)

Seasonal corrections for subgrade and granular moduli were also applied using the following relationships developed for different seasons (winter/ summer/ monsoon) as per IRC: 115-2014.

$$E_{sub\ mon} = 3.351 * (E_{sub\_win}) * 0.7688 – 28.9 \quad (2)$$

$$E_{sub\ mon} = 0.8554 * (E_{sub\_sum}) * 0.7688 – 8.461 \quad (3)$$

$$E_{granu\_mon} = - 0.0003 * (E_{granu\_Sum})2 + 0.9584 * (E_{granu\_Sum}) – 32.989 \quad (4)$$

$$E_{granu\_mon} = 10.5523 * (E_{granu\_win}) * 0.624\text{-}113 \quad (5)$$

The results from the above analysis along the physical and load characteristics of the pavement were given as inputs to the IIT PAVE software to obtain the peak strains at critical locations of the pavement. These strains are later used to find residual fatigue and rutting strengths of the pavement.

The layer moduli were used to analyze the pavement for critical strains which are indicators of pavement performance in terms of rutting and fatigue cracking as suggested by IRC. A diagram with different layers of flexible pavement and critical strain locations is shown in following Fig. 3.

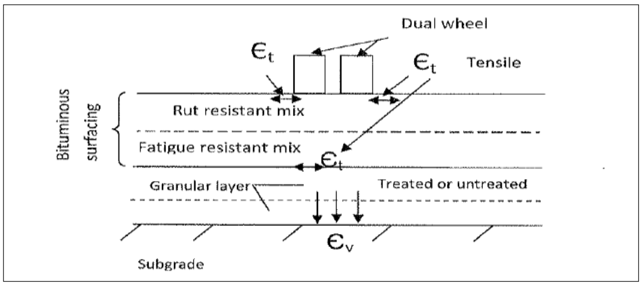

Fig. 2. Different layers of flexible pavement & Critical Strain locations

The fatigue (or fracture) life in Million Standard Axles (MSA) of the bituminous layer and the number of load repetitions in terms of standard axles that cause fatigue denotes the fatigue life of the pavement. The fatigue model for 90 percent reliability is given in following equation.

$$N_f = 0.711 * 10\text{-}0.4 * [1/\varepsilon_t]\ 3.89 * [1/M_R]\ 0.854 \quad (6)$$

Where,

N_f is Fatigue life in number of standard axles

ε_t is Maximum tensile strain at the bottom of bituminous layer

M_R is resilient modulus of the bituminous layer.

Rutting life in Million Standard Axles (MSA) is the permanent deformation in pavement usually occurring longitudinally along the wheel path. Rutting model for 90 percent reliability level was given in following equation.

$$N = 1.41*10\text{-}8 * [1/\varepsilon_v]\ 4.5337 \quad (7)$$

Where,

N is Number of cumulative standard axles

εv is Vertical strain in the subgrade

Thus the obtained fatigue and rutting life of the pavements are compared with the design strength to arrive the design thickness of the pavement overlay.

III. Pavement Characteristics and Deflection Measurement Scheme

In this study, the pavement of interest is four lane dual carriageway from NH5. The project stretch from Km. 951.500 to Km 1022.500 both on LHS and RHS at 250m spacing on outer wheel path of outer lane and at 500 m spacing on outer wheel path of inner lane. Deflections obtained on each side of the carriageway has been normalized to correspond standard target load of 40kN as per guidelines.

Pavement layer thicknesses are essential inputs to the process of back-calculation of layer moduli and, in turn, to the estimation of remaining life and overlay requirements of the in-service pavement. A pit of size 0.6m x 0.6m was excavated at an interval of 10km as the records suggest the uniformity of the pavement composition. The total crust thicknesses of the pavement measured along the chainage varies 660 mm to 890 mm with bituminous layer of varying thickness from 200 to 360 mm and a granular layer of thickness 450 mm to 690 mm.

IV. Results and Discussion

The FWD test is calibrated to ensure the deflection values given by the sensors are reliable. The mean and standard deviation of deflections are calculated for twelve drops for each geophone separately. As per IRC:115-2014, the standard deviation of the peak load should be less than 5 percent of the mean value of the peak load.

The measured load deflection data was normalized by removing the erroneous output and processed by applying all temperature and seasonal corrections to arrive at representative moduli of each layer by back calculation through KGPBACK. The representative moduli of bituminous, granular and subgrade layers of LHS and RHS with all corrections applied are shown graphically in the below Fig. 3.

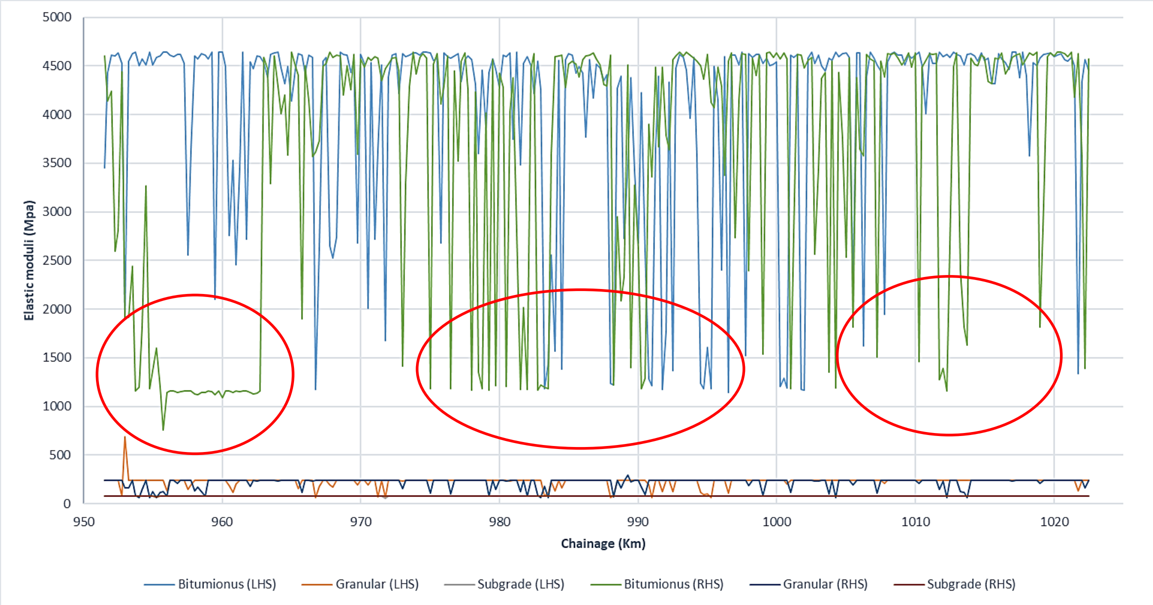

Fig. 3. Elastic moduli of different layers of pavement

It is clear from the above graphical representation, the RHS bituminous layer has very low values of moduli. Selection of 15th percentile modulus values (15% of the values will be less than this value) of each of the three layers considered for analysis. The design 15th percentile values are mentioned below Table I.

Table I: 15th Percentile Back Calculated Modulus Values on LHS and RHS Side

Side	15th Percentile of Moduli for the design		
	Bituminous (MPa)	Granular (MPa)	Subgrade (MPa)
LHS	2562.15	223.2669	77
RHS	1198.46	161.65	77

With the above elastic modulus, physical and load characteristics of the pavement, the critical strain values of the pavement were obtained from the IITPAVE and those strain results were used to calculate the fatigue and rutting life of the bitumen layer as shown in the below Table II.

Table II: Residual Life of pavement on RHS Side

Side	Analysis of pavement using IITPAVE		Remaining Life of Pavement	
	Horz. Tensile Strain (microns)	Vert. Comp. Strain (microns)	Fatigue (MSA)	Rutting (MSA)
LHS	114.40	163.20	187.78	2087.42
RHS	195.00	198.80	20.61	853.27

As the residual strength of the pavement is more than the required design strength there is no requirement for structural overlay on the LHS. However an overlay of 50mm is suggested for functional requirement which covers surface defects like cracks, potholes, roughness, etc. Along RHS, the residual strength of the pavement is 20.61 MSA which is much less than the design requirement of the pavement. A structural overlay is to be designed to meet the design strength. A trial of 100mm overlay is used on IITPAVE software along with other properties as input. Based on the design life of pavement, the residual life of the pavement is re-calculated as shown in below Table III.

Table III: Residual & Design life of pavement

Side	Design strength (MSA)	Residual strength (MSA)	Design overlay strength (MSA)	Overlay Thickness (mm)	Strength after overlay (MSA)
LHS	170	187.78	Not required	50	188
RHS	150	20.61	130	100	159.18

To summarize the results, a thickness of 50mm of functional overlay on LHS side and a thickness of 100 structural overlay on RHS side was arrived to meet design strength and foundational requirement of the pavement.

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Inquiry on Mechanical Properties of M30 Grade Concrete with Partial Replacement of Copper Slag and Dolomite Powder for Fine Aggregate and Cement

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Abstract: Concrete plays an important role in every construction. This paper is an experimental investigation to study the mechanical properties of the concrete with partial replacement of cement by dolomite powder and fine aggregate by copper slag. So, in this investigation, by usage of Dolomite powder in concrete on one side improves density and other side improves strength and hardness. Copper slag also increases density of concrete and toughness of concrete. The cement content replaced with dolomite and fine aggregate replaced with copper slag from 5% to 25% at regular intervals of 5%. In the designed mix proportion of M30 grade concrete is 1:2.17:2.95. The Superplasticizer Master Rheobuild 920SH of 0.5% dosage used as chemical admixture is added to the concrete to maintain 0.45 the water-cement ratio. The concrete cubes, cylinders were casted. The different mechanical properties like compressive strength, split tensile strength, flexural strength were tested after 3 days, 7 days and 28 days of curing from 5 to 25% at regular intervals of 5% replacement of cement with dolomite powder and 10% to 50% at regular intervals of 10% replacement of fine aggregate with copper slag.

Keywords: concrete, cement, dolomite powder, fine aggregate, copper slag, compressive strength, split tensile and flexural strength.

I. INTRODUCTION

Concrete is an adaptable designing material utilized in most of the construction. It is fundamentally made out of cement, water, fine aggregate and coarse aggregate. It is eventually noticed that, concrete is very crucial as it is made in such a way that it is economical, highly durable with good workability and it can be made it into any form and size with high compressive strength. The usage of supplementary solidifying materials like dolomite powder, egg shell, rice husk, silica fume, sugarcane bagasse, metakaolin, fly ash and so on which are natural pozzolans and so forth in concrete generation is one of the answers for reducing the cement content in concrete and therefore reducing the Co_2 content into the environment. Along these lines, conditions for additional protective and eco-pleasing establishing material have increased eagerness for inadequate bond replacement material. Replacing of cement content in concrete by pozzolanic material like Dolomite powder in reducing the cost of the concrete which also improves the mechanical properties. Meanwhile, the fine aggregate partially replaced with copper slag improves the workability and density of the concrete. The excavation of sand from the river beds lessen the water head, therefore less pervasion of water into the ground resulting lower ground water level. Along these lines, conditions for additional protective and eco-pleasing waste materials have increased eagerness for inadequate replacement of fine aggregate. By using with different mineral admixtures in concrete like dolomite, copper slag not only improves mechanical properties but also other properties like workability. The partial replacement of dolomite and copper slag have increased the compressive strength and flexural strength in an investigation [1] for M20 concrete with being copper slag replacement is made constant about 20% and with varying dolomite replacements from 20% to 30% at regular intervals of 5%. Some researchers have found that [2], the compressive strength have increased with varying replacements of dolomite from 10% to 30% and replacement of copper slag being 25% throughout for a M25 grade concrete. Usage of dolomite powder reduces the cost of concrete [3] and increases the strength of concrete. This paper examined the possible usage of dolomite as a partial replacement of cement. The replacements done were 0%, 5%, 7.5%, 10%, 12.5%. The optimum percentage was found to be at 7.5%. From the research paper [4], it was concluded that copper slag and recycled aggregates might be used as partial replacements of fine aggregate which are waste products. Copper slag with lesser water absorption and higher strength than fine aggregate can be effective in concrete. Some researchers [5] have found that, by partially replacing cement with dolomite and fine aggregate by manufactured sand, the compressive strength increased for certain replacement and then decreased gradually.

II. MATERIALS

The materials utilized for this trial work are OPC 53 grade cement, water, fine aggregate (river sand), coarse aggregate 20mm, Dolomite powder, Copper slag and water.

A. Ordinary Portland Cement

Cement used for all the concrete mixes in this experimental work is Ordinary Portland Cement. Fresh and no lumps were present in the cement used in this trial work. Cement was tested as per IS: 12269-1987. OPC 53 grade was used in this experimental work.

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Table:1 Characteristics Of Cement

CHARACTERISTICS	OBSERVED VALUE
Normal consistency	32%
Initial setting time	65 min
Final setting time	270 min
Specific gravity	3.15
Compressive strength at 28 days	57 Mpa

B. Fine Aggregate

Fine Aggregate helps the mix to be workable and consistent. Aggregate passing through 4.75mm sieve and held on 75micron sieve is named as fine aggregate. Fine aggregate was tested as per IS:383-1970.

Table:2 Characteristics Of Fine Aggregate

CHARACTERISTICS	OBSERVED VALUE
Grade zone	II
Specific gravity	2.6
Fineness Modulus	2.2

C. Coarse Aggregate

Coarse aggregate is the largest percentage in the concrete mix. Coarse aggregate used in this experimental work is an angular shaped aggregate. The aggregates passing through the 20mm sieve and were held on 10mm sieve. Coarse aggregate was tested as per IS 383-1970.

Table:3 Characteristics Of Coarse Aggregate

CHARACTERISTICS	OBSERVED VALUE
Water absorption	0.5
Specific gravity	2.64
Fineness modulus	6.8

D. Dolomite powder

The dolomite is an anhydrous carbonate mineral created out of calcium magnesium carbonate. Dolomite powder is obtained by crushing the dolomite mineral.

Table:4 Physical Properties Of Dolomite Powder

PROPERTY	DOLOMITE POWDER
Formula	$CaMg(Co_3)_2$
Specific gravity	2.85
Color	White
Tenacity	Brittle
Crystal system	Hexagonal
Sieve analysis	Zone III
Moisture content	Nil

Table:5 Chemical Properties Of Dolomite Powder

CHEMICAL COMPONENT	% OF CHEMICAL COMPONENT
Total carbonate	97.4%
$CaCo_3$	54.3%
$MgCo_3$	45.6%
Al_2O_3	0.02%
SiO_2	0.3%
Fe_2O_3	0.04%

E. Copper slag

Copper slag is a by-product of copper extraction by smelting process. During smelting, impurities become scoria that floats on the liquified metal. Scoria that's quenched in water produces angular granules that are disposed of as wastes are utilized in concrete for construction. Copper Slag used for this experimental work was collected from Sri Srinivasa Metalizers, Cherlapalli. The particle shape is multifaced. Its appearance is black and glassy. The specific gravity of the copper slag was found to be 3.15.

Table:6 Physical Properties Of Copper Slag

PROPERTY	DOLOMITE POWDER
Particle Shape	Multifaced
Appearance	Black and Glassy
Specific Gravity	3.15

Table:7 Chemical Properties Of Copper Slag

CHEMICAL COMPONENT	% OF CHEMICAL COMPONENT
SiO_2	33-35%
Fe_2O_3	40-44%
Al_2O_3	4-6%
CaO	0.8-1.5%
MgO	1-2%

F. Water

Water is the important factor in the concrete mix. When added, it reacts with cement to form a paste which helps in binding the ingredients in the concrete. Water also helps the concrete to hardened due to the hydration process caused between cement and water. The job of water is important in concrete due to the water to cement ratio plays an important role to get a perfect concrete mix.

G. Super plasticizer

Super plasticizer Master Rheobuild 920SH was used in this experimental work to improve the workability of the concrete.

TABLE:8 Properties of Super Plasticizer

State	Liquid
Color	Dark
Density	1.2
Chemical name	Naphthalene formaldehyde polymer
pH	8.40

III. EXPERIMENTAL INVESTIGATION

The mix design techniques utilized in various nations are mostly dependent on the empirical relationships, charts and graphs created from extensive trial examinations. A properly designed concrete mix should have least cement content without relinquishing quality so as to make in concrete mix. The aim of contemplating the different properties of the material of concrete, plastic concrete and hardened concrete, is to empower a concrete technologist to design a concrete blend for a specific strength and durability.

1. Mix proportion

In this experimental study, M30 grade of concrete was used and the mix proportions for cement, fine aggregate and coarse aggregate was taken as 1:2.17:2.95 which was designed as per IS:10262-2009, with a water-cement ratio as 0.45.

2. Casting and Demoulding

Weigh batching was done with the assistance of electronic scales. Batching was performed for each of the combination proportions. Tilting concrete mixture was used for mixing of concrete ingredients for about 2-3 minutes.

Placing and Compaction: First the cube, cylinder and beam moulds are cleaned and then oil is applied to them to avoid the bond between the moulds and the concrete. Placing of concrete into the mould is done in 3 layers with 25 blows given to each layer with the help of tamping rod. The air trapped in the fresh concrete which was put in the moulds is removed by the table vibrator. The fresh concrete is allowed to set for 24 hours after it is placed in the molds. Then they were marked with specific identification like M1, M2, M3 etc., for varying replacement percentages of dolomite and copper slag and were put in the curing tank at ambient temperature. The hardened concrete specimens were removed from the curing tank after 3, 7 and 28 days for testing.

3. Compressive strength test

The cubes of size 150mm x 150mm x 150mm were used to conduct the compression test in accordance with IS:516-1959. Three samples were used to test the compressive strength test after 3, 7 and 28 days curing.

4. Split tensile test

Spilt tensile strength test was performed according to IS 5816-1970, a standard test to get the tensile strength in indirect manner.

5. Flexural strength test

Flexural strength test is utilized to determine the flexural strength of concrete under bending. Flexural strength teste was performed according to IS:516-1959.

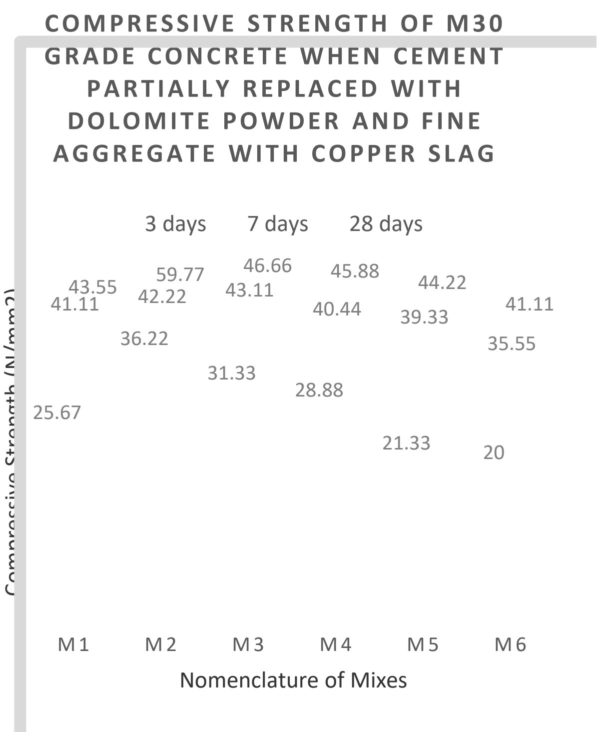
6. Concrete Mix

MIX	OPC Percentage	DOLOMITE POWDER Percentage	Fine Aggregate Percentage	COPPER SLAG Percentage
M1	100%	0%	100%	0%
M2	95%	5%	90%	10%
M3	90%	10%	80%	20%
M4	85%	15%	70%	30%
M5	80%	20%	60%	40%
M6	75%	25%	50%	50%

IV. TEST RESULTS

1. Compression test

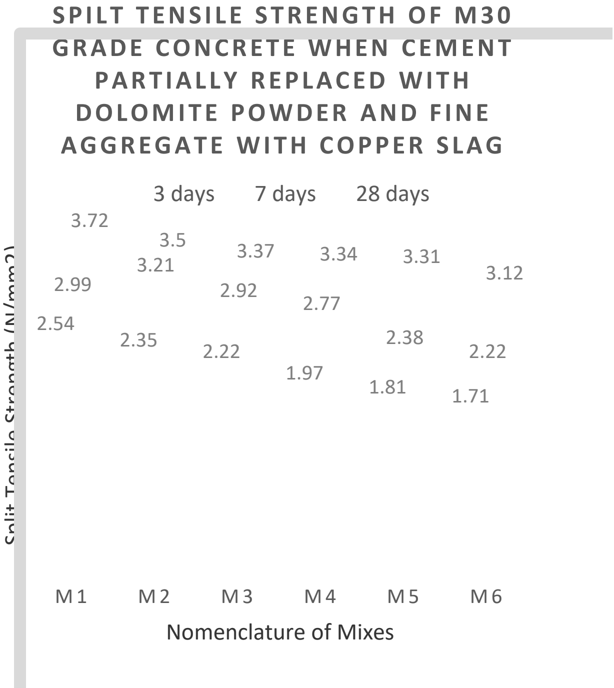
The Compressive strength for 3, 7 and 28days values are shown graphically in fig.1 below. It was observed that the compressive strength was optimum when 10% of cement replaced with dolomite powder and 20% of fine aggregate replaced with copper slag. It was also observed that 20% of cement replaced with dolomite powder and 40% of fine aggregate replaced with copper slag can be replaced which gives strength at par with conventional mix.



Fig(1) : Compressive Strength Results

2. Split tensile test

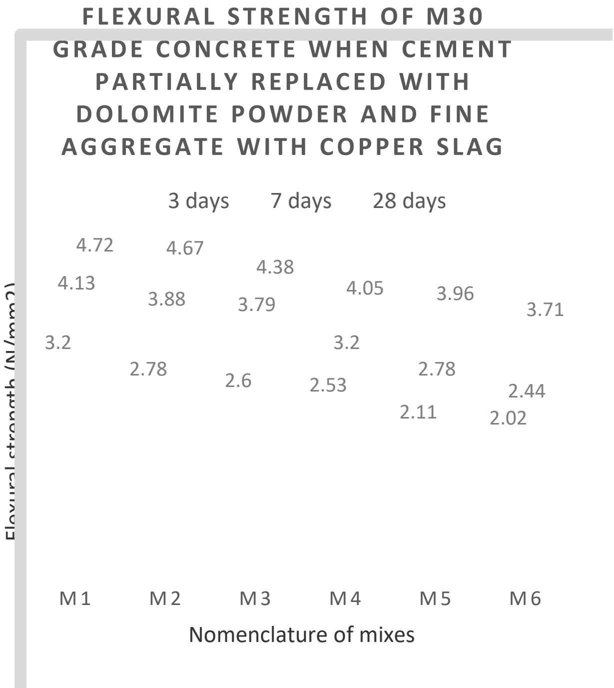
The split tensile strength for 3, 7 and 28days values are shown graphically in fig.2 below. It was observed that the split tensile strength was reduce gradually.



Fig(2) : Split Tensile Strength Results

3. Flexural strength test

The Flexural strength for 3, 7 and 28days values are shown graphically in fig.3 below. The flexural strength was observed to be gradually decreasing.



Fig(3) : Flexural Strength Results

V. CONCLUSION

Below are the conclusions that made from the inquiry are:

i. The partial replacement of cement with dolomite and copper slag with fine aggregate has increased the compressive strength

ii. The optimum compressive strength is observed at mix M3 i.e., at 10% replacement of cement with dolomite and 20% replacement of fine aggregate with copper slag.

iii. It was also observed that upto M5 i.e., at 20% dolomite and 40% copper slag can be replaced which gives compressive strength at par with conventional mix.

iv. The split tensile strength is observed to be gradually decreasing with the increase of replacement of dolomite and copper slag maybe due to reduce of interlocking between the ingredients of concrete mix.

v. The flexural strength is also observed to be decreasing with the increase of replacement of dolomite and copper slag.

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Dr. G V V Satyanarayana, Professor of Civil Engineering, completed his Ph.D from JNTUH, Hyderabad and has over Thirty two years of academic, Industrial and research experience in India. His Ph.D work was on Mechanical Response of Slab specimens with Mineral Admixtures Under Different Edge Conditions Subjected to Flexure, Punching Shear and Impact, Prior to PhD, he had earned Bachelors of Engineering in Civil Engineering from Osmania University, Hyderabad, and Masters of Engineering in Structural Engineering from JNTUH, Hyderabad. His research interests include developing modelling in FEM, various studies and applications of concretes like bi or triple blended concretes with bi-product materials, fibrous concrete etc., in which he has more than 16 publications, in various journals and conferences. He currently manages Co-Ordinator for M.Tech (STE) program at GRIET, Hyderabad and In-Charge for ACT laboratory and quality control In-Charge of GHMC consultancy works. He has been in this role since 2014. These GHMC consultancy for quality control are conducted for 3 Municipalities in GHMC, Hyderabad.

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Effect on Mechanical Properties of M35 Grade Concrete by Partial Replacement of Fine Aggregate with Copper Slag .

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Abstract: In present situation, fast urbanization has made a gigantic interest for regular sand consequently made it considerably more costly. Excess extraction of sand ,trending not only depletion of water table but also streams and rivers are diverting in their direction which leads to floods. Elective materials in all types of constructions are acquainted with decrease the weight on normal materials, further maintaining the economical status of project. While additionally dealing with the encompassing condition. Squander Materials like Copper Slag, Flyash, Carbonate Sand, stone residue and so forth having silica sythesis (SiO_2) could be utilized as a substitution for Fine aggregate in a concrete mix. In the process of manufacturing copper the bi-product Copper slag is produced in an heavy quantity. Copper slag has an high specific gravity and has glassy granular texture. Copper slag contains the same particle sizes as of fine aggregate so that it can be used as a replacement for fine aggregate in concrete mix. Here in this paper the main objective is to consider the utilization of Copper slag as an elective substitution material of Fine aggregate. Additionally examines the after effect of substitution of Fine aggregate with Copper slag on mechanical characteristics of cement concrete such as Compressive strength and Flexural strength.

Keywords: Concrete, Copper slag, Compressive strength, Fine aggregate, split tensile strength and Flexural strength.

I. INTRODUCTION

In the present situation, because of constant development in populace and industrialization there is enormous necessity of aggregates generally for construction industry due to excessive usage of natural sand it is causing disturbances to nature and also became more expensive. Day to day the availability of sand become decreased now a days sand is a scare material. So the researchers created plans for managing the waste coming from various Industries. such as substituting the fine aggregates by other materials to reach the explicit needs. Rapid industrialization producing the heavy quantity of waste and substantially natural resources are also getting depleted.

The eco agreeable and dependable advancement for development comprise the utilization of non customary and diverse waste materials and reusing of waste material for diminishing emanations in conditions and diminishing the utilization of natural resources. Copper slag has nearly same features as the fine aggregate. Copper slag is one of those materials which is disposed in to land as a waste material and which is produced as a by-product during the refining of copper. Here about 2.2 to 2.5 tons of waste is produced. Now this waste slag can be used as a replacement for the aggregates in concrete. Usage of copper slag as a partial replacement for fine aggregate, the cost of the construction can also be reduced. About 25%to30% of sand is present in copper slag which is the main component in natural sand and a negligible amount of copper (0.2%) is also present in the copper slag. In this present investigation the mechanical properties of M35 grade concrete were tested when fine aggregate partially replaced with copper slag ,i.e.,10%to50% at a regular interval of 10%.

Copper slag is used as a replacement for the fine aggregate as there is a large disposal of it and has the same properties as of fine aggregate investigations had done on the replacement of fine aggregate with copper slag with different percentages like in an investigation[1] the replacement of fine aggregate is done so as to find out the mechanical properties by replacing copper slag at different percentages from 0%to 50% of M40 grade concrete and concluded that maximum strength is achieved at 40% replacement when compared to conventional mix. In an Performance oriented investigation of M25 grade concrete[2]replacement of fine aggregate from 0 %to 100% the flexural strength and up to 75% has maximum compressive strength than control mix and also stated that increase in compressive and flexural strength is due to high toughness of copper slag. comparing to the conventional mix[3] the strength characteristics were find out by replacement of 20%40%60%80%100% of M20 mix and high strength is gained at 40% replacement which resulted in 37.55% increase in compressive strength and 5.3% increase in split tensile and 40.7% in flexural strength. From[4] the replacements at different levels it is studied that increase in replacement levels increases the compressive strength, flexural strength and split tensile strength up to an optimum point this is due to high percentages of silica and high toughness of copper slag and better heat of hydration. As per the review[5] on partial substitution of copper slag as a replacement the increase in strength is mainly depended on copper slag and the workability is also increasingly

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influenced due to the increased copper slag quantity and reduced water absorption characteristics of copper slag and glassy surface. Majorly the presence of copper in copper slag is only 0.2 %which is not so harm full. Here[6] M30 grade mix with replacement percentages between (0%to60%) has been casted and compressive strength is analysed in comparison to conventional and concluded that at 20% 40%and 60% compressive strength is increased and density along with workability also increased with increased in copper slag quantity. In a series of replacements [7]found that workability is increased with increase in copper slag and also concluded that partial replacement by copper slag has a major effect in raise of compressive strength and tensile strength of concrete thus partial replacement serves as a solution for the disposal of copper slag.

II. MATERIALS

1. Cement

The ordinary Portland cement of 53 grade is used through -out the investigation confining to IS:12269-1987.Test results are mentioned in Table1

TABLE : 1 Characteristics Of Cement

CHARACTERISTICS	OBSERVED VALUE
Normal consistency	32%
Initial setting time	65 min
Final setting time	270 min
Specific gravity	3.15
Compressive strength at 28 days	53 Mpa

2. Water

Portable water which is available in the premises of the lab is used for the curing and the experimental procedures which are free from the organic matter and dissolved salts.

3.*Coarse aggregate*

Locally available Crushed angular aggregate of size 20mm were used confining to IS 383:1970.Confining to IS 2386:1963 physical properties like specific gravity and water absorption were tested.Test results are mentioned in Table2.

TABLE: 2 Characteristics Of Coarse Aggregate

CHARACTERISTICS	OBSERVED VALUES
Water absorption	0.5
Specific gravity	2.64
Fineness modulus	6.8

3. Fine aggregate

Locally available fresh sand confining to IS 383:1970. Which is free from organic matter confining to IS 2386:1963 physical properties like specific gravity and water absorption were tested . Test results are mentioned in Table 3.

TABLE: 3 Charcteristics Of Fine Aggregate

CHARACTERISTICS	OBSERVED VALUES
Grade zone	II
Specific gravity	2.6
Fineness modulus	2.2

4. Copper slag

Copper slag used here was collected from the Sri Sai Metalizers located at Hyderabad. The physical and chemical properties of copper slag are mentioned in Table 4 and Table 5 .

TABLE :4 Physical Properties Of Copper Slag

PHYSICAL PROPERTIES	COPPER SLAG
Particle shape	Multifaceted
Appearance	Black and glassy
Specific gravity	3.15

TABLE: 5 Chemical Properties Of Copper Slag

Chemical component	Percentage of chemical component
SiO_2	33-35%
Fe_2O_3	40-44%
Al_2O	4-6%
CaO	0.8_1.5%
MgO	1-2%

5. Super plasticizer

Super plastisizer Master Rheobuild 920SH was used to improve the workability of concrete. The properties of Admixture are mentioned in Table 6

TABLE:6 Properties Of Super Plasticizer

State	Liquid
Colour	Dark
Density	1.2
Chemical name	Naphthalene formaldehyde polymer
Ph	8.40

III. EXPERIMENTAL INVESTIGATION

Experimental investigation was performed on partial replacement of fine aggregate with copper slag to study the mechanical properties of M35 grade concrete. The Replacement of fine aggregate with copper slag is done at different percentages from 0% to 50%at a regular interval of 10% by mass. The materials like cement, coarse aggregate ,fine aggregate and copper slag were tested in laboratory for suitability and used in mix design.

1. Mix proportion

The mix proportion of M35 grade concrete for the present investigation designed as per IS 10262-2009.The mix proportion used are 1:2.1:2.86 at w/c 0.17.

2. Compressive strength test

The cube specimen of size 150mm x 150mm x 150mm were casted ,cured and tested for compressive strength test in accordance with IS 516-1969.After 3 days 7 days and 28 days and for every test 3 samples were tested.

3. Split tensile test

The cylinder specimen of size 150mmdia x 300mm in height were casted, cured and tested for split tensile strength test in accordance with IS 5816-1970.After 3 days 7 days and 28 days and for every test 3 samples were tested.

4. Flexural strength strength

The specimen of size 400mm x 100mm x 100 mm were casted cure and tested for flexural strength. After 3 days 7 days and 28 days and for every test 3 samples were tested.

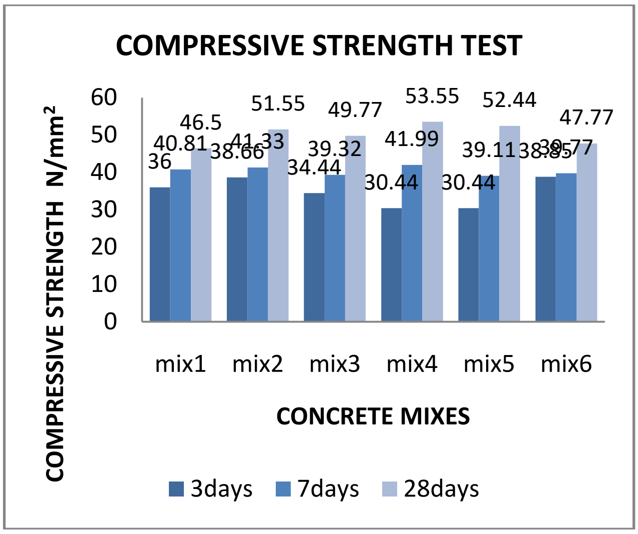
5. Concrete mix

MIX1:OPC +(100% fine aggregate + 0%copperslag)+coarse aggregate.
MIX2: OPC +(90% fine aggregate +10%copperslag)+coarse aggregate.
MIX3: OPC +(80%fine aggregate+20%copperslag)+coarse aggregate.
MIX4: OPC +(70% fine aggregate+30%copperslag)+coarse aggregate.
MIX5: OPC +(60% fine aggregate+40%copperslag)+coarse aggregate.
MIX6: OPC +(50% fine aggregate +50% copper slag)+ coarse aggregate.

IV. TEST RESULTS

1. Compressive strength

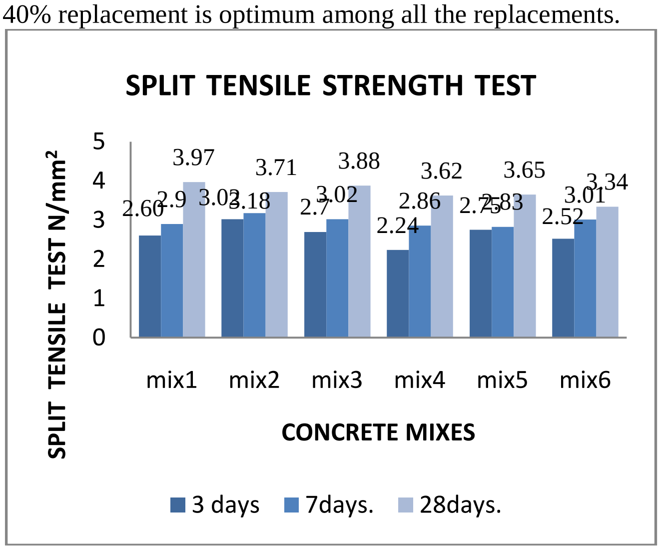
The compressive strength values for all the mixes at 3 days ,7 days and 28 days age are shown graphically in fig 1.It is observed that 40 % replacement is optimum among all replacement and compressive strength for 40%replacement is 23% more than the target mean strength at 28 days.



Fig(1): Compressive strength results

2. Split tensile strength

Split tensile strength values for all the mixes at 3 days,7 days and 28 days are shown graphically in Fig 2. It is observed that 40% replacement is optimum among all the replacements.



Fig(2) :Split tensile strength results

3. Flexural strength

Flexural strength values for all the mixes at 3 days,7days and 28 days are shown graphically in Fig 3.It is observed that 40% replacement is optimum among all the replacements.

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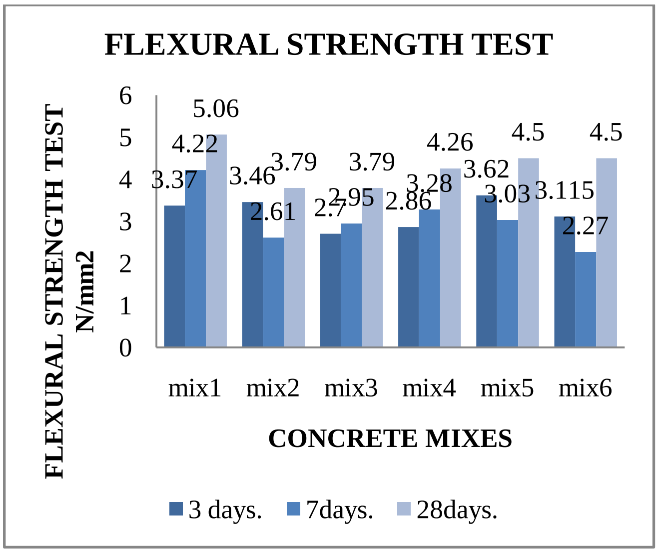

Fig (3) : Flexural strength results

V. CONCLUSION

following are the conclusions for the experimental investigations.

i. Considerable increase in compressive strength was seen when the copper slag is used in permissible limits.
ii. Up to 50% of replacement of fine aggregate copper slag shows better results when compared with conventional concrete
iii. With 30% replacement of fine aggregate with copper slag showed the 23% increased in compressive strength.
iv. By experimental results it is observed that the split tensile strength decreased at small percentages it may be due to lesser interlocking capacity between concrete ingredients.
v. By experimental results it is observed that the flexural strength decreased at small percentages it may be due to lesser interlocking capacity between concrete ingredients .
vi. The increase in compressive strength is mainly due to the high toughness and the glassy surface of the copper slag.
vii. The workability is also seen increased depending on the percentages of copper slag used.
viii. By this investigation it is clear that the copper slag can be used as a elective replacement material for fine aggregate up to 50% helps in keeping up the ecological and economical balance.

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Effect of Dolomite Powder on Mechanical Properties of M40 Grade Concrete When Cement was Partially Replaced

G.V.V Satyanarayana, B.V.N Ravi Teja Reddy

Abstract: Cement is one of the most significant constituents of concrete. Most of the properties of concrete depend on cement. By calcining argillaceous and calcareous material at a high temperature in cement production. During this procedure, huge amount of Co_2 is discharged into the air. India is the second biggest manufacturer of cement on the planet. It is assessed that the generation of one tonne of cement brings about discharge of 0.8 tonne of Co_2. The decline in the utilization of cement will lessen the cost of concrete and outpouring of Co_2. Dolomite powder acquired by pulverizing rock forming mineral deposit of dolostone can be utilized as a trade material for cement in concrete up to certain percentage. Dolomite powder has a few comparative attributes of cement. Utilizing dolomite powder in cement can diminish the expense of cement and may expand the solidarity somewhat. Dolomite powder is a pozzolonic material which will improve not only the density but also strengthen the hardness of concrete. This paper inspects the likelihood of utilizing dolomite powder as partial substitution material to cement. The substitution rates attempted were 0 to 25% at a regular interval of 5% by weight of cement. The outcome demonstrates that substituting of cement with dolomite powder improves the compressive, split tensile and flexural strength of concrete.

Keywords: concrete, cement, dolomite powder, compressive strength, split tensile and flexural strength.

I. INTRODUCTION

Cement is the essential building material utilized in the greater part of the building structure. Numerous materials are utilized to make great quality concrete. Cement, coarse aggregates, fine aggregates, chemical admixtures, mineral admixtures, water are the constituents of concrete. Cement is the most significant constituent material, since it holds together the aggregates and opposes the climatic activity. Be that as it may, production of cement transmits about 0.8 tons of Co_2 into the air for 1 ton of cement made. Dolomite is a carbonate material made out of Calcium Magnesium Carbonate ($CaMg(Co_3)_2$). Dolomite is a stone forming mineral which is noted for its astounding wettability and dispersibility. Dolomite has a decent enduring weather resistance. Dolomite is favored for building material because of its higher surface hardness and thickness. Dolomite is preferred as a filler material for asphalt and concrete applications as it has higher strength and hardness. By usage of dolomite powder an improvement in early strength of concrete with no side effects over long term properties can be seen. By the compelling usage of dolomite powder, the target of decrease of expense of construction can be met. An endeavour has been made to investigate the plausibility of utilizing dolomite as a substitution material for cement. M40 grade concrete samples were made by supplanting 0 to 25% at a regular interval of 5% in cement with dolomite powder. The compressive, split tensile and flexural strength of the samples were tested at 3, 7and 28days of curing. Ideal substitution percentage of dolomite was resolved.

Most of the researchers are focused about utilization of other industrial or agro based wastages in partial replacement of cement in concrete production. So utilization of dolomite powder is a suitable solution.

Replacing of cement with dolomite powder in an investigation [1] is found to enhance the compressive strength of concrete for using M_{20} grade concrete. Another investigation [2] proved that compressive strength of cubes increased up to 15% of dolomite powder replaced in cement and a further increase reduced the compressive strength and split tensile and flexural strength increased up to 15% and 10% respectively and a further increase in both cylinders and beams reduced the strength and the grade used here is M_{30}. When dolomite powder and copper slag are used in an investigation [3] compressive strength and tensile strength are increased by replacing dolomite with cement in 10%, 20% and 30% and keeping copper slag replacement percentage constant at 25%. From an investigation [4] done by replacing cement with dolomite powder in the range of 5% to 25% it is found that at low replacement percentage 5% to 15% compressive strength is increased and at higher replacement percentage 20% and 25% compressive strength decrease drastically due to dilution. This experimental evaluation [5] found that replacing cement with dolomite powder will increase the compressive strength and flexural strength at 28 days by 10.4% and 17.8% respectively. By following the conclusions that are drawn by an investigation [6] state that the optimal percentage for replacement of dolomite and m-sand is 10% each and at this percentage the compressive and split tensile are said to have increased.

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II. MATERIALS

In this investigation OPC 53 grade cement, fine aggregate (river sand), coarse aggregate (20mm), dolomite powder, water and chemical admixture to enhance workability are used.

A. Ordinary Portland Cement

Cement is a binder, a substance that sets and hardens independently, and binds other materials together. Many types of cements are available in the market. The commonly used cement is Portland cement. Portland cement is of 53-grade was used for the investigation. The specific gravity of Portland cement was 3.15.

TABLE:1

CHARACTERISTICS	OBSERVED VALUE
Normal consistency	32%
Initial setting time	65 min
Final setting time	270 min
Specific gravity	3.15
Compressive strength at 28 days	57 Mpa

B. Fine Aggregate

The most significant purpose of the aggregate is to help with creating workability and consistency in blend. The fine aggregate likewise helps the cement mixture to hold the coarse aggregate bits in suspension. This activity advances plasticity in the blend and averts the conceivable segregation of mixture and coarse aggregate. It ought to be strong, clean and be free from natural issues. It should not have any obvious measure of clay balls and other containment for example alkalis, salt, coal, rotted vegetation etc. River sand is used as fine aggregate. The specific gravity of river sand is observed to be 2.6.

TABLE:2

CHARACTERISTICS	OBSERVED VALUE
Grade zone	II
Specific gravity	2.6

C. Coarse Aggregate

The coarse aggregate is the biggest segment of concrete. It is artificially a stable material. Usage of coarse aggregate lessens the dry shrinkage and other dimensional changes happening by virtue of development of dampness. Hard broken rock stones were utilized as coarse aggregate in concrete. Size of coarse aggregate in the examination was 20mm. The specific gravity of the coarse aggregate was observed to be 2.64.

TABLE:3

CHARACTERISTICS	OBSERVED VALUE
Water absorption	0.5%
Specific gravity	2.64
Fineness modulus	6.8

D. Dolomite powder

Dolomite is a carbonate material made out of calcium magnesium carbonate CaMg $(Co_3)_2$. The term is likewise used to portray the sedimentary carbonate rock dolostone. Dolostone (dolomite rock) is made dominatingly out of the mineral dolomite with a stoichiometric proportion of half or more prominent substance of magnesium supplanting calcium, frequently because of digenesis. Dolomite is a stone forming mineral which is noted for astounding wettability and dipersibility just as moderate oil and plasticizers absorption. Dolomite has great weather resistance.

TABLE:4(Properties)

PROPERTY	DOLOMITE POWDER
Formula	$CaMg(Co_3)_2$
Specific gravity	2.85
Color	White
Tenacity	Brittle
Crystal system	Hexagonal
Sieve alanysis	Zone III
Moisture content	Nil

TABLE:5(Chemical composition)

CHEMICAL COMPONENT	% OF CHEMICAL COMPONENT
Total carbonate	97.4%
$CaCo_3$	54.3%
$MgCo_3$	45.6%
Al_2O_3	0.02%
SiO_2	0.3%
Fe_2O_3	0.04%

E. Water

Water is a significant element of concrete as it effectively takes an interest in the substance response with cement. The water, which is utilized for making cement ought to be spotless and free from destructive debasements like oil, alkalis, acids etc. water for making cement ought to have pH value somewhere in the range of 6 to 8. Locally accessible drinking water was utilized in this work.

F. Super plasticizer

Super plasticizer Master Rheobuild 920SH chemical India Ltd. was utilized as water diminishing admixture, it expands workability.

TABLE:6

State	Liquid
Color	Dark

Retrieval Number: L26701081219/2019©BEIESP
DOI: 10.35940/ijitee.L2670.1081219

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Density	1.2
Chemical name	Naphthalene formaldehyde polymer
PH	8.40

III. EXPERIMENTAL INVESTIGATION

A. General

Tests were done on partial replacement of cement by dolomite powder to obtain mechanical properties of M_{40} grade concrete. The replacement percentages of 0%,5%,10%,15%,20%,25% were tried to get the test results. The materials like coarse aggregate, fine aggregate, cement, dolomite powder are experimented in laboratory for compatibility.

B. Mix proportion

The M40 grade concrete mix proportion is designed as per IS 10262-2009. The designed mix proportion is 1:1.72:3.11.and the w/c ratio used is 0.42.

C. Casting and Demoulding

The materials required were taken according to their mix and weighed in an electronic scale. Same was performed for every mix proportion and required specimens were casted. The concrete placed in moulds were permitted to set for 24 hours. After demoulding they were marked with markings like M1, M2, M3 etc., for every casted specimens according to their mixes and kept in curing tank which is maintained at an ambient temperature throughout the curing process. The concrete specimens were removed for their respective testing times which are 3, 7 and 28 days.

D. Compressive strength test

The specimen which is a cube of size 150mm x 150mm x 150mm were casted and experimented to obtain results in respective to IS 516-1969. For every test, 3 samples were taken on every 3 days, 7 days and 28 days.

E. Split tensile test

The specimen which is a cylinder of size 150mm diameter x 300 mm height were casted and experimented to obtain results in respective to IS 5816-1970. For every test, 3 samples were taken on every 3 days, 7 days and 28 days.

F. Flexural strength test

The specimen which is a beam of size 400mm x 100mm x 100mm were casted, cured and experimented on to obtain results. For every test, 3 samples were taken on every 3 days, 7 days and 28 days.

G. Concrete Mix

MIX	OPC Percentage	DOLOMITE POWDER percentage
M1	100%	0%
M2	95%	5%
M3	90%	10%
M4	85%	15%
M5	80%	20%
M6	75%	25%

IV. TEST RESULTS

A. Compression test

The values for the compressive strength of proportions 3 days, 7 days and 28 days are calculated and represented pictorially in the below chart Fig.1. It is found that the optimum replacement percentage is 10% and it has 7.6% increase in strength.

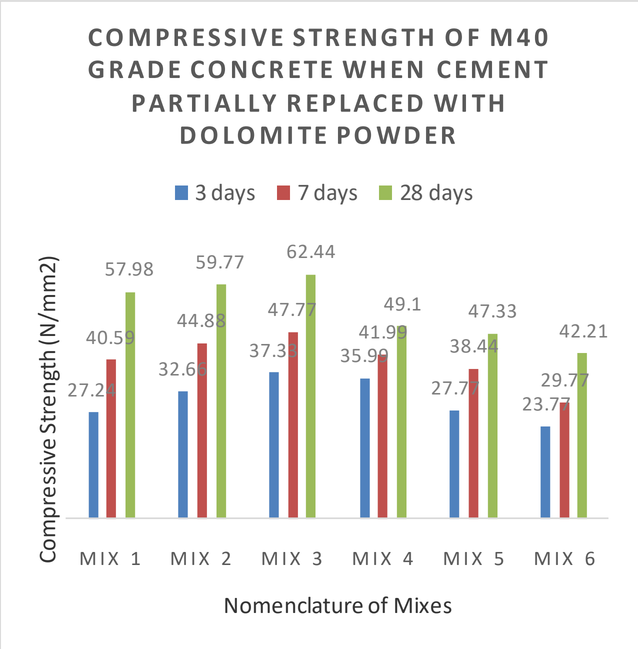

Fig.1

B. Split tensile test

The values for the split tensile test of proportions 3 days, 7 days and 28 days are calculated and represented pictorially in the below chart Fig.2. The optimum replacement percentage is observed at 10%.

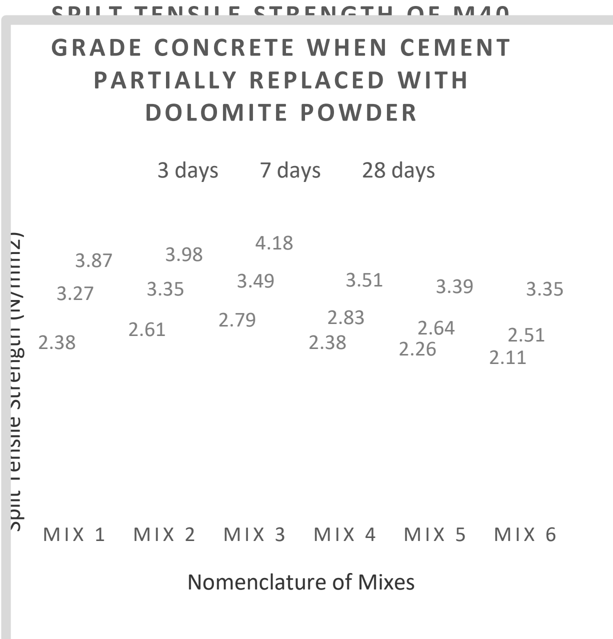

Fig.2

C. Flexural strength test

The values for the flexural strength test of proportions 3 days, 7 days and 28 days are calculated and represented pictorially in the below chart Fig.3. The optimum replacement percentage here is 10%.

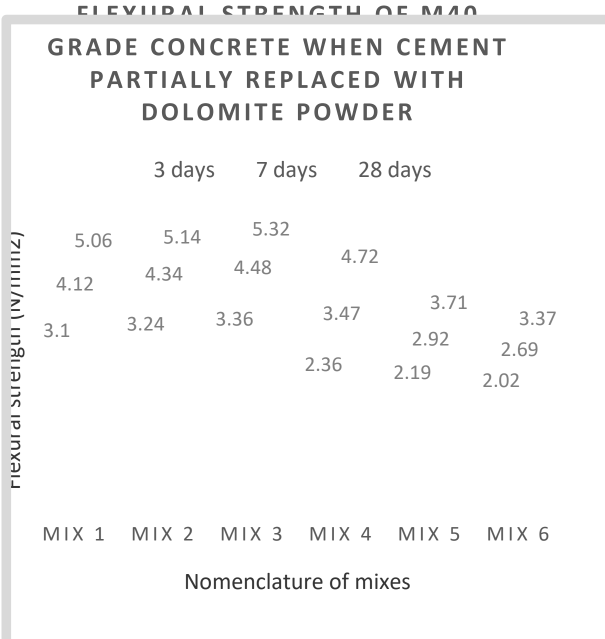

Fig.3

V. CONCLUSION

The below are the conclusions that are made from the investigation done:

1. The conclusions achieved from the investigation carried out are, when partially replacing dolomite in place of cement it is observed that compressive strength is increased by 7.6% in 'M3' i.e. at 10% replacement of dolomite in cement but a further increase in replacement of dolomite in cement reduced the compressive strength.
2. Even for 15% replacement of dolomite powder cement the compressive strength is in satisfactory level.
3. The split tensile strength is also noticed to be optimum at 10% dolomite replacement in cement and further increase in replacement gradually decreased the split tensile strength.
4. The replacement of dolomite powder in cement at 10% is also found to improve flexural strength.
5. By replacing dolomite powder with cement we reduce usage of cement which in turn reduce the overall cost of concrete and decreases the emission of Co_2.

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Dr. G V V Satyanarayana, Professor of Civil Engineering, completed his Ph.D from JNTUH, Hyderabad and has over Thirty two years of academic, Industrial and research experience in India. His Ph.D work was on Mechanical Response of Slab specimens with Mineral Admixtures Under Different Edge Conditions Subjected to Flexure, Punching Shear and Impact, Prior to PhD, he had earned Bachelors of Engineering in Civil Engineering from Osmania University, Hyderabad, and Masters of Engineering in Structural Engineering from JNTUH, Hyderabad. His research interests include developing modelling in FEM, various studies and applications of concretes like bi or triple blended concretes with bi-product materials, fibrous concrete etc., in which he has more than 16 publications, in various journals and conferences. He currently manages Co-Ordinator for M.Tech (STE) program at GRIET, Hyderabad and In-Charge for ACT laboratory and quality control In-Charge of GHMC consultancy works. He has been in this role since 2014. These GHMC consultancy for quality control are conducted for 3 Municipalities in GHMC, Hyderabad.

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Durability Properties Of M60 GradeSelf-Compacting Concrete With Partial Replacement Of Cement by GGBS, Lime Powder and Metakaolin

GVV Satyanarayana, B krishna Chaitanya

Abstract: In this investigation the Durability Properties of M60 grade Self compacting concrete (SCC) with partial replacement of cement by GGBS, Lime powder, and Metakaolin. Five mixes were prepared at 25% replacement of cement content with different admixture (.i.e.M1, M2, M3, M4&M5) at 0.34 w/c ratio and 1% super plasticizer dosage by cement content for maintaining required workability. Filling and passing ability were found out by slump test, V-funnel, L-box and U-box before casting the specimens. In this investigation M60 grade designed by means of Nansu method by fulfilling EFNARC guidelines for SCC. Durability properties tested under acid environment with H_2SO_4 and HCl and Sulphate environment with $MgSO_4$ and Na_2SO_4 at curing period of 28 days.

In this investigation the Lime-powder based mixes shows high durability comparatively to Metakaolin as well as addition of GGBS maintained sufficient compressive strengths.

Keywords : SCC, GGBS, Metakaolin and Lime Powder.

I. INTRODUCTION

Day today growth in civilization tends to rapid growth in construction activity such that high rise buildings, hallow shafts, express high ways and massive constructions. For achieving the appropriate requirements such as accomplishing the project on constraint time at optimum budget therefore here comes into picture the Self compacting concrete (SCC) which is compacted by its own weight and fill formwork especially in congested place like beam-column joint and spread into every corner of farm works. Self-compacting concrete (SCC) is non-segregating concrete that can spread into place, fill the formwork and encapsulate the reinforcement without any need of vibration. By this concrete speedy construction is possible and with nice finishing.It is a sensitive mix, strongly dependent on the composition and characteristics of its constituents. The use of mineral admixtures not only improves the hardened properties but also durability properties of the concrete. Durability is a general analysis of the service life and the performance of concrete in all aggressive environments.

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SCC is the most viable option for site conditions with constrained access and locations of congested reinforcements.

Many investigations undergone testing upon durability properties of SCC by partial replacement of different admixtures, Rizwan A khan concludes that SCC mix containing 20% Fly ash and 10% Metakaolin performs best in compressive strength, initial surface absorption and capillary suction tests [1]. Biswadeep Bharali states that the presence of fly ash in SCC improves workability of fresh concrete and addition of GGBS requires high dosage of super plasticizer to obtain acceptable workability therefore in the combined replacement of FA and GGBS cement shows increase in strength by increase in percentage of replacement [2].

M Jagadeesh describes replacing cement with fly ash reduce the strength of SCC mix when compared with GGBS and Normal SCC mix and also explains that the combined replacement of FA and GGBS withstands all the strength and obtained optimum results [3]. Srihari S and MV Seshagiri Rao explained that the addition of Metakaolin to concrete decreases the workability however can improve by increasing super plasticizer and change in w/b ratio and describes that replacement of cement by Metakaolin forms (C-S-H) gel which improves the compressive strength and makes concrete stronger by blocking existing pores in harden concrete [4].

B H V Pai investigation describes that to obtain acceptable workability requirement of SCC should adopt the mineral admixtures as powder content in concrete mix and states that presences of GGBS improves best results in compressive strength, split tensile strength and flexural strength. The low strength of SF based SCC mix is possible due to the high amount of SF (50.19%) [5]. S A Kristiawan, Sunarmasto and G P Tyas concludes that the degradation of SCC due to sulfuric acid attack as measured by compressive strength loss and diameter change can be reduced with a higher inclusion of fly ash to replace partially cement. The extent of the reduced degradation is more pronounced at a later age. The effect of fly ash content to modify SCC resistance against sulfuric acid could be explained by the combination of lower cement content, pozzolanic reaction and refinement of interparticle spaces [6].

II. MATERIALS USED

1. Cement:

The ordinary Portland cement is used for flexibility in adjusting pozzolanic material content in concrete mixes cement 53 grade of specific gravity 3.14 and normal consistency 28%.

2. Sand (FA):

River sand is used for this investigation with specific gravity of 2.53 and bulk density is about 1765Kg/m^3. Zone-II sand is used for this experimental work with 2.5% water absorption and 0.7% surface water content.

3. Gravel (CA):

Crushed stone aggregate of 10mm is used with specific gravity of 2.6 and bulk density is about 1523 Kg/m^3. These aggregates are more angular with 2% water absorption and 0.5% surface water content.

4. Mineral Admixture:

GGBS: Ground granulated blast furnace slag (GGBS) bought from JSW steel plant Allahabad had a specific gravity of 2.3 with pale yellow colour

Metakaolin: Presence of metakaolin improves durability properties of concrete comparatively. Metakaolin is available at Adhipathi minerals kothapally.

Lime powder: Lime powder is finer than cement collected from local resource.

5. Super plasticizer:

Master ease 3709 is used about 1% of cement content.

III. EXPERIMENTAL STUDIES

Specimens used in this experimental study are 120 cubes of 150X150X150 mm are undergone test i.e. acid attack and sulphate attack of concrete. Usually durability properties of concrete describe residual strength of concrete in mechanism. There are many tests to extract the durability properties such that permeability, sorptivity, water absorption, acid attack, sulphate attack etc. By using Nansu mix design method M60 grade of concrete is designed for this experimental study with fulfilling EFNARC guidelines for SCC. So many trail mixes performed to fix the final mix proportion. After a final proportion are fixed as 1(cement) :1.751(FA) :1.395(CA) for M60 grade of SCC. Mix proportions as shown in table 1. Mix M1 acts as a conventional concrete throughout investigation.

Table 1 Mix proportions

Mix	Proportions
M1	75%C+25%GGBS
M2	75%C+15%GGBS+10%LP
M3	75%C+15%GGBS+10%MK
M4	75%C+10%GGBS+15%LP
M5	75%C+10%GGBS+15%MK

IV. TESTING PROCEDURE

Since the concrete here is SCC need to conduct test on both fresh and harden concrete. To obtain acceptable workability of concrete it should satisfy the passing ability, filling ability and flowing ability. These tests are conducted as per EFNARC guidelines for SCC. After final mix fixed the mix design for mixes as shown in table 2

Table 2 Mix design

Mix	Cement (Kg/m^3)	Pozzalona (Kg/m^3)			FA (Kg/m^3)	CA (Kg/m^3)
		GGBS	*LP*	*MK*		
M1	436	145.5	0	0	1019	812
M2	436	87.3	58.2	0	1019	812
M3	436	87.3	0	58.2	1019	812
M4	436	58.2	87.3	0	1019	812
M5	436	58.2	0	87.3	1019	812

1. Fresh concrete test:

Workability test are conducted on SCC according to EFNARC guidelines for SCC and the fresh properties of SCC mixes with various composition of cementitious materials are tabulated in table 3 as follow.

Table 3 Test results on Fresh concrete

Property	M1	M2	M3	M4	M5
Slump (mm)	650	630	615	590	570
L-box (ratio)	0.9	0.86	0.81	0.75	0.7
V-funnel (sec)	10	11	12.5	14	16
U-box (ratio)	0.8	0.75	0.77	0.8	0.79

2. Harden concrete test:

2.1. Compressive test**:**

Table 4 Compression Test for 28 days

Mix	Proportions	compression test (28 days)			Average (MPa)
		1	*2*	*3*	
M1	75%C+25%GGBS	72.88	71.92	72.5	72.43
M2	75%C+15%GGBS+10%LP	84.2	83.6	83.4	83.73
M3	75%C+15%GGBS+10%MK	63.5	63.9	62	63.13
M4	75%C+10%GGBS+15%LP	71.6	72.8	72.2	72.2
M5	75%C+10%GGBS+15%MK	47.6	47.1	46.4	47.03

2.2. Acid attack:

2.2.1.1. H_2SO_4

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 5

2.2.1.2. HCl

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 6

2.3. Sulphate attack:

2.3.1.1. $MgSO_4$

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 7

2.3.1.2. Na_2SO_4

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 8

Table 5 Compressive strengths after acidic environment (H_2SO_4) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.21	8.33	8.34	8.33	8.34	8.21	8.22	8.26	8.24	8.19	8.31	8.23	8.21	7.96	8.30
After	8.01	8.05	8.18	8.05	8.18	8.19	8.06	8.09	8.04	7.88	8.00	8.11	7.79	7.66	8.00
%Loss of wt	2.38	3.29	1.90	3.29	1.90	0.17	1.86	2.08	2.43	3.73	3.67	1.43	5.12	3.73	3.65
% of loss in wt (Avg)	2.4			1.8			2.1			2.9			4.2		
f_{ck}	72.4			83.7			63.1			72.2			47.0		
f^{1}_{ck}	52.1			59.6			38.8			40.6			38.6		
% of loss in strength	28.06			28.80			38.53			43.79			17.95		

f_{ck} =Average Compressive Strength after 28 days water curing
f^{1}_{ck} = Average Compressive Strength after 28 days curing in Acidic environment

Table 6 Compressive strengths after acidic environment (HCl) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.43	8.18	8.21	8.18	8.20	8.24	8.28	8.14	8.15	8.17	8.33	8.21	8.12	8.00	8.10
After	8.41	8.13	8.19	8.11	8.14	8.12	8.23	8.10	8.11	8.16	8.26	8.19	8.08	7.91	8.00
%Loss of wt	0.31	0.57	0.19	0.89	0.76	1.44	0.59	0.52	0.41	0.17	0.78	0.17	0.39	1.09	1.27
% of loss in wt (Avg)	0.4			1.0			0.5			0.4			0.9		
f_{ck}	72.4			83.7			63.1			72.2			47.0		
f^{1}_{ck}	62.8			58.6			49.8			53.7			41.39		
% of loss in strength	13.29			30.04			21.10			25.67			11.93		

f_{ck} =Average Compressive Strength after 28 days water curing
f^{1}_{ck} = Average Compressive Strength after 28 days curing in Acidic environment

Table 7 Compressive strengths after Sulphate environment (MgSO4) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.40	8.31	8.21	8.29	8.23	8.33	8.29	8.28	8.16	8.44	8.34	8.24	8.09	7.97	8.08
After	8.47	8.38	8.28	8.33	8.29	8.37	8.33	8.32	8.20	8.49	8.39	8.29	8.13	8.01	8.14
%Loss of wt	0.73	0.90	0.86	0.49	0.73	0.48	0.46	0.48	0.49	0.56	0.65	0.61	0.51	0.43	0.74
% of loss in wt (Avg)	0.8			0.6			0.5			0.6			0.6		
f_{ck}	72.4			83.7			63.1			72.2			47.0		
f^{1}_{ck}	73.1			76.6			64.7			66.5			48.6		
% of loss in strength	-0.87			8.58			-2.49			7.93			-3.37		

f_{ck} =Average Compressive Strength after 28 days water curing
f^1_{ck} = Average Compressive Strength after 28 days curing in Sulphate environment

Table 8 Compressive strengths after Sulphate exposure (Na2SO4) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.42	8.18	8.23	8.39	8.20	8.24	8.19	8.25	8.23	8.39	8.19	8.23	8.14	8.28	8.16
After	8.47	8.23	8.24	8.41	8.24	8.27	8.24	8.28	8.28	8.43	8.23	8.27	8.16	8.30	8.21
%Loss of wt	0.59	0.68	0.06	0.30	0.49	0.36	0.56	0.40	0.56	0.48	0.40	0.46	0.33	0.24	0.61
% of loss in wt (Avg)	0.45			0.38			0.51			0.45			0.40		
f_{ck}	72.43			83.73			63.13			72.20			47.03		
f^1_{ck}	65.01			55.11			66.25			66.04			48.95		
% of loss in strength	10.25			34.18			-4.94			8.54			-4.08		

f_{ck} =Average Compressive Strength after 28 days water curing
f^1_{ck} = Average Compressive Strength after 28 days curing in Sulphate exposure

V. DISCUSSION AND CONCLUSION

1. The investigation results shows that the compressive strength is high in mix M2 i.e. when 25% of cement content replaced with 10% LP and 15% GGBS.
2. As increasing the percentage of Lime-powder content there is decreasing the compressive strength.
3. The investigation results shows that in acidic environment with H_2SO_4 percentage of loss in compressive strength is observed moderate in mix M2 when compared with other mixes.
4. Percentage of loss in compressive strength for mix M1 is observed moderate in acidic environment with HCL when cement was partially replaced with 25% GGBS.
5. The percentage weight loss and compressive strengths of mixes M3 and M5 were all most zero against Sulphate attacks i.e. $MgSo_4$ and Na_2SO_4

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Effect of Air Quality Parameters in Hyderabad and Mapping Using QGIS and Detection Management Software

K.Hemalatha, T.Srinivas, G.Swetha, V.Haripan

Abstract**:** ***This paper mainly focuses on determination of particulate matter (PM), carbon dioxide and Carbon monoxide, relative humidity (RH), temperature, volatile organic compounds (VOC) and dew point in eleven most polluted areas in Hyderabad using equipment (3MTM EVM series) environmental monitor. In this paper we represented above parameters in the form of graph using Detection Management software in the duration of readings taken in a day and also we have done mapping using QGIS software.***

Keywords **:** ***Environmental monitor, Detection management software, QGIS mapping, pollution contaminants.***

I. INTRODUCTION ON ENVIRONMENTAL MONITOR (EVM)

The EVM is able to carry or move as instrument is light weight with a laser-photometer that measures various toxic gases, dust, any type of matter related to pollution [1-3]. The below equipment uses modern technology which measures up to three gases simultaneously in a selection of various toxic gases, volatile compounds, pollutants [4-7].

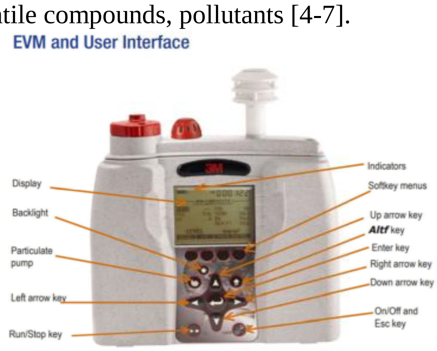

Fig 1 EVM keypad and display

II. OBJECTIVES

- Determination of particulate matter(PM), CO2, CO, Humidity, presence of temperature, volatile organic compounds (VOC) and dew point in eleven most polluted areas in Hyderabad using equipment (3MTM EVM 7 series) environmental monitor.
- Analyzing and Representation of above parameters in the form of graph using DETECTION MANAGEMENT software.
- Mapping this Data using QGIS software.

A. Significance

- To Measure several air pollutants or toxic gases including 10 microns and smaller particulate sizes which is harmful to human being will be obtained from this studies.
- Measuring humidity which reduces the in festivity of aerosolized influenza virus.
- Finding carbon monoxide which is responsible for heart disease, anemia and breathing problems.
- Measuring Volatile compounds as its vulnerability leads to major health issues like visual impairments, memory loss.
- Presence of moisture mixed with dust particles will be detected from these studies.
- Locating levels of Relative humidity.

III. EXPERIMENTAL STUDY

Total Eleven areas were chosen for experimental studies which are majorly involved in pollution contaminants [8-11]. The reasons for the selected areas are listed below:

1. In Miyapur Y-junction, petrol bunk and bus stop are very near, so more rush is present which cause more pollution.
2. More software companies present in Kondapur and Jubilee Hills, so more traffic present in that area.
3. In Erragadaa and Koti where more rush is present because of vehicles and public, potential area to cause more suffocation damage to health due to pollutants.
4. Secunderabad railway station, JNTUH and Shilparamam where more rush is present because of public and vehicles.
5. Uppal and Begumpet out skirts of the city where fluctuation in pollutant concentration is less.
6. L.B Nagar is suffocated area and more traffic area which cause pollution.

IV. MAPPING POLLUTION CONTAMINANTS DATA IN DIFFERENT AREAS USING QGIS SOFTWARE

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V.Haripan, Department of civil engineering, Gokaraju Rangaraju Institute of Engineering & Technology, Hyderabad.

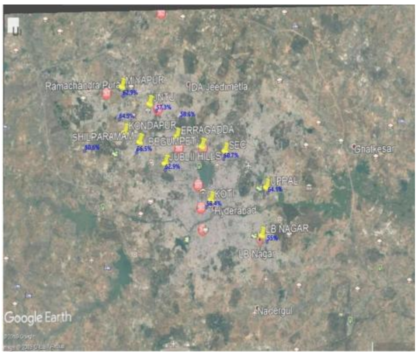

Fig 4.1 Humidity data at different areas in Hyderabad

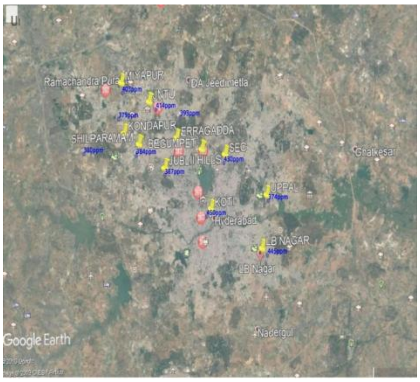

Fig 4.2 Co2 data at different areas in Hyderabad

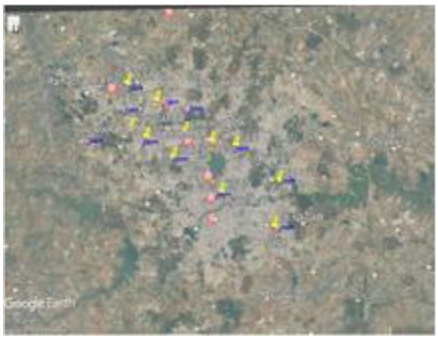

Fig 4.3 CO data at different areas in Hyderabad

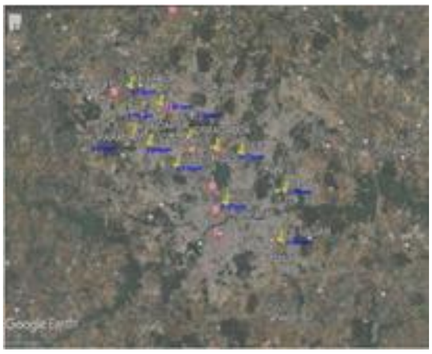

Fig 4.4 PM data at different area in Hyderabad

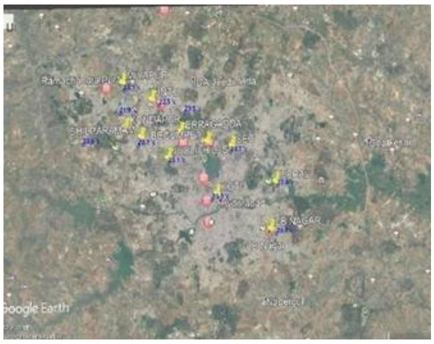

Fig 4.1.5 Dew point at different areas at Hyderabad

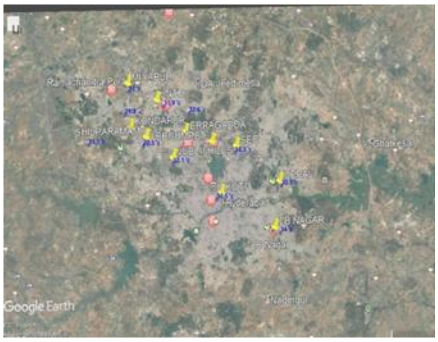

Fig 4.1.6 temperature data at different areas

A. *Graphical Representation of analysis using Detection Management Software*

MIYAPUR

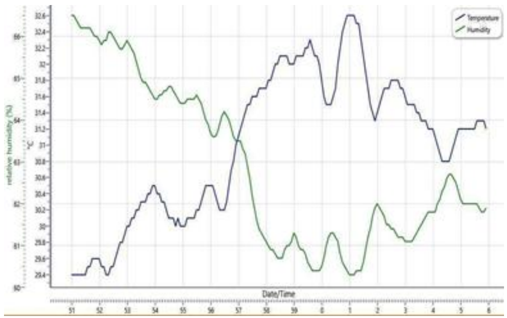

Fig 4.1 Humidity and Temperature

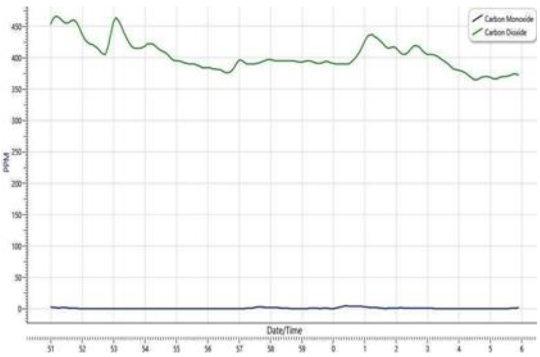

Fig 4.2 Carbon monoxide and Carbon dioxide

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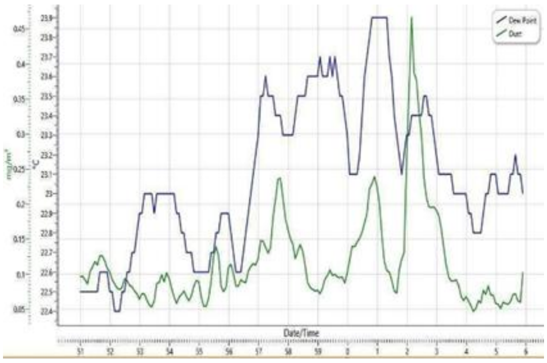

Fig 4.3 Dust, Dew point

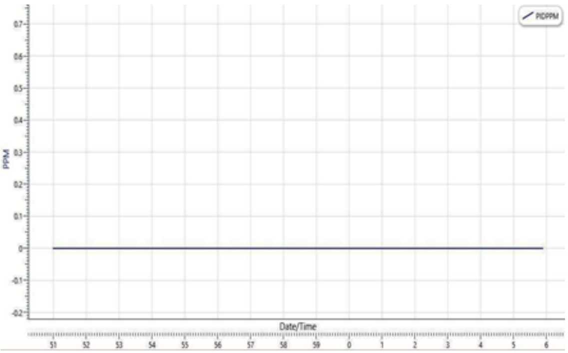

Fig 4.4 PID (volatile compounds)

KONDAPUR

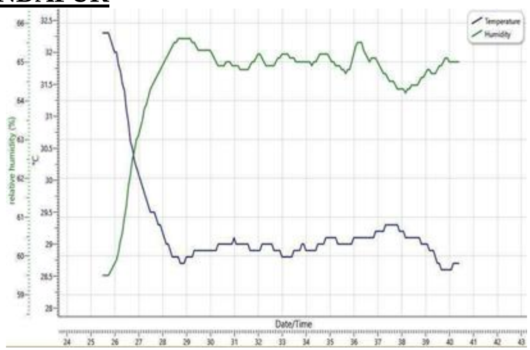

Fig 4.5 Humidity and Temperature

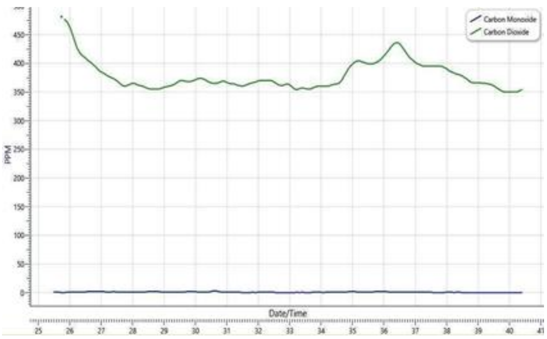

Fig 4. 6 Carbon monoxide and Carbon dioxide

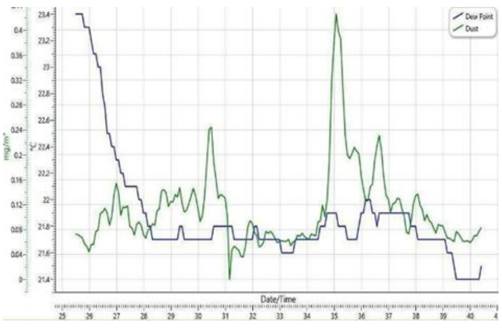

Fig 4.7 Dust and Dew point

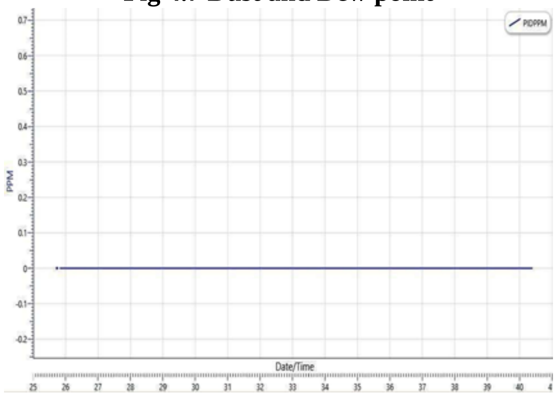

Fig 4. 8 PID (volatile compounds)

SHILPARAMAM

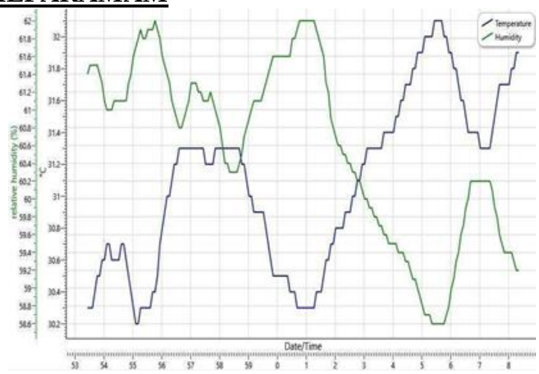

Fig 4.9 Humidity and Temperature

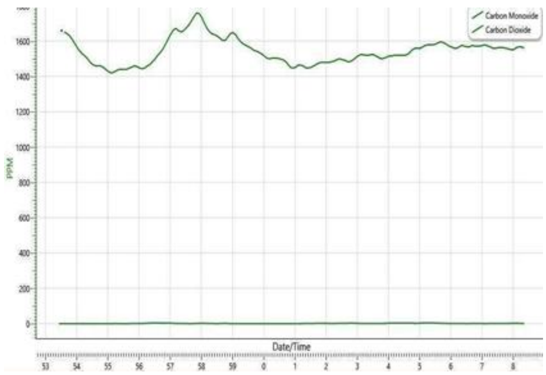

Fig 4.10 CO and Carbon dioxide

Fig 4.11 Dust and Dew point

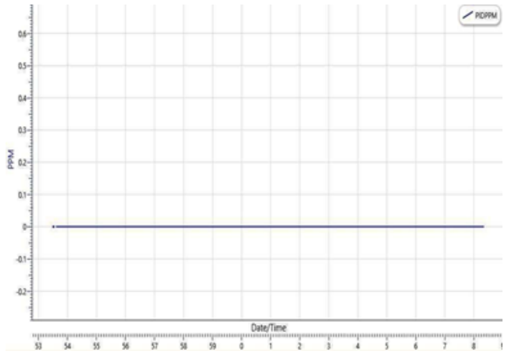

Fig 4.12 PID (volatile compounds)

JUBLIEE HILLS

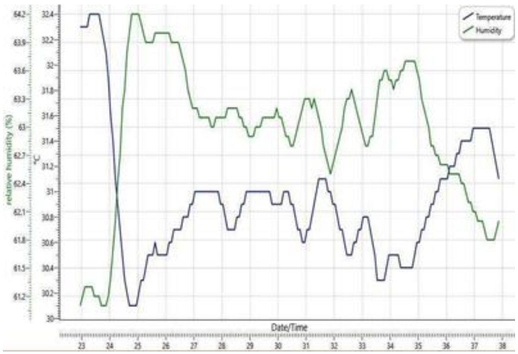

Fig 4.13 Humidity and Temperature

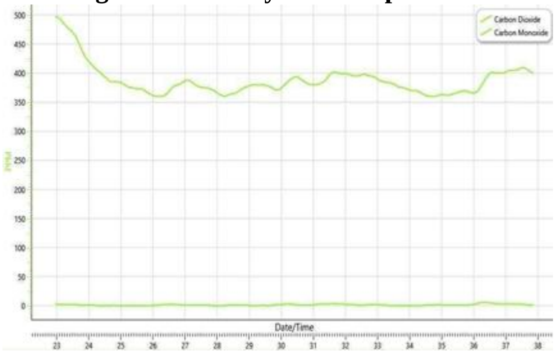

Fig 4.14 CO and Carbon dioxide

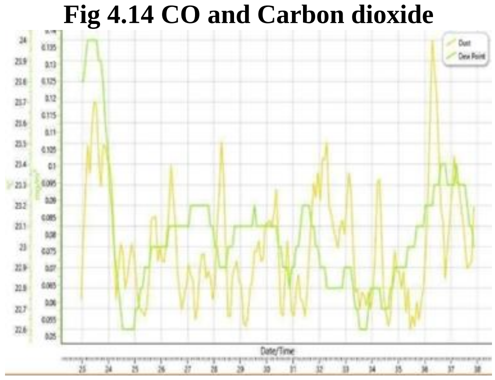

Fig 4.15 Dust and Dew point

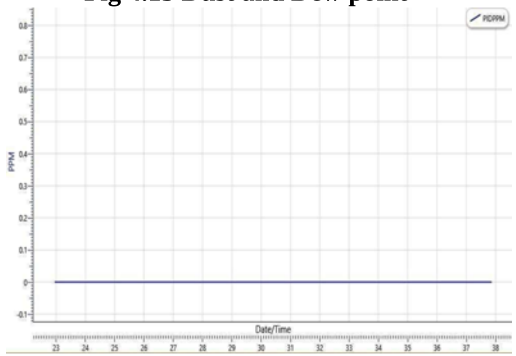

Fig 4.16 PID (volatile compounds)

ERRAGADDA

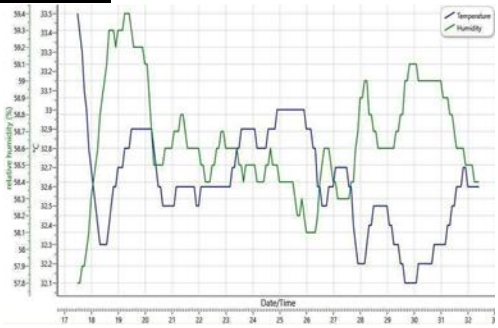

Fig 4.17 Humidity and Temperature

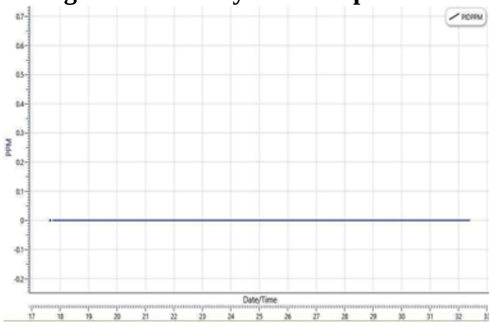

Fig 4.18 PID (volatile compounds)

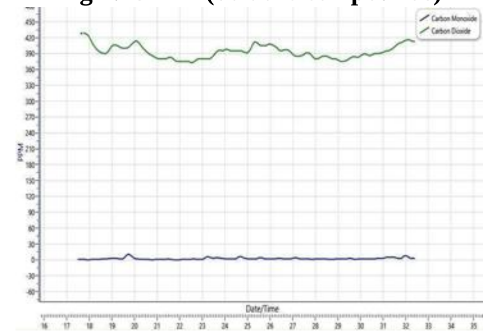

Fig 4.19 carbon monoxide and carbon dioxide

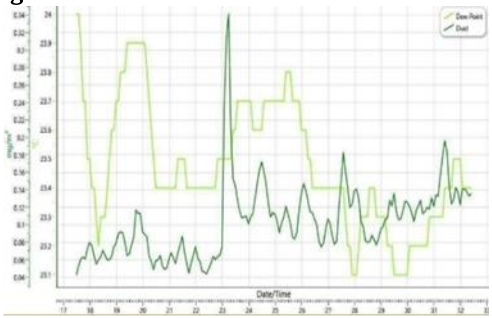

Fig 4.20 Dust and Dew point

JNTUH

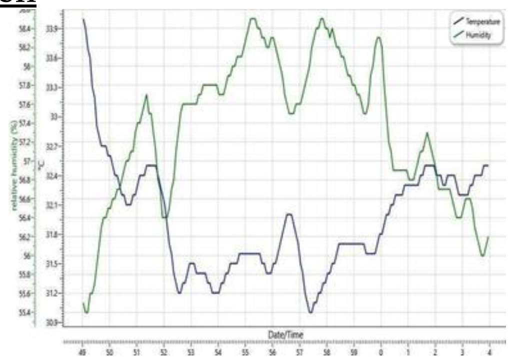

Fig 4.21 Humidity and Temperature

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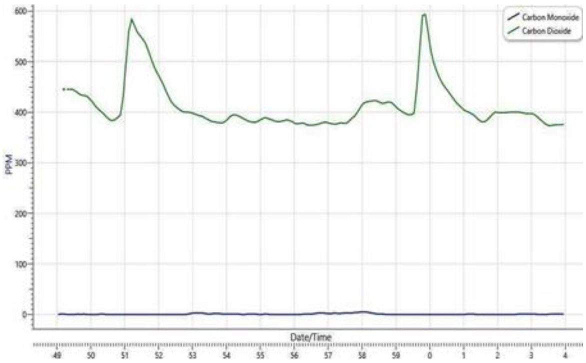

Fig 4.22 CO and Carbon dioxide

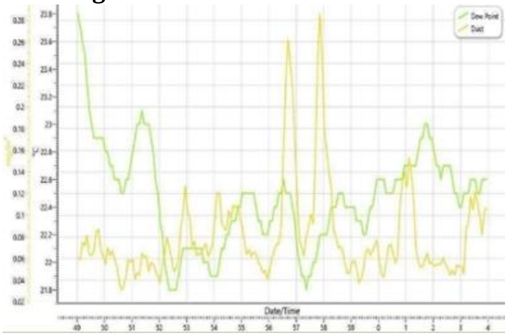

Fig 4.23 Dust and Dew point

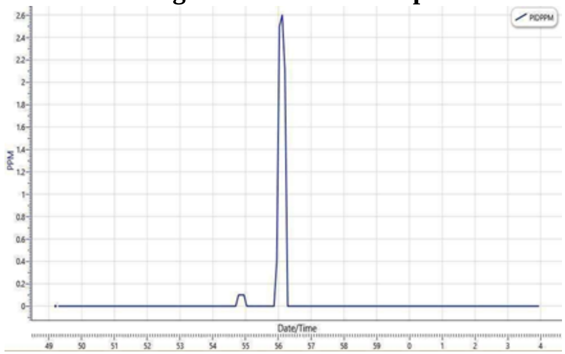

Fig 4.24 PID (volatile compounds)

SECUNDARABAD

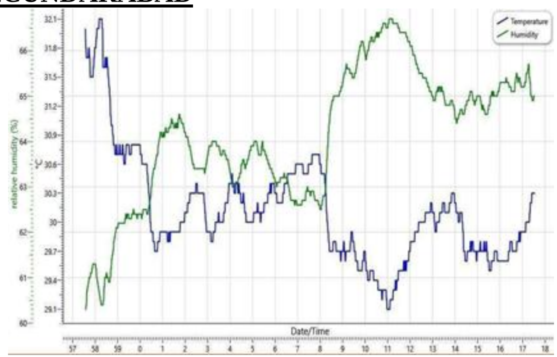

Fig 4.25 Humidity and Temperature

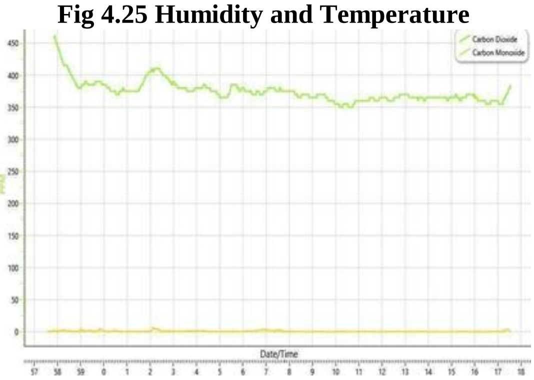

Fig 4.26 CO and Carbon dioxide

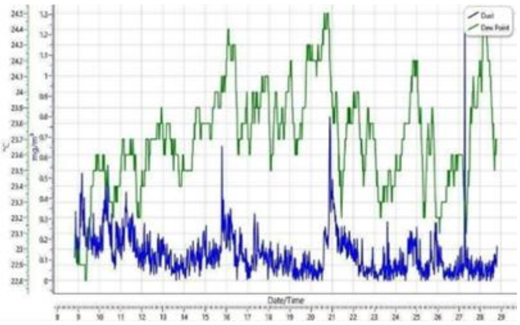

Fig 4.27 Dust and Dew point

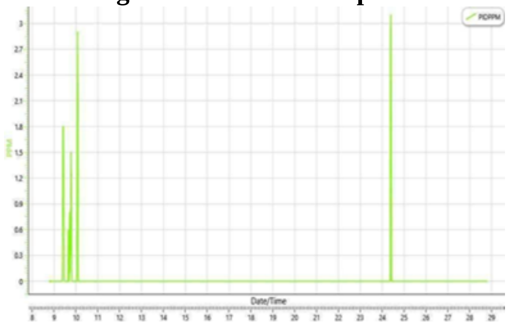

Fig 4.28 PID (volatile compounds)

UPPAL

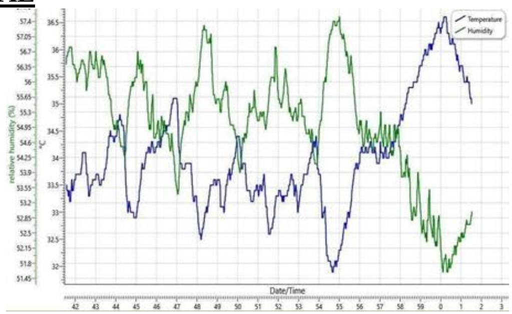

Fig 4.29 Humidity and Temperature

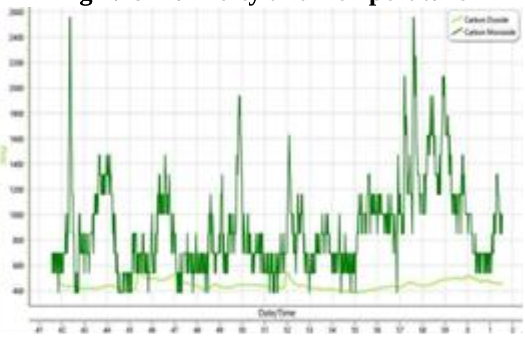

Fig 4.30 CO and Carbon dioxide

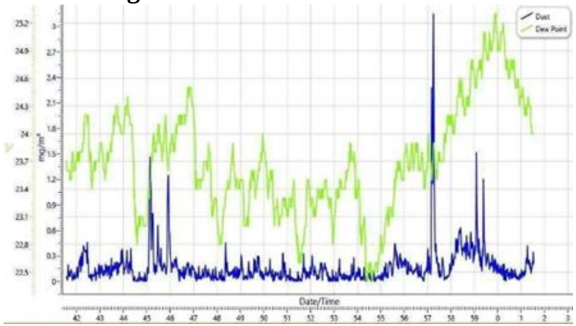

Fig 4.31 Dust and Dew point

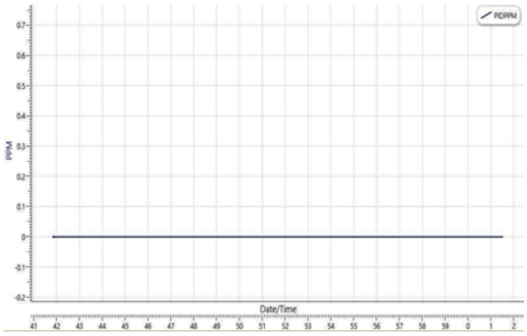

Fig 4.32 PID (volatile compounds)

<u>L B NAGAR</u>

Fig 4.33 Humidity and Temperature

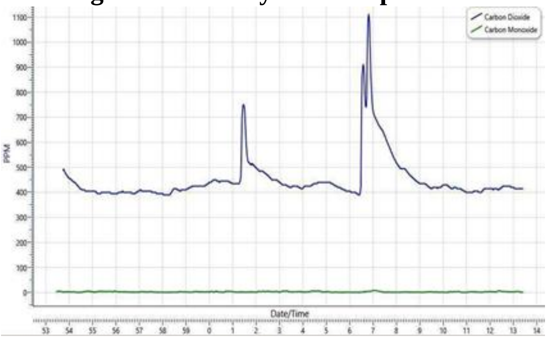

Fig 4.34 CO and Carbon dioxide

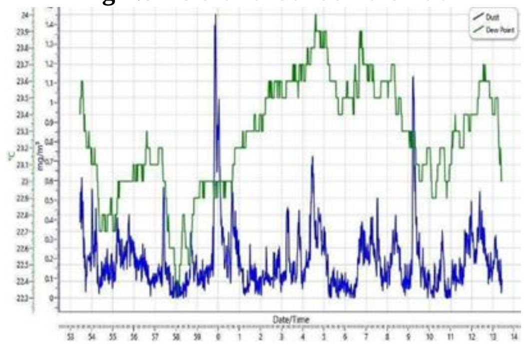

Fig 4.35 Dust and Dew point

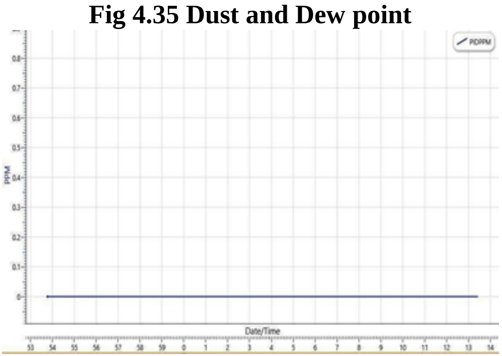

Fig 4.36 PID (volatile compounds)

<u>KOTI</u>

Fig 4.37 Humidity and Temperature

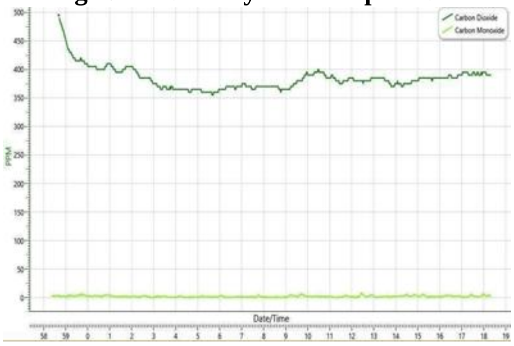

Fig 4.38 CO and Carbon dioxide

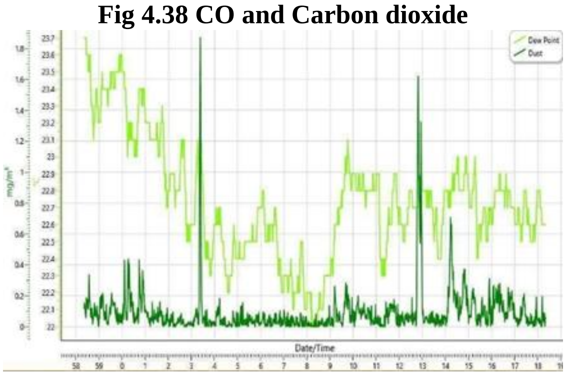

Fig 4.39 Dust and Dew point

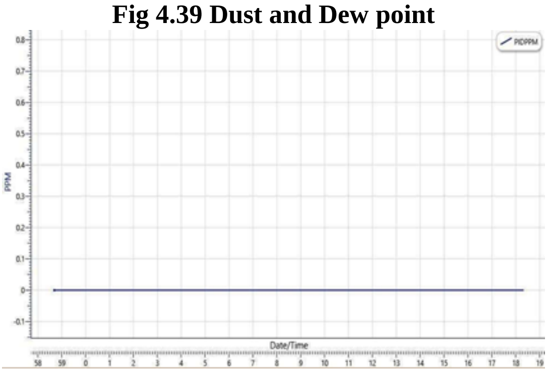

Fig 4.40 PID (volatile compounds)

<u>BEGUMPET</u>

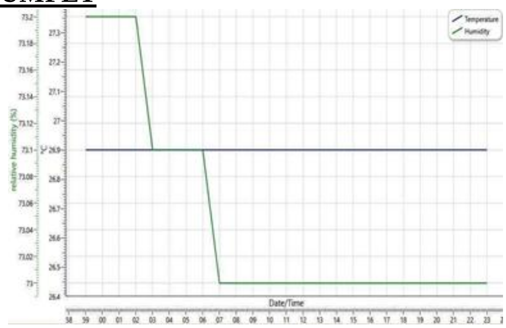

Fig 4.41 Humidity and Temperature

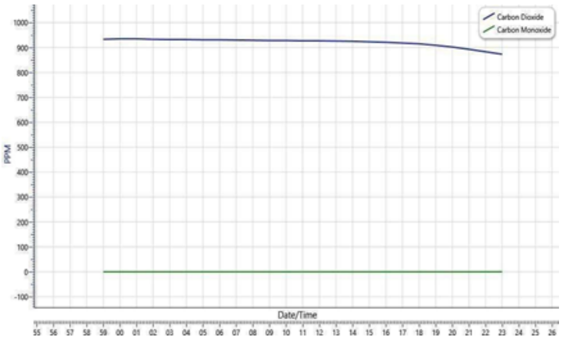

Fig 4.42 CO and Carbon dioxide

B. *DISCUSSIONS*

1. Particulate matter in some areas extremely high compare to other areas and in some areas within the range [10-13]. As per Air quality standard Particulate matter should not exceed 0.1 PPM

2. The levels of carbon monoxide are in measurable range. As per the standards, maximum limit of CO concentration in air is 0.2 PPM which doesn't harm human beings.

3. Volatile compounds in all areas are under range except in JNTUH.

4. Fluctuates in temperature is slightly high in some areas it is stable in outskirt like Begumpet. Measurable temperature is 35 0C to 42 0C

5. Dew point almost within the range in all measured areas.

6. Humidity level are high in some areas and in some areas it is stable measurable range 25% to 60%

7. Carbon dioxide levels is almost same in all areas only slight fluctuations compare to one area toanother.CO2 range is 350 to 450PPM.

V. CONCLUSIONS

The following conclusions are drawn indicating highest in two areas and least among all of seven parameters which are listed below:

1. Particulate matter found high in L.B. Nagar (3.145PPM) followed by Begumpet (1.869PPM) and least in Jubilee hills (0.137PPM).

2. Carbon monoxide found high in L B Nagar (14PPM) followed by Erragada (11PPM) and least in Shilparamam (4PPM).

3. Carbondioxide found high in Koti (1110PPM) followed by Secunderabad (615PPM) and least in Erragadda (429PPM).

4. Volatile compounds is high in Secunderabad (3.10PPM) followed by JNTUH (2.60PPM) and ZERO in remaining areas.

5. We found remaining parameters like temperature, humidity and dew point nearly same in almost all areas.

6. From above we conclude slightly high fluctuations almost in all areas except in Begumpet as we got stable readings.

VI. SUGGESTION BASED ON PRESENT WORK

1. Electrostatic precipitators, renewable energy, alternative energy and using respiratory masks in highly polluted and traffic areas usages are very important to prevent emission of particulate matters in the environment.

2. Many preventive measures are to be carefully studied and make them habituate with available knowledge by considering the differences in pollutant mixtures, concentration levels, exposure patterns, and various underlying population characteristics.

3. Government of India has taken several prevention measures like banning old vehicles more than 15 years, using battery vehicles. Apart from this, Government has to implement laws for preventing increased pollution and emission standard.

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Influence of Support Reactions on RCC Building Frames a Computational Method

Y. Kamala Raju, S. VenkatCharyulu, T. Srikanth

Abstract—High-rised structures, when planned, are ready to Satisfy essential angles and workableness. While Vigor of construction relies upon burdens forced, it requires consideration. The plan includes load computations and breaking down the entire structure. The structure strategies utilized in STAAD.Pro and ETABS investigation are Cutoff state configuration adjusting to Indian standard code of training. In this paper we have broke down and structured the G+3 multi-story building utilizing STAAD.Pro and ETABS independently and the adjustments in configuration results shear power, bowing minute and redirection of individuals from RCC building examined by utilizing STAAD.Pro and ETABS are thought about. This investigation draws out the benefits of utilizing ETABS over STAAD.Pro.

Keywords : G+3 multi-storey building, shear force, bending moment and deflection of members.

I. INTRODUCTION

The fortification is generally inserted inactively in concrete earlier than the solid set. The fortification desires the accompanying property in any event for the solid and tough development: High relation quality, High tolerates of elastic damage, Great cling to solid, independent of pH, dampness, comparative feature. Warm similarity, not making unsatisfactory worries accordingly changing temperatures.

II. REVIEW OF LITERATURE

Varikuppala Krishna, Chandrashekhar et.al(2015) "Analysis, Design of multi storied building with ETABS software. The study stated that geotechnical engineering cannot be neglected while building high rise buildings and ETABS is more user friendly and is more detailed compared to STAAD.Pro.

Sanghani (2011) contemplated to conduct of shaft and segment at different story levels. It was discovered that the greatest pivotal power created.

Poonam (2012) Consequences of the mathematical investigation demonstrated the story, particularly the primary story, must not be milder/more fragile than the story's above or beneath. Mass circulation likewise adds to the expanded reaction of the structures. The anomalies, whenever required to be given, should be given by suitable and broad investigation and configuration forms.

Prashanth.P (2012) Examined to conducted ordinary and unpredictable multi story house construction in STAAD.Pro and ETABS. Examination and configuration was found in IS: 456 and IS: 1893. Additionally physically computations analyzed outcome. It was discovered the ETABS gave the steel region in STAAD Pro. Stacking mixes were not considered in the investigation and impact of story stature on the auxiliary conduct was not depicted.

SaqibHabib (2010), "Correlation of structure of a structure utilizing ETABS and STAAD.Pro" In their investigation it was seen that It was discovered that the ETABS gave the smaller steel zone as that of STAAD Pro. Loading combinations were not measured in the analysis and impact of story tallness on the basic conduct was not depicted.

Yahyaei (2011)"Relative investigation of the static and dynamic examination of multi-story unpredictable structure". Their study stated that by comparing the results of two structure, the frame element of regular is maximum bending moments, shear forces and axial forces for different loading conditions in both softwares.

S.K Dubey (2012), "Examination of configuration consequences of a structure planned utilizing STAAD.Pro and ETABS programming .Their investigation expressed that in the two virtual products, the design results shows 0.4%-0.5% more steel in ETABS.

III. BASIC DATA FOR BUILDINGS MODEL

1. Plan : 18x 18 m
2. Height of each storey: 3 m
3 Number of storeys: G+ 3 storeys
4. Column: (450 X 230) mm
5. Beam: (230 X450) mm
6. Walls Thickness: (230) mm thick
7. Grade of the concrete: M 25
8. Grade of the steel: Fe-415
9. Type of Soil: Type II, Medium Soil
10. Seismic Zone: II
11.Building Frame : Ordinary RC moment-resisting
12. Live Load on Typical Floor: 2000N/m^2
13 Wind speed: 44 m/s
14. Support: Fixed

Live load:

Load 3.5 KN/m^2 is considered, zone: 5, type of soil: II, reaction decrease factor: 5.0, Importance factor: 1.0, Damping : 5.0%. Individuals are stacked with dead load, live burden.

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Earthquake burdens as indicated by IS code 875 (Part-1, Part -2) and IS: 1893 (Part-1) : 2002.

Self weights

Self-weight contains the heaviness of shafts, sections and chunk of the structure.

Dead loads

Every perpetual development of the structure dead load.

The dead burden contains the loads of dividers, parcel floor completions, floors at other changeless developments in the structure. Dead burden comprises

a) Wall loads = (Density of block stone work X divider thickness x divider tallness)

= 21000 N/m^3 * 0.250m * 3.1m

= 13.8 kN/m (following up bar)

b) Wall load in because of Parapet divider at highest floor

= (unit weight of block stone work * parapet divider thickness * Height)

= 21000 N/m^3 X 0.115mtrs X 950mm

= 2090 N/m (following up bars)

c) Floor load (because of floor thickness)

unit weight of solid * floor thickness

= 24000 N/m^3 * 1350mm

= 3255 N/m^2 (Acts on the beam)

Live load

Live loads incorporate heaviness of the portable segments, disseminated and thought load, load because of effect and vibration of residue loads. Live loads do exclude stacks because of wind, seismic movement, day off burdens because of heat changes to which the structure exposed to and so on. Live burden changes acc. to sort of structure.

Live load= 3 kN/m2 every floor.

Earth quake loading.

Sesmic burden can be determined taking the perspective on quickening reaction of the ground to the superstructure. As per the seriousness of seismic tremor power they are isolated into 4 zones.

As per the IS : 1893 (part-1):2002, flat Seismic Coefficient Ah for a Structure can be figured, the accompanying articulation

Ah= (ZISa)/(2Rg)

Where Z= Zone factor contingent on the zone the structure has a place with.

For Zone 2: for Z is 0.110

For Zone 3: for Z is 0.160

For Zone 4: for Z is 0.241

For Zone 5: for Z is 0.360

I= 1.50

R= Response decrease aspect

Sa/g = Average reaction Acceleration Coefficient, Here Seismic weight is taken Equivalent Length & Equivalent Width

LOAD DUE TO WIND CALCULATION

Design Wind force PZ= 0.6*(VZ$_2$)

Configuration Wind rate $V_z = V_b*K_1*K_2*K_3$

Hazard Coefficient K1 = 1.08

IS: 875-1987 (part3), sec 5.3.1, Table -1

Terrain & Height Factor K_2 = varies with height table 3.1

IS: 875-1987 part-3, sec 5.3.2, Table -2

According To Table -2

K_2 = 1.1055

K_2 is Values are linearly interpolated

Topography Factor

K_3 =1.00

IS: 875-part-3, sec 5.3.3.1)

Basic Wind speed

VB=44m/sec (Hyderabad)

Design Wind Speed

$Vz = Vb*K_1*K_2*K_3$

= 44*1.08*1.1055*1.00*1

= 48.802m/sec

Design Wind Pressure Pz = 0.6 *VZ$_2$

= 0.6* (48.81)^2

= 2375 N/m^2

Loads and Factors Calculation

Calculating the loads and factors values which are using in the software STAAD. Pro program:

A. Live Load:

Live load for the Residential building in each storey = (2) kN/m2 as per IS: 875 (part 2) – 1987.

B. Dead loads:

Dead loads which include Slabs, beams, columns, Floor finish and Wall Load are taken as prescribed by the IS: 875 -1987 Part-1 Code of Practice Design Loads (other than earthquake) for Buildings and structure.

C. Seismic Loading:

In this study, the building is located in Hyderabad which comes under

1. Zone-II,
2. Response reduction factor- 3, I
3. Importance factor- 1,
4. Soil Type is medium,

using the IS 1893 (Part-1) -2002 the following are the various values for the building considered

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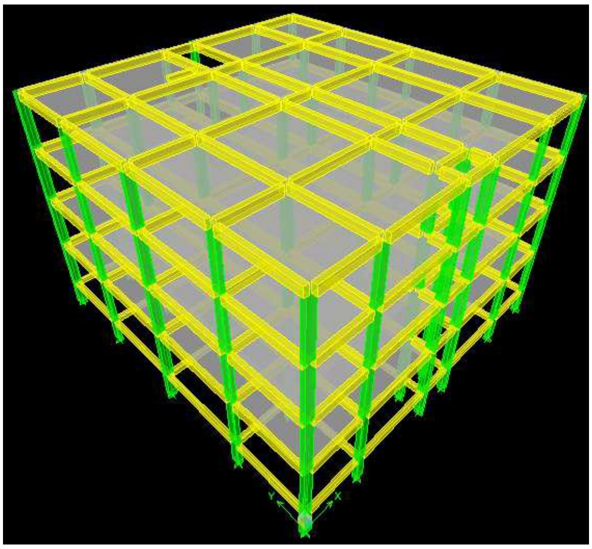

Fig. 1*: 3-D View of the G+3 storey building in ETABS*

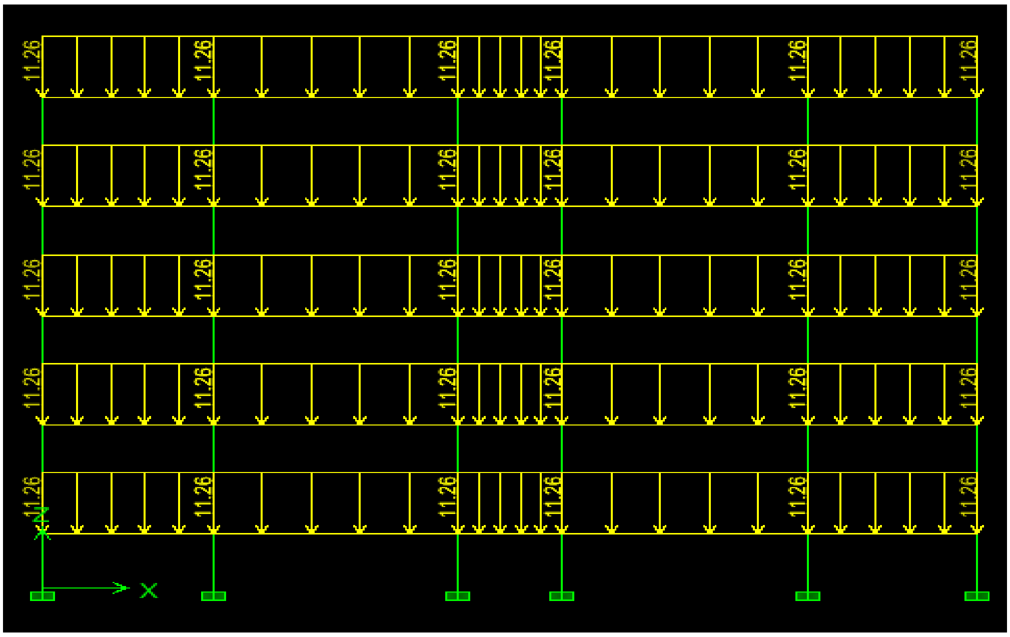

Fig. 2: Wall and Parapet load distribution in ETABS

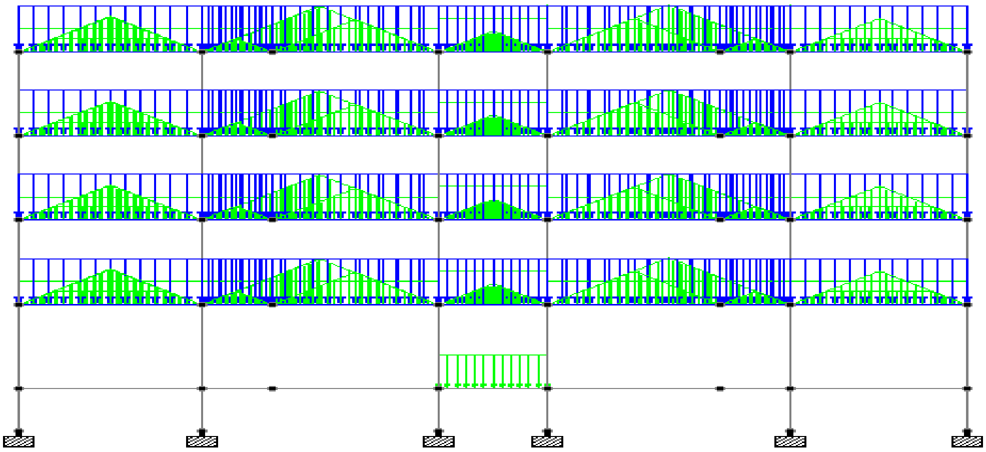

Fig. 3: Modeling In Staad.Pro

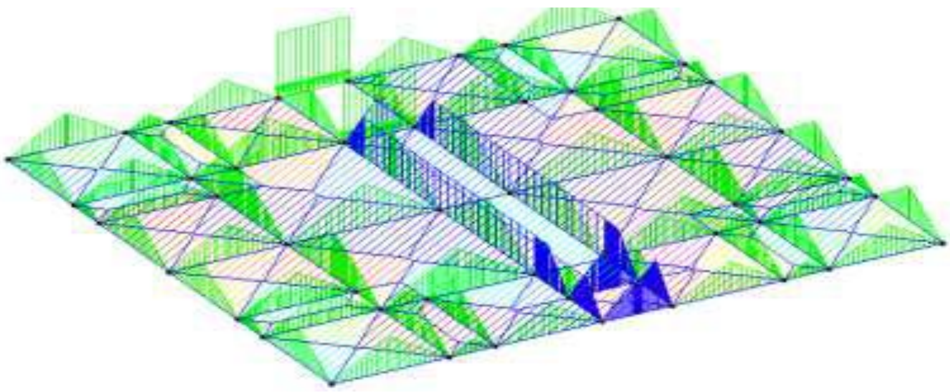

Fig. 4: Loading Display

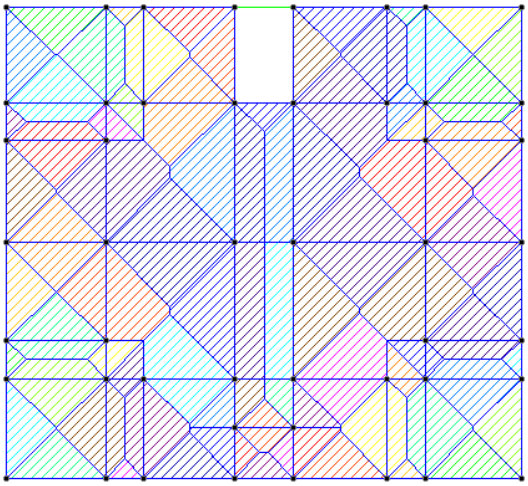

Fig. 5: Floor load (Plan View)

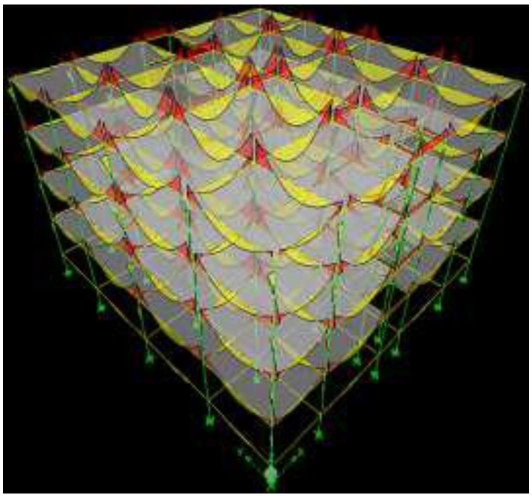

Fig. 6: B.M. Diagram for Self weight

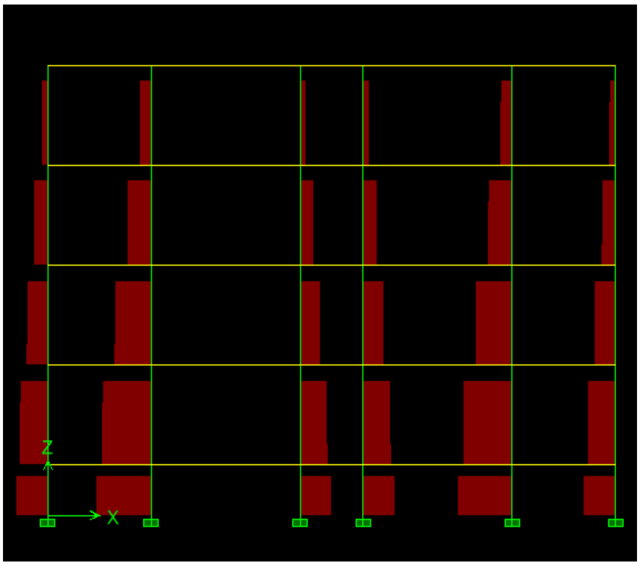

Fig. 7: Shear Force diagram for Self weight

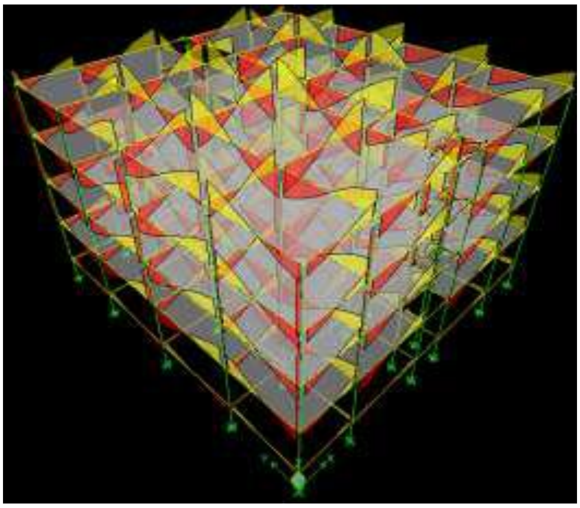

Fig. 8: Shows that controlling load combination for flexural and shear is DCON2(1.5 Self +1.5Dead)

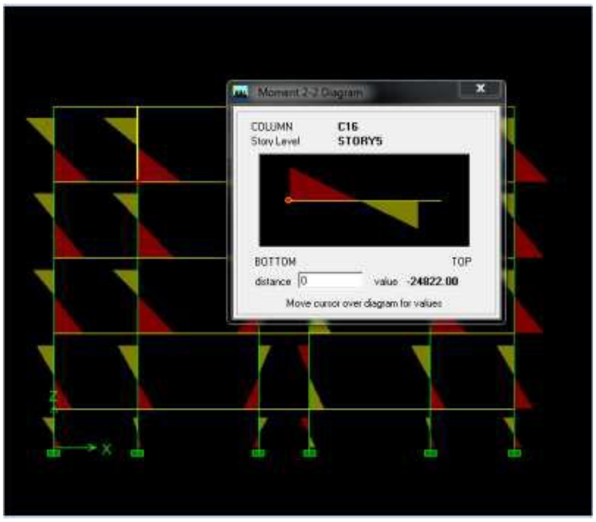

Fig. 9: Axial Force (b) B.M. Diagram for load 1.5(Self +Dead load +EQ length)

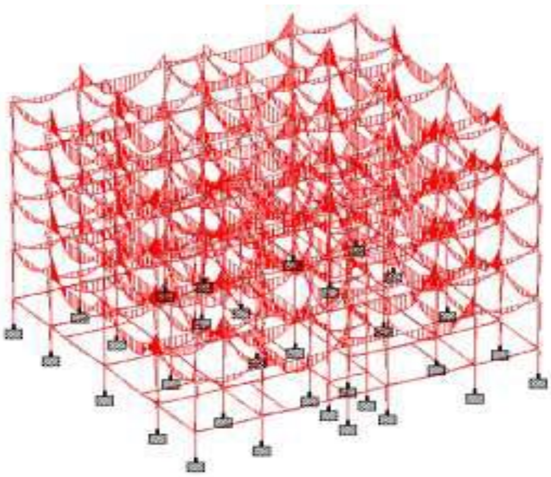

Fig. 10: BM diagram for load 1.5(Self +Dead)

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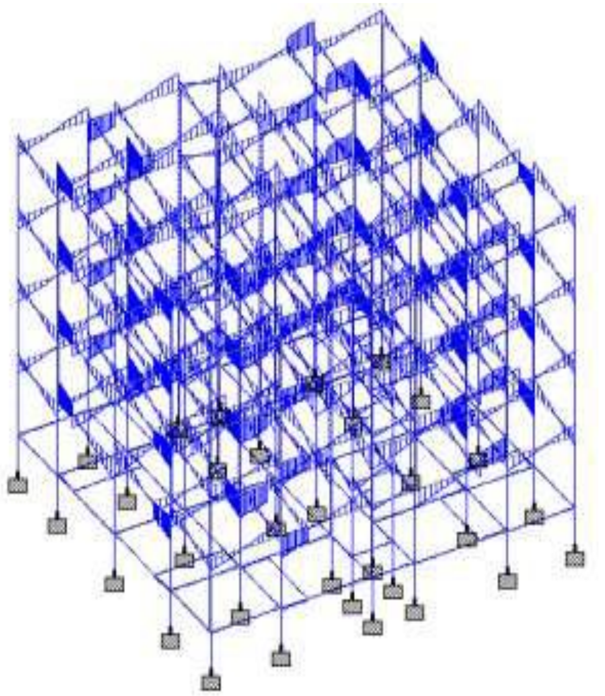

Fig. 11: Shear Force diagram for load 1.5(Self +Dead)

Table- I Support Reactioms from ETABS

Storey	Point	Load	F_x	F_y	F_z	M_x	M_y	M_z
BASE	1	DCON2	8.14	-5.7	1114.64	2.799	4.022	-0.027
BASE	2	DCON2	-8.14	-5.7	1114.64	2.799	-4.022	0.027
BASE	3	DCON2	4.66	-4.1	1173.12	0.832	2.554	-0.004
BASE	4	DCON2	3.38	-2.54	1883.03	1.176	2.565	-0.012
BASE	5	DCON2	-3.38	-2.54	1883.03	1.176	-2.565	0.012
BASE	6	DCON2	-4.66	-4.1	1173.12	0.832	-2.554	0.004
BASE	7	DCON2	3.51	0.28	1984.28	-0.338	2.714	-0.012
BASE	8	DCON2	-3.21	-0.73	1972.2	0.364	-1.422	-0.01
BASE	9	DCON2	3.21	-0.73	1972.2	0.364	1.422	0.01
BASE	10	DCON2	-3.51	0.28	1984.28	-0.338	-2.714	0.012
BASE	11	DCON2	-7.77	6.05	1102.89	-3.377	-3.736	-0.014
BASE	12	DCON2	-2.93	3.27	1860.31	-1.935	-2.136	0.004
BASE	13	DCON2	4.45	5.25	1172.16	-2.994	2.399	0
BASE	14	DCON2	8.14	-11.72	643.35	5.367	4.03	-0.024
BASE	15	DCON2	7.91	12.17	650.25	-6.018	3.82	0.027
BASE	16	DCON2	7.77	6.05	1102.89	-3.377	3.736	0.014
BASE	17	DCON2	-10.3	1.42	642.31	-1.427	-4.944	-0.075
BASE	18	DCON2	-0.75	5.07	675.42	-2.998	-0.168	-0.05
BASE	19	DCON2	0.75	5.07	675.42	-2.998	0.168	0.05
BASE	20	DCON2	10.3	1.42	642.31	-1.427	4.944	0.075
BASE	21	DCON2	-7.91	12.17	650.25	-6.018	-3.82	-0.027
BASE	22	DCON2	-4.45	5.25	1172.16	-2.994	-2.399	0
BASE	23	DCON2	3.54	10.15	1599.96	-5.042	1.613	-0.016
BASE	24	DCON2	-3.54	10.15	1599.96	-5.042	-1.613	0.016
BASE	25	DCON2	5.69	0.31	1276.12	-0.367	3.878	-0.001
BASE	26	DCON2	-5.69	0.31	1276.12	-0.367	-3.878	0.001
BASE	27	DCON2	-5.5	-4.98	1647.18	2.832	-2.623	-0.012
BASE	28	DCON2	5.5	-4.98	1647.18	2.832	2.623	0.012
BASE	29	DCON2	-11.7	-14.2	978.43	6.774	-5.595	-0.003
BASE	30	DCON2	11.7	-14.2	978.43	6.774	5.595	0.003
BASE	31	DCON2	-8.14	-11.72	643.35	5.367	-4.03	0.024
BASE	32	DCON2	2.93	3.27	1860.31	-1.935	2.136	-0.004

TABLE- II SUPPORT Reactions fromSTAAD PRO

Node	L/C	Force-X kN	Force-Y Kn	Force-Z kN	Moment-X kNm	Moment-Y kNm	Moment-Z kNm
74	12	-0.50	1428.14	-0.20	-0.31	-0.04	-1.15
79	12	1.03	1425.83	-0.20	-0.30	0.04	0.73
64	12	-3.17	1344.38	0.60	0.48	0.06	0.13
69	12	3.08	1327.93	0.59	0.47	-0.06	-0.50
75	12	0.32	1253.50	0.92	0.41	-0.01	-1.02
80	12	-0.42	1251.80	0.91	0.41	0.01	1.15
73	12	-1.69	1235.53	-1.53	-1.06	-0.01	1.03
78	12	1.89	1233.24	-1.51	-1.04	0.00	-1.19
77	12	-2.80	1104.62	1.32	2.13	0.02	1.37
76	12	2.77	1091.16	1.30	2.10	-0.03	-1.35
70	12	0.85	980.48	-0.24	-0.33	-0.02	-2.60
63	12	-0.96	964.20	-0.23	-0.31	0.03	2.34
66	12	-0.82	871.38	-1.17	-0.60	-0.07	-1.22
71	12	0.66	862.66	-1.17	-0.61	0.07	1.11
62	12	1.42	820.66	1.02	0.59	0.00	-0.96
72	12	0.64	817.84	-2.10	-2.42	0.02	-0.30
61	12	-1.60	805.69	1.05	0.61	0.00	1.06
65	12	-0.71	803.44	-2.08	-2.37	-0.02	0.31
58	12	-1.34	769.88	-1.43	-1.05	0.00	1.53
52	12	1.41	768.09	-1.45	-1.06	-0.01	-1.58
57	12	-0.77	766.07	1.13	0.55	0.01	1.28
51	12	0.90	764.10	1.14	0.55	-0.01	-1.44
55	12	-3.12	647.81	3.11	3.06	0.03	1.50
53	12	3.20	637.85	3.09	3.03	-0.04	-1.58
56	12	0.44	539.07	0.24	-0.18	0.03	-0.19
54	12	-0.39	530.94	0.20	-0.22	-0.04	0.15
67	12	-0.24	518.22	-1.36	-0.82	-0.11	0.09
68	12	0.32	514.60	-1.39	-0.85	0.10	-0.17
50	12	1.32	438.82	-1.14	-0.99	0.04	-1.83
60	12	-1.54	429.43	-1.11	-0.97	-0.04	1.84
49	12	1.46	425.03	0.86	0.49	0.00	-1.96
59	12	-1.63	415.41	0.84	0.49	-0.01	1.88

IV. RESULT AND DISCUSSION

1. The maximum vertical responses of a G+3 building max response created is 1984.28kN in ETABS and 1428.24kN in STAAD.Pro because of burden 1.5(Self +Dead +Live).
2. Deformation of members in STAAD.Pro are 0.029mm,0mm and 0.036mm respectively where as in E-TABS are 0.0031mm,0.0039mm and 0.001mm respectively.
3. The maximum displacement is along x- direction and its value is 29 mm in STAAD.Pro. and 31mm in ETABS along x-direction. So, more precise results are generated by ETABS which leads to economical design of the building.
4. Live loads to be considered on stair and lading are specified in IS875-1964 LL on stairs, landings and corridors is taken as 37KN/M2 (not liable to over crowing). When these are liable to overcrowding them the LL is adopted as 56KN/M^2.
5. In a residential house the tread may be 250mm wide and rise may be160mm height. The number of steps in a flight, at once stretch in a flight may not preferably be more than 12.

V. CONCLUSIONS

The following conclusions are made

1. The change in design results of G+3 multi storey building which is analysed using STAAD.Pro and ETABS are summarized below:

2. Results of max vertical responses of a G+3 customary structure has been reasoned that the maximum response created is 1984.28kN in ETABS and 1428.24kN in STAAD.Pro because of burden 1.5(Self +Dead +Live)

3. Max Deformation of members of G+3 residential building in x,y,z-direction in STAAD.Pro are 0.029mm,0mm and 0.036mm respectively where as in E-TABS are 0.0031mm,0.0039mm, 0.001mm respectively. the max. deformation is along x- axis, its value is 29 mm (in STAAD.Pro.) and 31mm (in ETABS) along x-direction. So, more precise results are generated by ETABS which leads to economical design of the building.

4. Bending moment of beam member 481 of top storey building using STAAD.Pro is 35.932 kN.m whereas for beam B1 in E-TABS is 38.579kN.m for a load combination of1.5 (DL+LL).Here there is an increment of BM by 10% in ETABS which shows more reinforcement is required in ETABS which leads to uneconomical design.

5. Deflection of beam member 481 of top storey building using STAAD.Pro is 2.956mm whereas for beam B1 in E-TABS is 2.241mm for a load combination of 1.5(DL+LL)

6. Shear force of beam member 481 of top storey building using STAAD.Pro is52.565kN.m whereas for beam B1 in E-TABS is 58.78kN.m for a load combination of1.5 (DL+LL)

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AUTHORS PROFILE

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Strength and Durability Characteristics of Steel Fibre Reinforced Concrete with Mineral Admixtures

N. Sanjeev, K. Harish Kumar, Kaza Prem Rakshit Kumar

Abstract: ***The present investigation is carried out to study the strength and durability characteristics of steel fibre reinforced concrete, by replacing Ordinary Portland cement with Fly Ash, Ground Granulated Blast Furnace Slag (GGBS) and Metakaolin. In this study, cement is replaced by 30% and 40% with Fly Ash, GGBS and Metakaolin for M30 and M35 grades of concrete. Steel fibres @ 1% by weight of binder is used in all the mixes. Strength characteristics like compressive strength and split tensile strength are tested at 7 days and 28 days age. Additionally, durability tests such as water absorption and Sorptivity tests are conducted after 28days curing. The test results have shown that 30% replacement is optimum for strength criteria. And when metakaolin is used with fly ash, durability properties were improved and workability reduced.***

Keywords: ***Concrete, Fly Ash, GGBS, Steel fiber, M-Sand, Compressive Strength, Sorptivity and Water Absorption***

I. INTRODUCTION

Concrete is a composite material, comprising of coarse aggregate, fine aggregate, binder material to hold the aggregate matrix and water which is added proportionately. The utilization of concrete is increasing day by day in construction field which intern increasing production of cement and depletion of natural sand. Every tonne of cement production produces one tonne of CO_2 and which lead to cause global warming and environmental pollution. Hence it became imminent to explore alternatives for cement and natural sand. Fly ash, GGBS, metakaolin, silica fume and rice husk ash are the mineral admixtures which could act as pozzolanic and cementitious material. and manufactured sand is a suitable alternative material for natural sand as fine aggregate. Manufactured sand is a crushed granite stone which is sieved to required size. In recent days, usage of M-sand becoming popular in concrete. Fly ash and GGBS are the by-products obtained in thermal power stations and steel manufacturing industries respectively. However, Ground Granulated Blast Furnace Slag is obtained as the result of quenching the molten iron slag in the water and then it is grounded to powdered form. And Metakaolin is a product that is manufactured for use rather than a by-product and is formed when china clay, the mineral kaolin, is heated to high temperatures.

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The utilization of these by-products as replacements of cement will help in retarding the global warming and environmental pollution and their disposal problems to some extent. Fibres are generally added to improve strength, impact resistance, toughness and cracking resistance due to plastic and drying shrinkage. Some of them are steel, glass and poly propylene fibres. These fibres are available in different forms, shapes and sizes. Fibres are basically defined or adapted based on their aspect ratio (i.e. L/d ratio) and in most of the cases steel fibres are used for structural applications.

The objective of the present study is to determine strength and durability characteristics of M30 and M35 grade Steel Fibre reinforced Concrete on replacing OPC with Fly Ash, GGBS and Metakaolin, and natural sand by M- Sand.

II. MATERIALS USED

A. Cement:

In this study for all the Concrete mixes, the cement used was Ordinary Portland Cement (OPC) of 53 grade in accordance with IS 12269:1987.

Table-1: Properties of Cement

Cement	Grade	Specific Gravity	IS Code
OPC	53	3.15	IS 12269:1987

B. Fine Aggregate:

M-sand is used as fine aggregate conforming to zone II IS 383:1970. The physical properties such as specific gravity and water absorption were tested are in accordance with IS 2386:1963.

Table-2: Properties of Fine Aggregate

Fine Aggregate	Specific Gravity	Water Absorption	IS Code
M - Sand	2.6	2.5%	IS 2386:1963.

C. Coarse Aggregate:

Crushed angular aggregates are used and these aggregates are of size 20mm in accordance with IS 383:1970. The specific gravity and water absorption were tested conforming to IS 2386:1963.

Table-3: Properties of Coarse aggregate

Coarse Aggregate Size	Specific Gravity	Water Absorption	IS Code
20mm	2.64	0.5%	IS 2386:1963

D. Fly Ash:

Fly ash of Class F is used as the mineral admixture in this study according to ASTM C 618-2003. The fly ash is acquired from RANK RMC Plant.

Table-4: Properties of Fly Ash

Type	Colour	Bulk Density	Specific Gravity	Fineness
Class-F	Dark Grey	1024 Kg/m^3	2.1	336 m^2/Kg

E. GGBS:

In Accordance with ASTM C989-06, GGBS serves as mineral admixture in concrete. The GGBS is acquired from LAFARGE RMC PLANT.

Table-5: Properties of GGBS

Colour	Bulk Density	Specific Gravity	Fineness	Water Absorption
Off white	1281 Kg/m^3	2.81	342 m^2/Kg	NIL

F. Metakaolin:

Metakaolin is a pozzolanic material used in concrete in replacement of cement. It is a product that is manufactured for use rather than a by-product and is formed when china clay, the mineral kaolin, is heated to high temperatures.

Table-6: Properties of Metakaolin

Colour	Bulk Density	Specific Gravity	Fineness	Water Absorption
Off white	786 Kg/m^3	2.71	352 m^2/Kg	NIL

E. Steel Fibre:

Hooked end steel fibres are used. Length - 30mm, diameter-0.75mm and aspect ratio - 40.

F. Super Plasticizer:

Master Rheobuild 920SH is used as super plasticizer and its properties are as in Table VII below.

Table-7: Properties of Super Plasticizer

State	Colour	Density	Chemical Name	pH
Liquid	Dark Brown	1.2	Naphthalene Formaldehyde polymer	8.40

III. EXPERIMENTAL INVESTIGATION

A. General

Strength properties test such as compressive strength test, split tensile strength test and durability properties tests like water absorption test and Sorptivity test were done to study the behavior of fibre reinforced concrete of M30 and M35 grades by author-2 and author-3 respectively. In this study, steel fibres of 1% by weight of binder is used in each and every mix and replacement of cement is varied by 30% and 40% with fly ash and GGBS for M30 grade concrete and by fly ash and metakaolin for M35 grade concrete. The samples were casted and tested at 7 days and 28 days age to analyse mechanical properties and at 28 days age to analyse durability properties. The tests carried out to study mechanical and durability properties of all the mixes are as below.

B. Compression Test

Cubes of size 150mm x 150mm x 150mm are casted and are used to test the compressive strength of concrete in accordance with IS 516-1969. Three samples are tested at each of 7 days and 28 days curing.

C. Split Tensile Strength Test

Split tensile strength of concrete is determined in indirect way and this standard test is done in accordance with IS 5816-1970.

D. Water Absorption Test

The aim of this test is to establish the water absorption rate of steel fibre reinforced Concrete of M30 and M35 grades. 100mm x 100mm x 100mm size concrete cube specimens are casted and treated with water for 28 days as per ASTM C 642-97. In order to eliminate powdered material from the surface of specimen, it should be washed with deionized water. After curing of specimens with water for 28 days, the specimens are oven dried at 110^o C for a duration of 24hrs. And then the specimens are submerged in water such a way as to ensure the height of water above the specimen after submersion is 2 cm. Withdraw the specimen at programmed interval and blot the surface with damp cloth to remove surface water and then record weight specimen. Re-immerse the specimen after measuring the weight at each interval of time. This is continued until the weight difference between two successive 24hr interval measurements is less than 1%.

Amount of water absorbed with respect to the mass of dry specimen is stated as below:

$$M_i\% = \frac{m_i - m_0}{m_0} \times 100$$

Where, m_i = weight of the specimen at time t;

m_o = weight of dry specimen.

Concrete samples should be weighed a few minutes after immersion, and then at increasing intervals (15min, 30min, 1 hr, etc.) for first three hours. All the specimens should be weighed at 8 hours after the beginning of the test and then at 24 hours until the weight difference between two successive 24hr interval measurements is less than 1% of the total mass.

Amount of water absorbed with respect to the mass of dry specimen at each interval is recorded on data sheet and a graph is plotted with the values with respect to the time.

D. Sorpitivity Test

The intention of this test is to estimate the sorptivity of steel fibre reinforced concrete of M30 and M35 grades as per ASTM C 1585. Sorptivity is the accumulated change in volume of water absorbed per unit area against the square root of time. Cylindrical specimens of size 100mm diameter and 50mm thickness are used for this sorptivity test. Following the 28 days of curing, the specimens are oven dried at 110^o C for 24hrs. The specimen sides are sealed with electricians' tape or sealant. Suction face and the face opposite to it should be kept unsealed. The specimens were positioned as illustrated in the figure below.

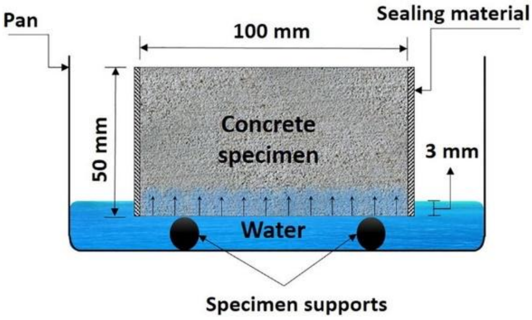

Fig 1: Representation of Sorptivity Test

The rate of water absorption or sorptivity = K = is the slope of I vs √t graph

$$I = \frac{W}{A \times d}$$

Where, W = the amount of water absorbed in kg

A = area of the cross section of the specimen that is in contact with water,

d = density of the medium in which specimen was immersed (1000kg/m^2 in case medium is water).

E. Mix Proportion:

The mix proportioning of cement, fine aggregate and coarse aggregate for the present work is done as per the guidelines of IS 10262-2009. For M30 grade by author-2 mix proportion is is 1:2.17:3, with a binder ratio of 0.43. Whereas, for M35 grade by author-3 mix proportion is 1:2.13:2.86, with water binder ratio of 0.42.

F. Concrete Mixes

AUTHOR-2

Table-8: For M30 Grade of Concrete

MIX	OPC	FLY ASH	GGBS	STEEL FIBRE
M1	100%	0%	0%	1%
M2	70%	15%	15%	1%
M3	60%	20%	20%	1%

AUTHOR-3

Table-9: For M35 GRADE CONCRETE

MIX	OPC	FLY ASH	METAKAOLIN	STEEL FIBRE
P1	100%	0%	0%	1%
P2	70%	15%	15%	1%
P3	60%	20%	20%	1%

IV. TEST RESULTS

A. Workability

The workability for different mixes of M30 and M35 grade concrete is shown Fig-2 and Fig-3 respectively. From these Figures it is observed that when OPC is replaced with fly ash and GGBS workability got increased whereas, it is decreased by replacing with fly ash and metakaolin.

Workability of M30 grade concrete

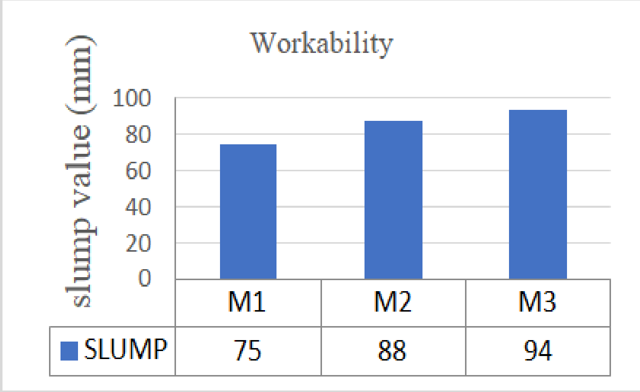

Fig-2: Workability of M30 grade concrete

Workability of M35 grade concrete

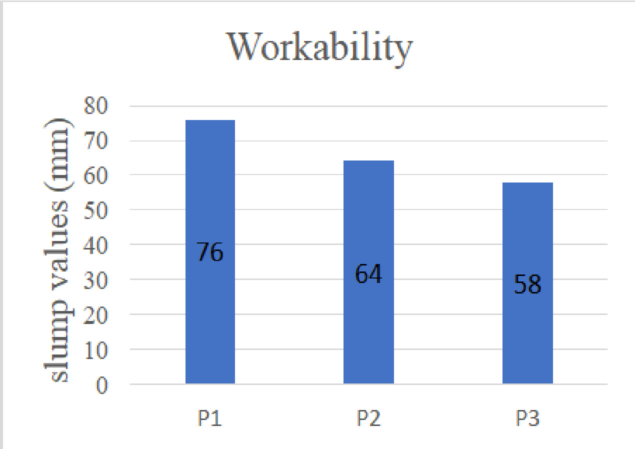

Fig-3: Workability of M35 grade concrete

B. Compressive Strength

7 days and 28 days age compressive strength values of all mixes are shown in graphical form in Fig-4 for M30 grade concrete and in Fig-5 for M35grade concrete. From the graphs below, it is noted that 30% replacement is ideal amongst all the replacements.

Compressive Strength of M30 grade concrete

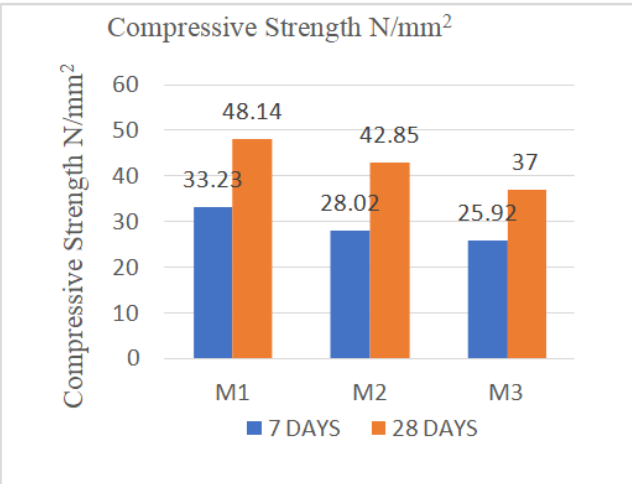

Fig-4: Compressive Strength of M30 grade concrete mixes

Compressive Strength of M35 grade concrete

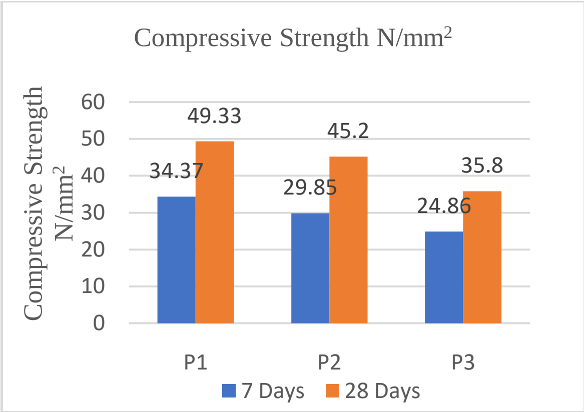

Fig-5: Compressive Strength of M35 grade concrete mixes

C. *Split Tensile Strength*

7 days and 28 days split tensile strength values for all mixes are shown in graphical form in Fig-6 for M30 grade concrete and in Fig-7 for M35 grade concrete. From the graphs below it is observed that 30% replacement is ideal amongst all the replacements.

Split Tensile Strength of M30 grade concrete

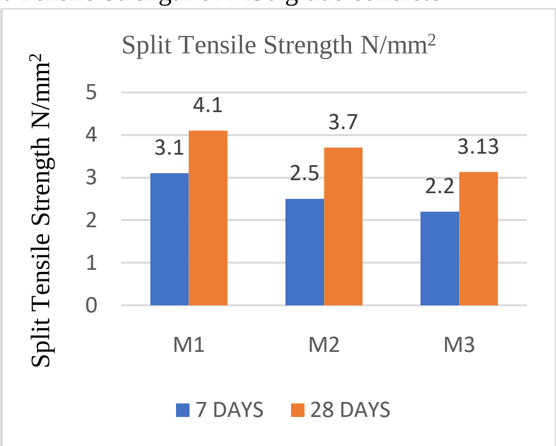

Fig-6: Split Tensile Strength of M30 grade concrete mixes

Split Tensile Strength of M35 grade concrete

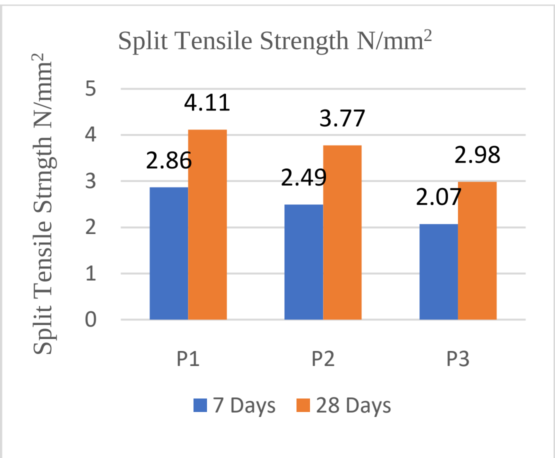

Fig-7: Split Tensile Strength of M35 grade concrete mixes

D. *Sorptivity*

Sorptivity for all mixes are obtained from the graph shown below in Fig 8 and Fig (9). It was found that sorptivity of the concrete is improved when metakaolin is used with fly ash instead of GGBS

SORPTIVITY of M30 (Fly ash+GGBS) Grade Concrete

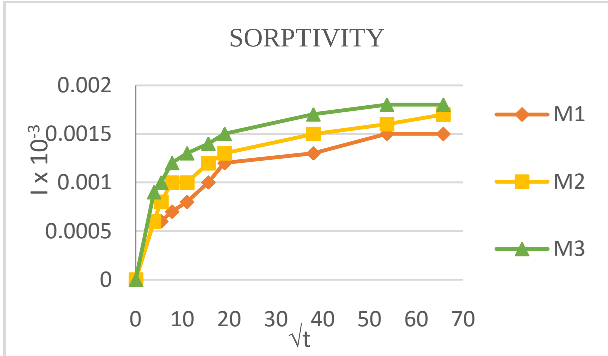

Fig-8: Sorptivity values of M30 grade concrete mixes M1, M2 and M3

SORPTIVITY of M35 (Fly Ash+ Metakaolin) Grade Concrete

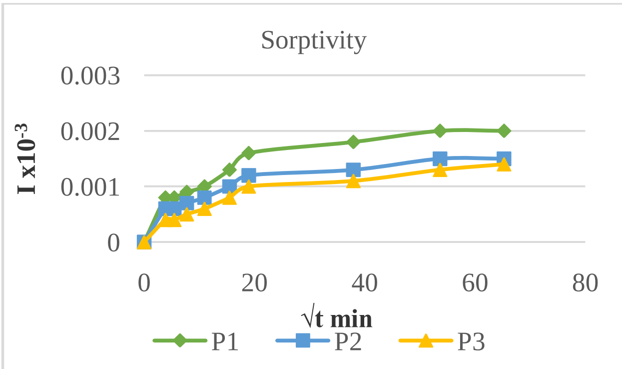

Fig-9: Sorptivity values of M35 grade concrete mixes P1, P2 and P3

E. *Water Absorption*

Results for water absorption test for all mixes are represented graphically in Fig 10 and Fig 11. It was found that water absorption rate of the concrete is improved when metakaolin is used with fly ash instead of GGBS

Water absorption of M30 grade concrete

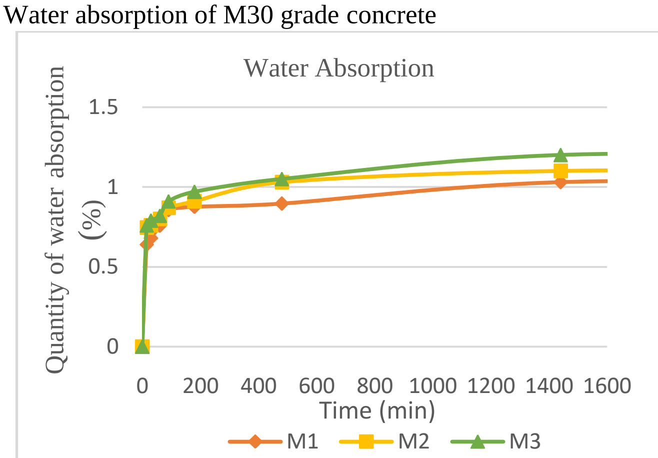

Fig-10: Water absorption values of M30 grade concrete mixes M1, M2, M3

Water Absorption of M35 grade concrete

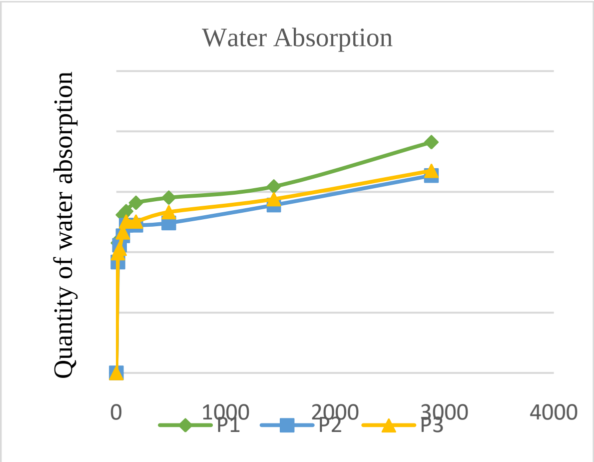

Fig-11: Water absorption values of M35 grade concrete mixes P1, P2 and P3.

V. CONCLUSIONS

Based on the experimental investigation, the following conclusion are made

A. The workability of the Concrete was increased from 75mm to 94 mm when the 40% of Cement was replaced by Fly Ash and GGBS together by the author-2; However, workability of the Concrete was decreased from 76 mm to 58 mm when the 40% of Cement was replaced by Fly Ash and Metakaolin together by the author-3.

B. In the study by author-2, 30% replacement of Cement was found to be ideal since 28-day compressive strength was about 13% more than by the target mean strength. However, in the Study by author-3, same 30% replacement of Cement was found to be ideal as 28-day compressive strength was about 6% more than the target mean strength,

C. In the experimental investigation conducted by both the authors-2 and 3, the split tensile strength was noted to be maximum for 30% replacement when compared to other replacement (40%) of OPC with mineral admixtures.

D. In the present study by the author-2, there was no considerable improvement in the durability properties such as water absorption and sorptivity. However, these properties were improved with replacement of cement by fly ash and metakaolin together in the study of author-3.

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LIST OF CODES

1. ASTM C1585 Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes
2. ASTM C 642-97. Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

AUTHORS PROFILE

Dr.N.Sanjeev, got his first degree from NIT Warangal in 1983. Joined government of India through UPSC Engineering Services (so called IES)-1983 batch and was Engineer in Charge for the construction of longest runway in Asia near Chennai. After 21 years of service retired from government service. Served private and corporate construction industries for 6 years up to level of Vice President. Worked as professor in KLU for 2 years and presently professor in civil engineering department in Gokaraju Rangaraju Institute of Engineering and Technology since November 2014.

Kaza Prem Rakshit Kumar, completed Bachelor of Technology (Civil Engineering) in Institute of Aeronautical Engineering (IARE) College (Hyderabad), 2009-2013 batch with first class degree. Presently pursuing Master of Technology (Structural Engineering) in Gokaraju Rangaraju Institute of Engineering and Technology (Hyderabad), participated in some of the considerable conferences conducted by The Institute of Engineers (India) and also took part in workshops conducted by Indian Concrete Institute New Delhi Centre and very much interested to carry out experimental investigation on concrete incorporating various mineral admixtures.

K. Harish Kumar, completed Civil Engineering at Institute of Aeronautical Engineering College (IARE), Dundigal, Hyderabad in 2017. Btech project was on "Effect of organic admixtures on compressive strength of concrete under elevated temperatures". Presently pursuing Master of Technology in Structural Engineering at Gokaraju Rangaraju Institute of Engineering and Technology (GRIET), participated in some of the major conferences conducted by The Institute of Engineers (India) and also participated in workshops like Modern developments in concrete and building technology keenly interested to conduct experimental investigation on mechanical properties and some durability properties of fiber reinforced concrete made with different mineral admixtures under the guidance of Dr N Sanjeev.

Mechanical and Durability Properties of Fly Ash and GGBS Based Fiber Reinforced Concrete

N. Sanjeev, K. Harish Kumar

Abstract: ***Concrete is one of the most commonly and widely adopted material for construction. Cement is used as primary binder material to produce Concrete. However, every tonne of Cement production releases one tonne of greenhouse gases which results in global warming; due to continuous and ever increased usage of Cement and natural sand are causing uncontrollable global warming and depletion of natural resources respectively year by year. This tendency needs to be retarded if not arrested, by developing a comprehensive approach to use more and more pozzolanic mineral admixtures and manufactured sand (M-Sand) in Concrete. In this study on fiber reinforced concrete (with steel fiber @ 1% of binder), Ordinary Portland Cement (OPC) is replaced up to 50% with Fly Ash and Ground Granulated Blast-Furnace slag (GGBS) for M30 grade of Concrete. Mechanical properties like compressive strength and split tensile strength at 7 days and 28day age are tested. Additionally, durability tests like water absorption and sorptivity tests are conducted after 28days of curing. The test results indicated that workability was increased and there was no significant improvement in durability properties on increasing the percentage of OPC replacement. However, 30% of OPC replacement is found to be optimum for strength criteria***

Keywords: Concrete, Fly Ash, GGBS, Steel fiber, M-Sand, Compressive Strength, Sorptivity and Water Absorption

I. INTRODUCTION

Concrete is one of the most commonly adopted material for construction. Durability, potential to sustain extreme weather conditions and ability to be moulded in to any shape made this material widely acceptable. Concrete comprise of cement, fine aggregate, coarse aggregate and water. Though cement generally comprises 12% of Concrete mass [1], about 250 million tons of cement produced in India yearly. Which in turn produces 220 million tons of CO_2 approximately which cause environmental pollution and global warming. To overcome this, comprehensive approach is to be developed to use more and more pozzolanic mineral admixtures in Concrete. Most of the pozzolanic mineral admixtures are by-products and their usage in concrete could decrease consumption of cement in construction.

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Hence this could reduce environmental pollution and global warming to large extent. On the other hand, it became necessary to replace natural sand in Concrete by alternate material without compromising on the quality of Concrete as the available sources of natural sand are getting depleted and transportation of good quality sand from long distances may increase cost of construction. The past researches have shown that Fly Ash, Ground Granulated Blast-Furnace Slag (GGBS) could give better result on replacing Ordinary Portland Cement (OPC) [1]. And further, natural sand can be replaced completely by manufactured sand (M-Sand) in Concrete [1] to get same results as natural sand. Steel Fibers are generally added to improve cracking resistance due to plastic and drying shrinkage. Addition of Steel Fibers increases mechanical properties like compressive strength, split tensile strength and flexural strength [2].

The objective of the present study is to determine mechanical and durability properties of M30 grade Steel Fiber reinforced Concrete on replacing OPC with Fly Ash, GGBS and natural sand by M- Sand.

II. MATERIALS USED:

In the present investigation materials used are OPC, Fine aggregate (M-Sand), Coarse aggregate, Steel fiber, Fly Ash, GGBS, Superplasticizer and Water.

The properties of material used are discussed below:

A. Ordinary Portland Cement (OPC):

In this study Ordinary Portland cement of 53 grade was used conforming to IS 12269:1987. The properties of the cement are specific gravity (sp. Gravity) 3.15, normal consistency-32%, Compressive Strength - 3, 7, 28 days are 25.3MPa, 36.8MPa, 53MPa respectively, initial setting time 65mins and final setting time 270min.

B. Fine Aggregate:

Locally available M sand was used as fine aggregate conforming to zone II IS 383:1970. The specific gravity and water absorption were tested conforming to IS 2386:1963. The test result of specific gravity is 2.6. The water absorption of M sand is 2.5%

C. Coarse Aggregate:

Locally available Crushed angular aggregate of size 20mm were used conforming to IS 383:1970. The physical properties like specific gravity and water absorption were tested conforming to IS 2386:1963. The test result of specific gravity of coarse aggregate is 2.64. The water absorption of coarse aggregate is 0.5%.

D. Water:

the water used is potable water which is easily available near the lab premises for mixing Concrete ingredients and for curing the Concrete specimens.

E. Fly Ash:

Type -Class F, colour– dark grey, bulk density - 1042kg/m^3, fineness 336m^2/kg and sp. gravity - 2.1.

F. GGBS:

colour-off white, bulk density-1281kg/m^3, sp. gravity -2.81, fineness-342m^2/kg

G. Steel Fiber:

The fibers used are hooked end steel fibers of aspect ratio 40. And are randomly oriented and uniformly distributed. In this study 1% of steel fibers are used in all Concrete mixes.

H. Super Plasticizer:

Master Rheobuild 920SH was used as super plasticizer. State – liquid, colour - dark brown, density-1.2, chemical name – naphthalene formaldehyde polymers and P^H – 8.40.

III. EXPERIMENTAL INVESTIGATION

A. General

In this experimental investigation, Compressive strength and split tensile strength at 7 days and 28 days age were tested to study mechanical properties whereas water absorption and sorptivity tests were conducted at 28 days age to study durability properties of M 30 grade fiber reinforced Concrete. In this study replacement of OPC was varied at 30%, 40% and 50% by both fly ash and GGBS together. And hooked end steel fibers @ 1% by weight of binder were used in all the mixes. The following are the tests conducted to study mechanical and durability properties of all the mixes.

B. Compression Test

The compression test is conducted on cubes in accordance with IS 516-1969. 3 samples are tested for 7 days and 28days age.

C. Split Tensile Test

It is the standard test to determine tensile strength of Concrete in indirect way, this test was performed on cylindrical specimens in accordance with IS 5816-1970.3 samples were tested at each 7 days and 28 days age.

D. Sorptivity test

This aim of this test is to determine sorptivity of M30 grade fiber reinforced Concrete as per ASTM C1585. Sorptivity is the cumulative change in volume of water absorbed per unit area against the square root of time. This test was conducted on 100mm diameter and 50mm depth cylindrical specimen asper ASTM C 1585. After 28 days of curing, the specimens were oven dried at 110^o C for 24hrs [3]. The side faces of the specimens were sealed with Electricians tape or sealant whereas Suction face and the opposite face to it was kept unsealed. The cylindrical specimens were arranged as shown Figure (1). The mass of specimens was recorded at programmed intervals. Sorptivity is the slope of I vs √t graph. where I represent the gain of mass per unit area over the density of water and t represents the time elapsed.

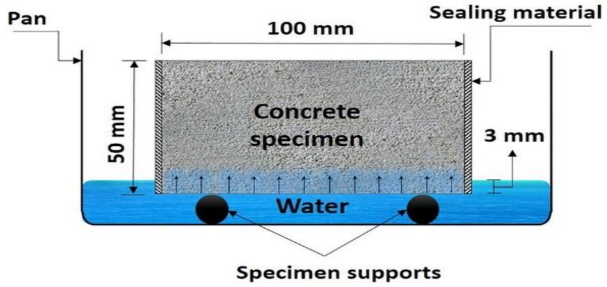

Fig (1)

I= (W_t -W_0)/ (A x d): where W_t = weight of the specimen at time t, W_0 = initial weight of specimen, A= area of suction face of the specimen and d= density of the medium in which specimen was immersed (1000 kg/m^3 in case medium is water)

E. Water Absorption

the objective of this test is to determine the water absorption rate of the fiber reinforced Concrete of M 30 grade. the specimens of size 10cm x 10cmx 10cm were oven dried at 110^o C for 24hrs after 28 days of curing [4]. And then specimens were placed in a container and it was filled with water until the water level reach 2 cm height above the specimen. Then record the weight of the specimen at programmed intervals until the weight difference between two successive 24hr interval measurements is less than 1%. And hence, the water absorption rate is established.

Quantity of water absorbed

M_i% =100 x (m_i-m_o)/m_o; where m_i = weight of the specimen at time t; m_o= weight of dry specimen

F. Concrete Mixes

mix proportion of cement, fine aggregate and coarse aggregate for the present study designed as per IS 10262-2009 is 1:2.17:3. With a binder ratio of 0.43.

M1: 100% OPC + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1% by weight of OPC.

M2: 70% OPC + 15% Fly Ash + 15% GGBS + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1% by weight of binder.

M3: 60% OPC + 20% Fly Ash + 20% GGBS + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1% by weight of binder.

M4: 50% OPC + 25% Fly Ash + 25% GGBS + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1 % by weight of binder.

IV. TEST RESULTS

A. Workability

The workability for different mixes is shown Fig 2. From this Figure it is observed that workability is increased as the replacement of OPC is increased.

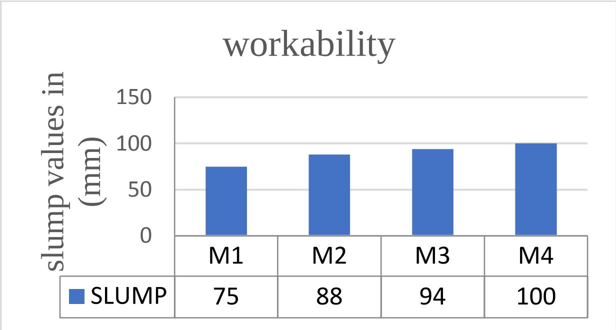

Fig (2)

B. Compressive Strength

The Compressive strength values for all the mixes at 7 days and 28days age are shown graphically in Fig 3. It is observed that 30% replacement is optimum among all the replacements.

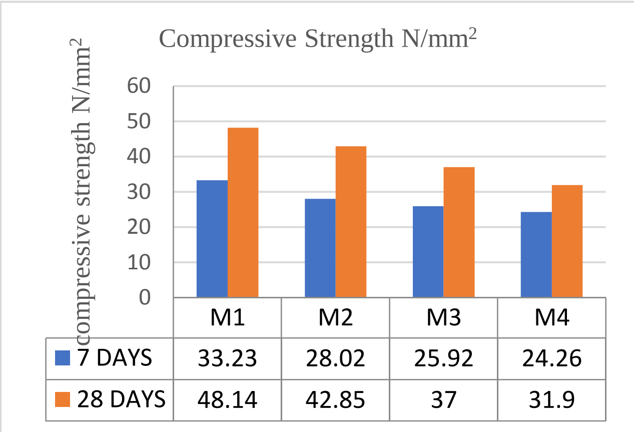

Fig (3)

C. Spilt Tensile Strength

Split tensile strength values for all the mixes at 7 days and 28 days are shown graphically in Fig 4. It is observed that 30% replacement is optimum among all the replacements.

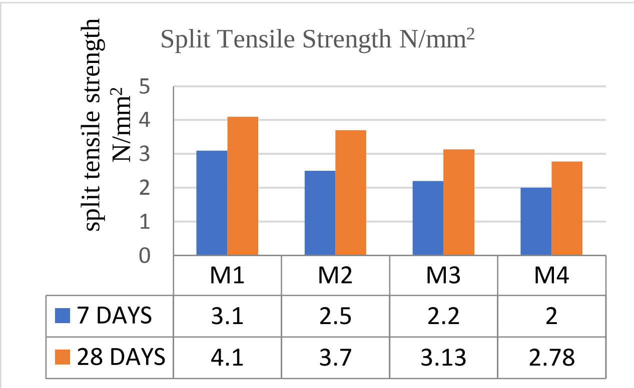

Fig (4)

D. Sorptivity

Sorptivity for all mixes are obtained from the graph shown below in Fig 5. It was found that sorptivity of the concrete is increased with increasing percentages of OPC replacement.

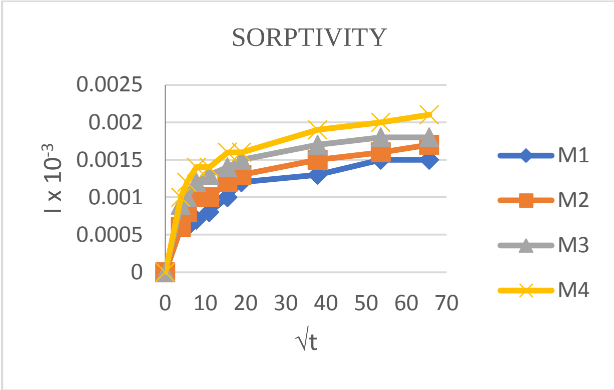

Fig (5)

F. Water Absorption

Results for water absorption test for all mixes are represented graphically in Fig 6. It was found that water absorption rate is increased with increasing percentages of OPC replacement.

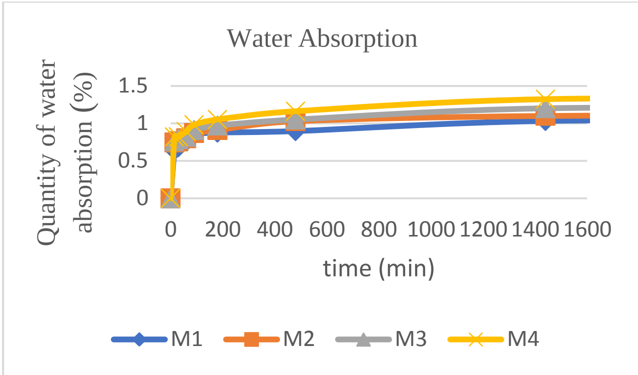

Fig (6)

V. CONCLUSIONS

Based on the experimental investigation, the following conclusion are made

A.The workability of the Concrete was increased from 75mm to 100mm when the 50% of OPC was replaced by Fly Ash and GGBS together.

B. 30% replacement of OPC was found to be optimum. Since, 28-day Compressive Strength was about 13% more than the target mean strength. However, for 40% replacement 28day compressive strength is reaching the target mean strength.

C.The 28 day Split Tensile Strength was observed to be maximum for 30% replacement of OPC with Fly Ash and GGBS when compared to other replacements.

D.It was observed that there was no significant improvement in durability properties on replacing OPC with Fly Ash and GGBS together.

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List of codes

1. IS-456:2000, 4th revision for plain and reinforced concrete.
2. IS 10262: 2009.for concrete mix design,
3. IS 12269- 1987: specifications of 53 grade OPC
4. IS 383-1970 for coarse and fine aggregate from natural sources for concrete
5. IS 2386-1963: methods of testing aggregates for concrete
6. IS 516-1959: methods of test for strength of concrete.
7. ASTM C1585 for measurement of absorption (sorptivity) of water by hydraulic cement concretes.
8. ASTM C642 -13 for density, absorption, and voids in hardened concrete

AUTHOR'S PROFILE

Dr. N. Sanjeev, He got his first degree from NIT Warangal in 1983

Joined government of India through UPSC engineering services (so called IES)-1983 batch and was engineer in charge for the construction of longest runway in Asia near Chennai. After 21 years' service retired from government service Served private and corporate construction industries for 6 years up to level of vice president. completed his PHD from Andhra university. And PHD thesis was on structural appraisal of reinforced cement concrete with high volume fly ash concrete. Worked as professor in KLU for 2 years and presently professor in civil engineering in Gokaraju Rangaraju institute of Engineering and Technology since November 2014.

K. Harish Kumar, Completed Civil Engineering at Institute of Aeronautical Engineering college (IARE), Dundigal, Hyderabad in 2017.

B tech project was on "Effect of organic admixtures on compressive strength of concrete under elevated temperatures". presently pursuing Masters in Structural Engineering at Gokaraju Rangaraju institute of Engineering and Technology (GRIET), participated in some of the major conferences conducted by institute of engineers (India) and also participated in workshops like Modern developments in concrete and building technology keenly interested to conduct experimental investigation on mechanical properties and some durability properties of fiber reinforced concrete made with different mineral admixtures. under the guidance of Dr n sanjeev

An Experimental Programme on Fibre Reinforced Concrete made with OPC, Fly Ash and Metakaolin

N. Sanjeev, Kaza Prem Rakshit Kumar.

Abstract*: Most commonly used composite building material in construction industry is Concrete due to ease of construction and its properties like compressive strength and durability. The basic ingredient of Concrete having adhesive nature is Ordinary Portland Cement(OPC). OPC is being replaced with Fly Ash and Metakaolin as these mineral admixtures possess pozzolanic properties which credit for strength gain and cost reduction in concreting. In this investigation, OPC is replaced up to 40% with Fly Ash and Metakaolin for M35 grade of Fibre Reinforced Concrete(FRC). Natural sand is replaced completely with Manufactured sand (M-sand). Steel fibres @ 1% of binder are used. Mechanical properties like compressive strength and split tensile strength at 7 days and 28 days age are tested. Additionally durability tests like water absorption and sorptivity after 28days curing are conducted. The test results indicated that 30% replacement of OPC was optimum for strength criteria, workability of Concrete was decreased with increase in replacement of OPC with Fly Ash and Metakaolin together.

***Keywords* : Fly Ash, Manufactured Sand, Metakaolin, Ordinary Portland Cement (OPC), Steel fibres, Sorptivity and Water Absorption.**

I. INTRODUCTION

A typical Concrete is composite material composed of binding material, aggregates and water. Widely used binding material in concrete is cement which glues the concrete together and aggregates used acts as filler material in concrete. Demand for cement is drastically increasing in developing countries which leads to more production of cement. This increased demand for production of cement leads to emission of CO_2 which results in global warming. This adverse effect of uncontrolled global warming due to increased production of cement is to be minimised by developing an alternate approach of producing more environmentally friendly Concrete. Environmental friendly Concrete is made by partially replacing the amount of cement in Concrete with by-products materials or mineral admixtures such as Fly Ash and Metakaolin. Further, natural river sand which is used as fine aggregate in Concrete takes a million of years to form and it is not replenishable. Because of its limited supply and disproportionate cost of transportation from natural sources, shortage of good quality of natural sand occurs, causing serious menace to environment as well as the society. Hence, it is proper to replace natural sand with manufactured sand. As the Concrete is brittle in nature and can't resist tensile forces, fibres are used to enhance the tensile strength and to increase the structural integrity of the Concrete. And also cracking due to plastic and drying shrinkage of Concrete can be controlled by making use of addition of fibres in Concrete. In this experimental programme, steel fibres are used @ 1% of binders and an attempt is made to investigate the strength and durability properties of M35 grade of fibre reinforced concrete with partial replacement of OPC with Fly Ash and Metakaolin up to 40%.

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II. MATERIALS

The materials used for present investigation are Ordinary Portland Cement, Fine Aggregate, Coarse Aggregate, Steel Fibres, Fly Ash, Metakaolin, Super Plasticizer and Water. The material properties are discussed below:

A. Ordinary Portland Cement (OPC):

OPC of 53 grade conforming to IS 12269:1987 was used for all the concrete mixes in the present investigation. The properties of OPC are Specific gravity - 3.15, Normal consistency - 32%, Compressive strength - 3, 7, 28 days are 25.3MPa, 36.8MPa, 53MPa respectively, Initial setting time - 65 minutes and Final setting time - 270 minutes.

B. Fine Aggregate:

Locally available Manufactured sand was used as fine aggregate conforming to zone II IS 383:1970. The physical properties like specific gravity and water absorption were tested conforming to IS 2386:1963. The test result of specific gravity is 2.6. The water absorption of Manufactured sand is 2.5%

C. Coarse Aggregate:

Locally available crushed angular aggregate of size 20mm were used conforming to IS 383:1970. The physical properties like specific gravity and water absorption were tested conforming to IS 2386:1963. The test result of specific gravity of coarse aggregate is 2.64. The water absorption of coarse aggregate is 0.5%.

D. Water:
The water used is potable water which is easily available near the lab premises for mixing concrete ingredients and for curing the concrete specimens. The pH value of water shall not be less than 6.

E. Fly Ash:
Class F Fly Ash is the mineral admixture used. Fly Ash is a by-product obtained in thermal plants. It improves workability of concrete it sets slowly thus concrete with fly ash generates low heat of hydration. The properties of fly ash are colour – dark grey, specific gravity is 2.1.

F. Metakaolin:
Metakaolin is an artificial pozzolanic admixture obtained from calcination of clay mineral called kaolin at a temperature of 600 to 800^{o}c. The specific gravity of Metakaolin is 2.7.

G. Steel fibre:
The fibres used are hooked end steel fibres, which are randomly oriented and having aspect ratio of 40. In this investigation 1% of steel fibres are used in all concrete mixes.

H. Super plasticizer:
Super plasticizer is added to increase the workability of concrete. Master Rheobuild 920SH was used as super plasticizer. The properties of super plasticizer are State - Liquid, Colour - Dark Brown, Density - 1.2, pH - 8.40. IS 9103-1999 has recommended that super plasticizer can be added up to 1 to 2% of binder. In this investigation, super plasticizer used was 1.2% of binder.

III. EXPERIMENTAL INVESTIGATION

A. General
The experimental investigation was done to study mechanical properties such as compressive strength, split tensile strength and durability properties such as water absorption and sorptivity of Fibre Reinforced Concrete of M35 grade. In this study, steel fibres of 1% by weight of binder is used in every mix and replacement of cement is varied by 20%, 30%, 40% with Fly Ash and Metakaolin together for M35 grade of Concrete. The samples were casted and tested at 7 days and 28 days age to study the mechanical properties and at 28 days for durability properties. The following are the tests conducted to study mechanical and durability properties of all the mixes.

B. Compression Test:
The compression test was conducted on cubes of size 150mm x 150mm x 150mm are tested in accordance with IS 516-1969. 3 samples were tested at each of 7 days and 28 days. Each sample consists of 3 specimens.

C. Split Tensile Strength
It is the standard test to determine tensile strength of concrete in indirect way, this test was performed in accordance with IS 5816-1970.

D. Sorptivity Test
Sorptivity measures the rate of penetration of water into the pores of concrete by capillary action. The objective of this test is to determine sorptivity of fibre reinforced concrete of M35 grade as per ASTM C1585. Sorptivity is the cumulative change in volume of water absorbed per unit area against the square root of time. The sorptivity tests were done on cylindrical specimen of size 100mm diameter and 50mm height. After 28 days of curing, the specimens were oven dried at 110^o C for 24hrs. The sides of specimens were sealed with electricians tape or sealant. Suction face and the face opposite to it were kept unsealed. The specimens were arranged as shown in the Figure 1 below.

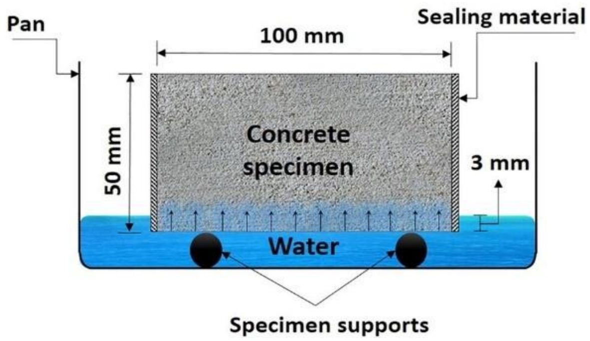

Fig 1: Illustration of Sorptivity Test

The rate of water absorption or sorptivity = K = the slope of I vs √t graph.
'I' value is calculated using the following equation,

$$I = \frac{W}{A \times d}$$

Where, W= the amount of water absorbed in kg, A=area of the cross section of the specimen that is in contact with water, d = density of the medium in which specimen was immersed (1000 kg/m^3 in this case medium is water).

E. Water Absorption
The aim of the test is to determine the total water absorption of fibre reinforced concrete of M30 grade. Concrete cube specimens of 100mm x 100mm x 100mm size were casted and cured for 28 days after the curing period, the specimens were oven dried at 110^{o}C for 24hrs and then specimens were immersed in water such a way that the height of water above specimen after immersion is 2 cm. The weight of the specimens was recorded at programmed interval and hence, the water absorption was established. At each interval, the quantity of water absorbed with respect to the mass of dry sample is expressed as:

$$M_i\% = \frac{m_i - m_0}{m_0} \times 100$$

Where, m_i = weight of the wet sample at time t; m_o= weight of dry sample.

F. Mix proportion

The mix proportion of cement, fine aggregate and coarse aggregate for the present study designed as per IS 10262-2009 is 1:2.13:2.86, with water to binder ratio of 0.42.

G. Concrete Mixes

The four types of concrete mixes used are as follows:

i) P1: 100% OPC + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibres @ 1% by weight of binder.

ii) P2: 80% OPC + 10% Fly Ash + 10% Metakaolin + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibres @ 1% by weight of binder.

iii) P3: 70% OPC + 15% Fly Ash + 15% Metakaolin + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibres @ 1% by weight of binder.

iv) P4: 60% OPC + 20% Fly ash + 20% Metakaolin + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibres @ 1 % by weight of binder.

IV. TEST RESULTS

A. Compression Strength

The results obtained in Compression Strength test are represented by histogram vide Fig 2. It was observed that 30% replacement is optimum among all the replacements. The compressive strength is 4.5% more than target mean strength at 28 days.

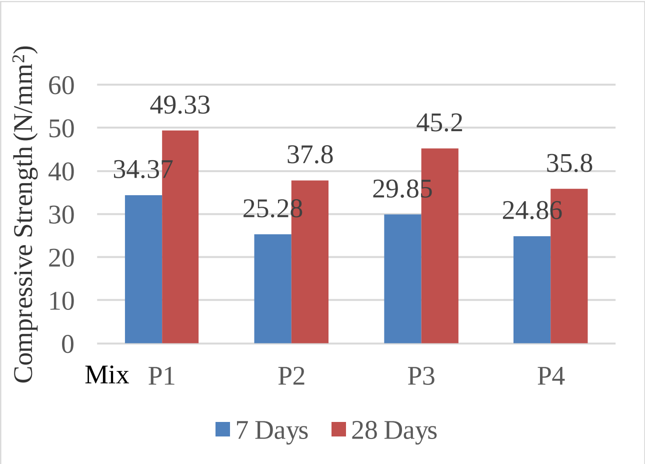

Fig 2: 7 days and 28 days Compressive Strength of concrete mixes P1, P2, P3 and P4

Table-I: 7 days and 28 days Compressive Strength of concrete mixes P1, P2, P3 and P4

Mix	Compressive Strength (N/mm^2)	
	7 Days	28 Days
P1	34.37	49.33
P2	25.28	37.80
P3	29.85	45.20
P4	24.86	35.80

B. Split Tensile Strength

Split Tensile test results are represented by histogram vide Fig 3. It is observed that 30% replacement is optimum among all replacements.

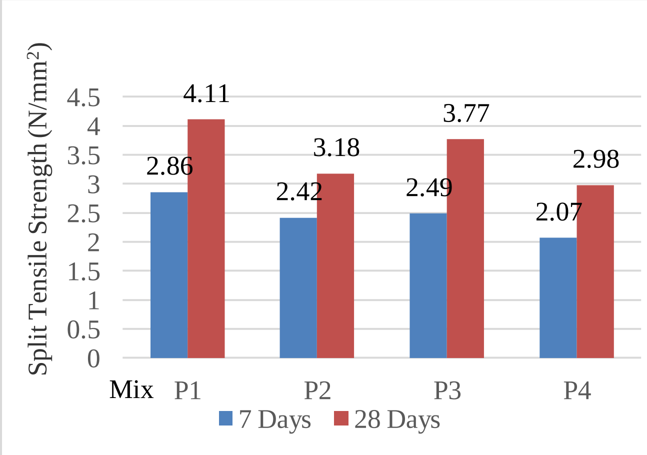

Fig 3: 7 days and 28 days Split Tensile Strength of concrete mixes P1, P2, P3 and P4.

Table-II: 7 days and 28 days Split Tensile Strength of concrete mixes P1, P2, P3 and P4.

Mix	Split Tensile Strength (N/mm^2)	
	7 Days	28 Days
P1	2.86	4.11
P2	2.42	3.18
P3	2.49	3.77
P4	2.07	2.98

C. Workability

The slump values for all mixes are represented by histogram vide Fig 4. From this Fig 4, it is observed that workability is decreased with increased replacement of Ordinary Portland Cement.

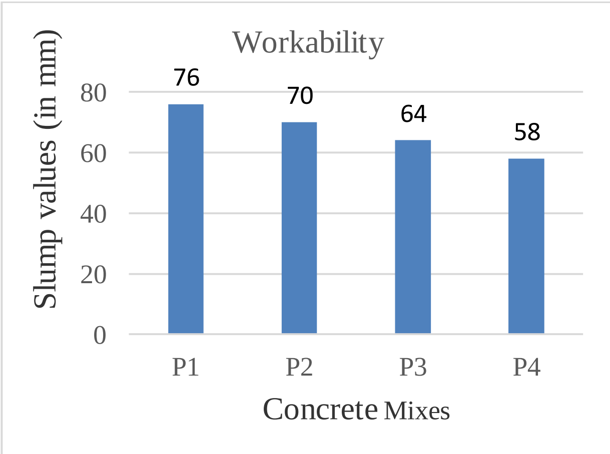

Fig 4: Slump values

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Table-III: Slump values

Mix	Slump (in mm)
P1	76
P2	70
P3	64
P4	58

D. Water Absorption

Results for water absorption test for all mixes are represented graphically vide Fig 5. It is observed that water absorption is minimum for P2 mix.

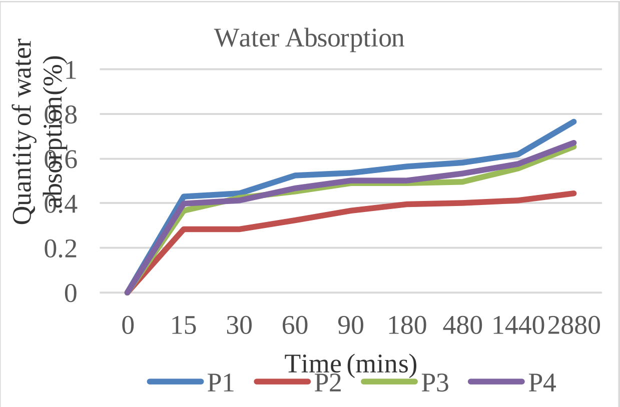

Fig 5: Water absorption values of concrete mixes P1, P2, P3 and P4.

E. Sorptivity

Results for sorptivity test for all mixes are represented graphically as shown in Fig 6. It is observed that rate of water absorption was decreased with increased replacement of Ordinary Portland Cement.

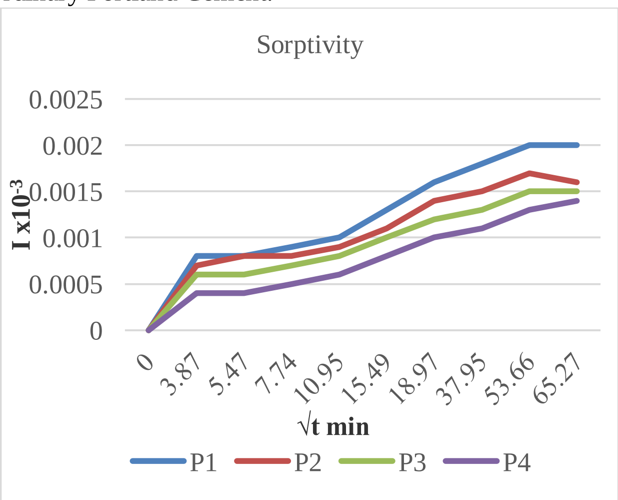

Fig 6: Sorptivity values of concrete mixes P1, P2, P3 and P4

V. CONCLUSIONS

Based on the experimental investigation, the following conclusions are made:

1. The workability of the Concrete was decreased from 76 mm to 58 mm i.e, for the mix with 100% OPC to 60% OPC respectively.
2. In this Study, 30% replacement of Cement was found to be optimum as 28-day compressive strength was about 4.5% more than the target mean strength.
3. The Split Tensile Strength was observed to be maximum when Ordinary Portland Cement was replaced by the Mineral Admixtures to an extent of 30%.
4. The durability properties like water absorption and sorptivity were improved with replacement of Ordinary Portland Cement by Fly Ash and Metakaolin together @ 20% and 40% respectively.

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7. IS 12269:1987, Specifications for Ordinary Portland Cement 53 Grade.
8. IS 383:1970, Indian standard specifications for coarse and fine aggregate from natural sources for Concrete.
9. IS 2386:1963, Methods of testing aggregates for Concrete
10. IS 516:1959, Methods of test for strength of Concrete
11. ASTM C1585: Standard test method for measurement of absorption (sorptivity) of water by hydraulic Cement Concretes.
12. ASTM C642-13: Standard test method for density, absorption, and voids in hardened Concrete.

AUTHORS PROFILE

Dr.N.Sanjeev, got his first degree from NIT Warangal in 1983. Joined government of India through UPSC Engineering Services (so called IES)-1983 batch and was Engineer in Charge for the construction of longest runway in Asia near Chennai. After 21 years of service retired from government service. Served private and corporate construction industries for 6 years up to level of Vice President. Worked as professor in KLU for 2 years and presently professor in civil engineering in Gokaraju Rangaraju Institute of Engineering and Technology since November 2014.

Kaza Prem Rakshit Kumar completed engineering in Institute of Aeronautical Engineering College (Hyderabad) in the batch of 2009-2013 with first class degree. Presently pursuing Master's in Structural Engineering in Gokaraju Rangaraju Institute of Engineering and Technology (Hyderabad), keenly interested to conduct experimental investigation on concrete made with different mineral admixtures.

Mechanical and Durability Properties of Fibre Reinforced Concrete made with OPC, GGBS and Metakaolin

N. Sanjeev, T. Sampath Kumar Reddy

Abstract: ***Concrete is a globally utilized material in the construction field. In the last few decades, Concrete consumption has become multifold and usage has enhanced in massive scale due to the rapid growth of infra sector. Generally, Concrete consists of cement, aggregate, and water; these ingredients become more expensive day by day and additionally hard to please and is increasing widely. During the process of making Ordinary Portland Cement(OPC) produces a large amount of greenhouse gases and the environment being polluted. To minimize the cement utilization and environmental issues is essential to switch the cement by another alternate materials such as pozzolanas. The various number of pozzolanic materials comes from industrial wastes are Ground Granulated Blast furnace Slag (GGBS), Fly Ash (FA), Silica Fume (SF), Metakaolin (MK) etc are utilized in concrete. Similarly, the availability of river sand is getting drained furthermore it turns out troublesome. In order to avoid this problem river sand is alter by Manufactured Sand (M Sand). An attempt is made in the present investigation to study on properties of fiber reinforced concrete (steel fibers @ 1% of binder) of M40 grade made with OPC, GGBS, MK and manufactured sand. In this study, OPC is replaced by GGBS and MK in different proportions. By casting requisite number of cubes, cylinders then Mechanical properties are determined such as Compressive strength, Split tensile strength tests and durability properties are determined by conducting Water absorption and Sorptivity tests. Test results are compared between controlled concrete and innovative concrete of M40 grade.It is observed that 30%(15%GGBS,15%MK) replacement is optimum for strength and durability criteria.***

Keywords: ***Compressive strength, GGBS, MK, OPC, Split tensile strength, steel fibers, Sorptivity, Water absorption.***

I. INTRODUCTION

Concrete is one of the most extensively utilized construction material in the world and about 6 billion tons of concrete is consumed by the construction industry every year. At present preparing of concrete is to increase both strength and durability properties to meet the demands of modern construction. Concrete is manufactured by mixing the cement, aggregates and water in required proportions. During cement manufacturing process it emits large amount of CO_2 and environment is polluted. To overcome this problem cement is replaced by pozzalonic materials conforming to Ground Granulated Blast furnace Slag (GGBS), Fly Ash (FA), Metakaolin (MK) etc are used to some extent. These mineral admixtures acts as reactive binder components like cement.Natural sand is mainly obtained by excavation from riverbeds .

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The availability of Natural sand is getting drained furthermore it turns out troublesome. Because of that Natural sand is completely alter by Manufactured sand (M-sand) in concrete. It not only enhancing the performance of concrete but also of their economic and environmental advantage [1][2]. Generally Concrete is weak in tension and brittle in nature. Fibers are added to control cracking and also to increase the tensile strength, flexural strength. Based on the availability we use different type of fibers like Steel fibers , Glass fibers , Nylon fibers etc., with different aspect ratio. In the present study hooked end steel fibers are used. The past researches have shown that GGBS,MK can be replaced up to 30%.However,it gives optimum results in strength [3][4]. The slump value decreases gradually by increase in Metakaolin content[5]. By adding of 1% fibers in concrete makes reduce crack formation and enhancing strength, durability properties [6]. An attempt is made in present investigation to study on properties of fiber reinforced concrete of M40 grade made with OPC, GGBS,MK and manufactured sand of different proportions.

II. MATERIALS

The materials utilized in the present investigation are Cement, Fine Aggregate(FA), Coarse Aggregate(CA), GGBS, MK, water, fibers, super plasticizer. The materials used for casting were discussed below .

A. Ordinary Portland Cement (OPC):

For all mixes 53 grade of OPC (PENNA CEMENT) conforming to IS:12269-1987 (specifications for 53 grade)[7] is used. The Specific Gravity (SG) of OPC is 3.15.

B. Fine Aggregates (FA):

M-sand was used in place of Natural sand conforming to zone II conforming to IS 383:1970 [8]. It was collected from RANK Ready Mix Concrete Private Limited, Hyderabad, India. The Specific gravity ,water absorption and Fineness modulus was observed to be 2.6, 2.5% and 3.10 respectively. The conducted tests were conforming to IS 2386:1963 [9] .

C. Coarse aggregates (CA):

In this investigation locally available crushed angular aggregates with grain size of 20 mm down grade were used conforming to IS 383:1970. The Specific gravity, water absorption and Bulk density was observed to be 2.64 ,1% and 1592 Kg/m^3 respectively. The conducted tests were conforming to IS 2386:1963 [9].

D. GGBS:

In the present work GGBS is procured from Lafarge RMC Plant located in Hyderabad, India. According to ASTM C989-06 GGBS is used as mineral admixture in concrete.

Table-I: Physical properties of GGBS (As per manufactures certificate):

S. No	Property	RESULT
1	Appearance	Off white
2	Specific Gravity	2.8
3	Bulk density	1280 kg/m^3
4	Fineness	340m^2/kg

E. Metakaolin:

MK is refined from clay of kaolin by heating of 650^{0}C-900^{0}C. It is not a by product of industrial waste. MK is reacts with calcium hydroxide to produce additional cementing compounds, the material is responsible for holding of concrete.In this the specific gravity of Metakaolin is 2.7 and colour is off white(As per manufactures certificate).

F. Water:

potable water is used which is easily available in the lab premises for blending of **C**oncrete ingredients and curing of concrete specimens .The p^H ≥7 .

G. Fibers: In this investigation hooked end steel fibers are used with aspect ratio of 40. Steel fibers added @ 1% by weight of binder in all concrete mixes. Fibers are used to reduce the cracks and increase the strength. Fiber are conforming to IS: 280-2006 [10].

H. Super plasticizer:

Master Rheobuild 920SH was used as super plasticizer. The purpose of super plasticizer to enhancen the workability properties of concrete and reduce the water content . The properties of super plasticizer are State – liquid, colour - dark brown, density-1.2, chemical name – naphthalene formaldehyde polymers and P^H – 8.40. By recomendations of IS 9103-1999 [11] Super plasticizer usage up to 2% of binder . However, In the present study used super plasticizer @ 1% of binder.

III. ZEXPERIMENTAL INVESTIGATION\

A. General

The experimental investigation was done by casting 3 samples(each sample consists of 3) of cubes of size 15cm ,9 samples of cylinders of size 15cm diameter × 30cm height. The specimens are cured in water for 7&28days to study mechanical properties such as compressive strength, split tensile strength and durability properties such as water absorption and sorpitivity tests of M40 grade Concrete. In the present study, steel fibers @ 1% by weight of binder are used in every mix and Cement is replacd with GGBS , Metakaolin of various proportions like 20% (10% GGBS , 10% MK), 30% (15% GGBS , 15% MK), 40% (20%GGBS,20%MK) by weight.

B. Compressive Strength test:

In this investigation Each mix three samples cubes of size 15cm are casted , kept with water curing for 7 & 28days .The test was conducted in compliance with IS:516-1969 (Method of test for strength of concrete). Testing was done by compression testing machine of capacity 2000 KN .

Compressive Strength C = L/A

Where, L = failure load (KN)

A = Area of Cross section in mm^2

C. Split Tensile strength :

The test was conducted in compliance with with IS 5816:1970.

Split tensile strength (fs) = 2P/πDL

Where fs is splitting strength (MPa), P is the load (KN), L is length in mm , D is diameter (mm).

D. Sorptivity Test

Sorptivity measures the rate of penetration of water into the pores in concrete by capillary suction. The objective of this test to determine sorptivity of fibre reinforced concrete grade of M40 as per ASTM C1585.The test was conducted by casting 100mm diameter and 50mm depth. After curing 28 days , the specimens are oven dried at 110^{0}c for 24 hours. The sides of concrete specimen typically coverd with sealant or electrician tape while the suction face and opposite face were kept unsealed . The sample is immersed in water at a depth of 5 to10mm. Then record the initial mass of the specimen and time of start . The procedure is repeated at various timings .

The rate of sorptivity (K) is the slope of I vs √t graph .

I= W/ (A x d)

Where W= The amount of water absorbed in kg,

A = Area of the specimen that is in contact with water m^2,

d = density of the medium in which specimen was immersed (1000kg/m^{3}in case medium is water).

E. Water Absorption Test

The aim of the test is to determine the total water absorption of fibre reinforced concrete of grade M40 .By casting Concrete cube specimens of size 10cm. The specimens are cured with water for 28 days , After the curing period is completed the specimens are kept in oven dried @ 110^{0}c for 24 hours. The specimens are completely immersed in a water up to a depth of 120mm in container. Record the initial mass of the specimen and time of start . The procedure is repeated at various timings. The quantity of water absorbed with respect to the dry sample

$M_i\% = 100 \times (m_i - m_o)/ m_o$;

where

m_i = weight of the wet sample @ time t;

m_o= weight of dry sample.

F. Mix proportion

The design procedure for concrete mix of M40 grade as per IS 10262-2009. In the present study the obtained mix proportion of cement , Fine aggregate(M-sand) ,Coarse aggregate is 1 :1 .98:2.79 with water binder ratio 0.40.

G. Concrete mixes

M0: OPC 100% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder)

M1: OPC 80% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder) + 10%GGBS + 10%Metakaolin

M2: OPC 70% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder) + 15%GGBS +15%Metakaolin

M3: OPC 60% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder) + 20%GGBS +20%Metakaolin

IV. TEST RESULTS

A. Workability

The workability test results is shown as histogram vide Fig (1) and values in Table(2). From this test results , it observed that workability is Gradually decreased as replacement of OPC with GGBS and Metakaolin increases.

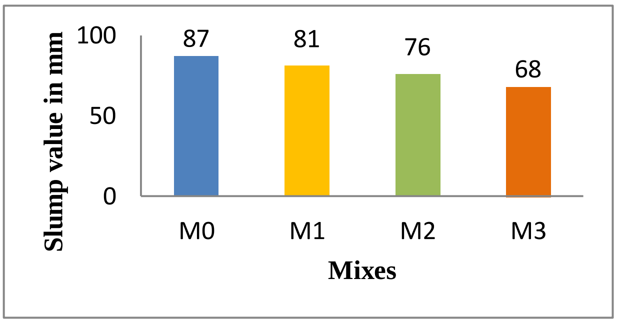


Fig (1). workability of concrete mixes M0,M1,M2,M3

Table II :Slump values of Concrete mixes M0,M1,M2,M3

MIX	Slump Value (mm)
MO	87
M1	81
M2	76
M3	68

B. Compressive Strength test

For all the mixes 7& 28 days compressive strength is shown as histogram vide Fig (2)and values in Table III Test results indicated that 30% replacement of OPC is optimum among all the replacements. The compressive strengths for 30% replacement of OPC is 39.72 N/mm^2 and 57.26 N/mm^2 for 7 & 28 days respectively .

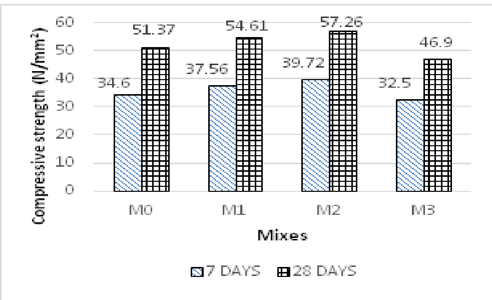


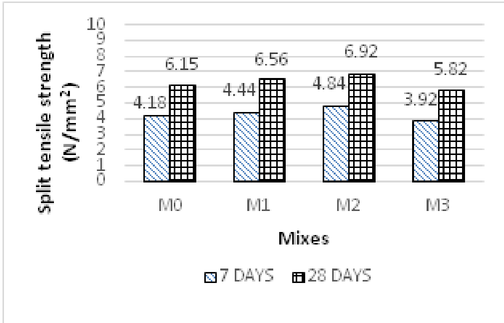
Fig (2). 7 &28 days compressive strength of concrete of mixes M0, M1, M2 , M3

Table III: compressive strength of concrete of mixes M0, M1, M2 , M3 for 7 &28 days.

MIX	Compressive Strength in N/mm^2	
	7 days	28 days
M0	34.6	51.37
M1	37.56	54.61
M2	39.72	57.26
M3	32.5	46.9

C . Split tensile strength

For all the mixes 7& 28 days split tensile strength is shown as histogram vide Fig (3).Test results indicated that 30% replacement of OPC is optimum among all the replacements. The compressive strengths for 30% replacement of OPC is 4.84 N/mm^2 and 6.92N/mm^2 for 7 & 28 days respectively .



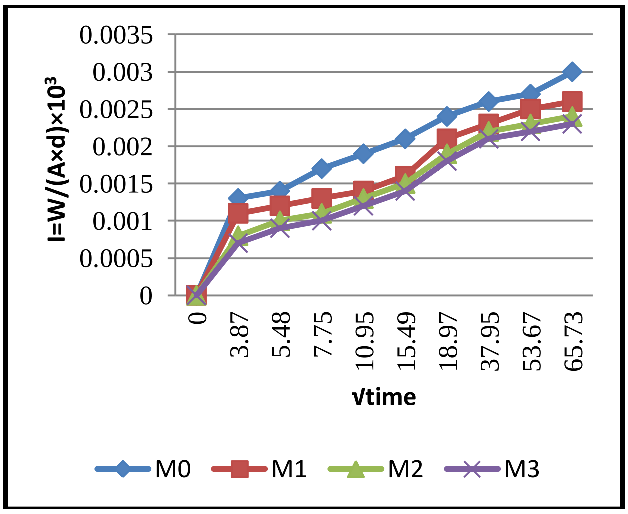
Fig(3). 7 &28 day split tensile strength of concrete of mixes M0,M1, M2 , M3

Table IV :Split tensile strength of concrete of mixes M0, M1, M2 , M3 for 7 &28 days.

MIX	Split tensile Strength in N/mm^2	
	7 days	28 days
M0	4.18	6.15
M1	4.44	6.56
M2	4.84	6.92
M3	3.92	5.82

D. Sorptivity test

Sorptivity values for all mixes are shown as graphycally vide Fig (4). It was observed that rate of water absorption is observed gradually decreased as the percentage replacement of cement is increased



Fig(4). Sorptivity of various mixes M0, M1, M2 , M3

E. Water absorption test

Water absorption test results for all mixes are represented graphically as shown in fig (5). It was indicated that water absorption is decreased with increasing percentages of cement replacement with GGBS and MK .

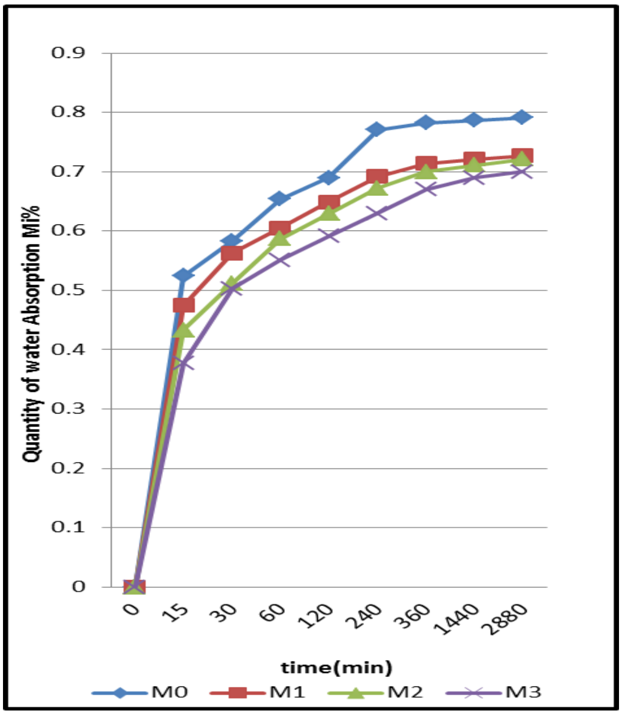


Fig (5). Water absorption of various mixes M0, M1, M2 , M3

V. CONCLUSIONS

From this Experimental investigation the following conclusion are made

1. The workability of the Concrete was decreased from 87mm to 68mm , when the mix contains 100% OPC to 60% OPC.
2. The compressive strength was to be maximum when Cement was replaced by at an extent of 30% (Mix -M2). It was observed by 14.8% and 10.5% more than that of the controlled concrete (Mix-M0) for 7 and 28 days respectively.
3. The split tensile strength was observed to be maximum when Cement was replaced by the MK and GGBS to an extent of 30% (Mix-M2).It was shows 15.78% and 12.52% more than the controlled concrete (Mix-M0) at 7, 28 days respectively.
4. There was significant improvement in the durability properties like water absorption and Sorptivity when GGBS and MK percentage increses in the concrete @20% to 40% respectively.
5. Based on the test results we concluded that the Mix M2 consists of 15% GGBS and 15% Metakaolin is better to use in construction industry.

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Dr.N.Sanjeev,He got his first degree from NIT Warangal in 1983.He completed his PhD from Andhra University, Visakhapatnam. He Joined government of India through UPSC engineering services (so called IES)-1983 batch and was engineer in charge for the construction of longest runway in Asia near Chennai.

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An Experimental Programme on Frc with Opc, Flyash, Ggbs, and Metakaolin

N. Sanjeev, Katta.Manoj

***Abstract** The production of Ordinary Portland Cement (OPC) is increasing year by year world over. Further, the production of every tonne of OPC generates one tonne of green house gases, (CO_2) which results in Global Warming. Usage of OPC is more in construction industry as it is a major ingredient in Concrete. As the usage of Concrete is increasing year by year, more and more is the OPC production and hence the environment is getting polluted; added to this undesirable scenario, the natural resources like lime stone used to manufacture cement and river sand are getting depleted year by year. In order to prevent the usage of large amounts of OPC in Concrete, mineral admixtures like Ground Granulated Blast furnace Slag (GGBS), Fly Ash and Metakaolin which are pozzolanic and cementitious in nature are adopted to replace certain percentages of OPC. Manufactured Sand (M-sand) is adopted to replace river sand. Experimental investigation is conducted on fiber reinforced concrete with steel fibers @1% of weight of binder by casting requisite number of cubes and cylinders of concrete of grade M25; in these mixes OPC is replaced with GGBS, Fly Ash and Metakaolin up to 45%. Mechanical properties are determined by conducting compressive strength and split tensile strength tests; additionally some of the durability properties are established by conducting Water absorption and Sorptivity tests. Test results are comparable between controlled concrete and innovative concrete of present investigation.*

***Keywords:** Compressive strength, Fly Ash, GGBS, Metakaolin, split tensile strength, Water absorption and Sorptivity tests.*

I. INTRODUCTION

Concrete plays a vital role in construction industry. Concrete is a mixture of cement, coarse aggregates, fine aggregates and water. Cement is the major ingredient of the concrete compared to all other ingredients, as it has better binding capacity of structure together. However One ton production of cement almost emits same amount of CO_2 into atmosphere. Many modern concrete mixes are modified with addition of admixtures, which improve the microstructure as well as decrease the calcium hydroxide concentration, by consuming it through a pozzolanic reaction. There are different Pozzolanic materials such as Fly Ash, Ground Granulated Blast Furnace Slag (GGBS) and Metakaolin. These mineral admixtures acts as a reactive binder components like Cement [1]. Concrete failure is brittle if once failure is initiated there is a loss of loading capacity which makes its application limited.

Fibers are added to control cracking due to plastic and drying shrinkage and to increase the tensile strength, flexural strength. Different types of fibers are available with different characteristics of their own. Steel fibers, glass fibers, nylon fibers are some of the fibers used mostly.

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A. ***Steel fibres:-***There are several types of steel fibres are available as reinforcement. Some of them are straight, hooked end, crimped steel fibres. The typical diameter ranges from 0.25 to 0.5mm. And fibres are made from mild steel wire of diameter 0.3 to 0.75 mm conforming to IS: 280-2006[2] which are practically used in India. Steel fibers are available in different aspect ratios (l/d) such as 40, 55, 60 and 80. And a certain amount of steel fibre in concrete can increase resistance to cracking and toughness of concrete. Addition of steel fibers increases mechanical properties (flexural and tensile strength) and lowers the workability[3].

B. ***Fly Ash: -*** Fly Ash is a material which is coal combustion product extracted from the flue gases through electrostatic precipitators in dry form. This ash is fine material and has good pozzolanic property. According to IS 456-2000, ASTM C618 fly ash can be used as the additive material. Use of Fly Ash in concrete is desirable because of its benefits such as increased workability reduction of cement consumption and decreased permeability[4]. Thermal cracks and heat of hydration are reduced when Fly Ash is used as replacement to OPC in Concrete. Fly ash adds additional strength to concrete mass as it converts released lime in the hydration of OPC into additional binding material. 10% to 20% replacement of cement with Fly Ash shows good compressive strength for 28 days[5].

C. ***Ground Granulated Blast furnace Slag (GGBS):-*** Ground Granulated Blast furnace Slag is a cementitious material used for the replacement of cement, which is a by-product of iron and steel manufactured blast furnaces. GGBS is obtained by heating of iron ore, limestone and coke in a blast furnace for about 1500 degree Celsius. GGBS consists of alumina, silica and some other oxides. The main constituents of blast furnace slag are CaO, SiO2, Al2O3 and MgO, These minerals are mostly found in most of the cementitious substances. Addition of slag to cement increases the durability properties of concrete and also reduces the porosity of concrete[6] ,Some of the recent studies in various parts of the world have revealed that GGBS can protect the steel reinforcement more efficiently, so that it can resist corrosion, and thus the structure as a whole[1]. A 30 to 40% of replacement of cement by GGBS was found to produce optimum strength of concrete [7].

D. ***Metakaolin:-***Metakaolin is an anhydrous calcined form of mineral kaolinite. Metakaolin is very reactive pozzolana. Kaolin is converted into Metakaolin when it is heated to temperature between 600 to 850°C. Metakaolin particle size is smaller than cement particle size. Optimal performance is achieved by replacing 7% to 15% of the cement in concrete with Metakaolin. The benefits are not fully realized until at least 10% Metakaolin is used [8].

This paper is an experimental investigation on how the strength and durability characteristics vary on replacement of cement with pozzolanic materials in fiber reinforced concrete.

II. MATERIALS

A. Cement

Cement used in this study is ordinary Portland cement of 53 grade confirming to IS: 2269-1987 specifications.

B. Fine aggregates

Manufacturing sand is used instead of river sand in this investigation as fine aggregate which is having specific gravity of 2.6, fineness modulus of 3.10.

C. Coarse aggregates

Crushed angular aggregate used in this study confirming to IS: 383-1970.Which was bought from the quarry nearby and the size of coarse aggregate used is 20 mm which is free from deleterious materials. Coarse aggregate used has specific gravity is 2.64 and bulk density of 1592 kg/mm^3.

D. Flyash

Fly Ash is the mineral admixture used in this study confirming to ASTM C 618-2003.

Properties(As per manufactures certificate)

Color	Dark grey
Bulk density	1042 kg\m^3
Class	F
Specific gravity	2.1

E. GGBS

GGBS is a granular material formed when molten iron blast iron slag is rapidly chilled by immersion in water .GGBS specific gravity is 2.8. (As per manufactures certificate)

Properties of GGBS:

S. No	Property	RESULT
1	color	Off white
2	Specific gravity	2.8
3	Bulk density	1280 kg/m^3
4	Fineness	340m^2/kg

F. Metakaolin

Metakaolin is an anhydrous calcined form of mineral kaolinite. Metakaolin used in this investigation has Specific gravity of Metakaolin is 2.7. (As per manufactures certificate)

Physical properties of Metakaolin:

color	OFF white
Bulk density	365(gm/liter)
moisture	0.27%

G. Fibers

The fibres used are hooked end steel fibres. Which are randomly oriented and having aspect ratio of 40.In this study steel fibres@1% by weight of binder are used in all concrete mixes.

H. Super plasticizer

In order to have additional workability super plasticizer is used. These are used to reduce the water in concrete for same workability. Super plasticizer used in the study is MasterRheobuild920SH. (0.1%) by weight of cement based on Naphthalene formaldehyde polymers with following properties as per IS: 9103-1999[9].

Material used	Specific gravity	Water absorption
Cement	3.15	NIL
Fine aggregate	2.6	2.5%
Coarse aggregate	2.64	1%
Fly ash	2.1	NIL
Metakaolin	2.7	NIL
GGBS	2.8	NIL
Super plasticizer	1.20	NIL

III. EXPERIMENTAL INVESTIGATION

General

Experimental investigation is made by replacing cement with GGBS, Metakaolin and Fly ash in fiber reinforced concrete with 1% steel fibers in varied proportions 15%, 30%, 45%.Mechanical properties compressive strength, Split tensile strength are determined additionally some of the durability properties are established by conducting Water absorption and Sorptivity tests.

TESTS

A. Compressive strength

Cubes of 15 cm X 15 cm X 15 cm are commonly used. These specimens are tested by compression testing machine after 7 days or 28 days curing according to IS 516-1969 [10]. A loading rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

B. Slit tensile strength

Size of 150mm diameter and 300mm height cylinder is used to determine the tensile strength and it is the standard method and performed in accordance with IS 5816-1970.

C. Water absorption

Sizes of 100mm×100mm×100mm concrete cubes are used to determine the water absorption.

Specimens are dried at 110°C for 24 hrs after curing for about 28 days. Specimens are placed in container and it was fully immersed in such a way that height of water above the specimen after immersion is 2cm. Weights are noted at different intervals of time.

Mi%=100× (mi-mo)/mo

mi=weight of wet sample at time t

mo=weight of dry sample.

D. Sorptivity test

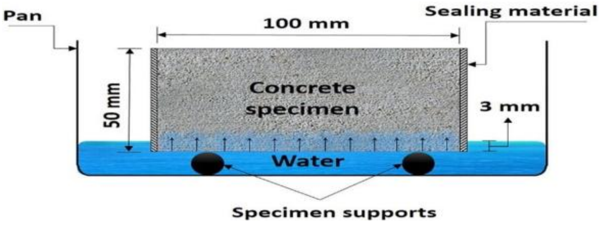
To determine the cumulative change in volume of water absorbed per unit area against square root of time as per ASTM C1585. Specimens are made about a Size of 100mm diameter and 50mm depth which were oven dried at 110°C for 24 hrs after curing for about 28 days. Sealant or tape are used to seal the sides of specimens but the suction face and face opposite to are not sealed .it is a placed in a container containing water about 5 to 10mm height of water .

Rate of water absorption =K

K is the slope of **I vs $\sqrt{t}$**

I = W/(A×d)

W= amount of water absorbed in Kg
A=Area of cross section contact with water; d=density of medium in which it is immersed (1000Kg/m^3 for water)



IV. MIX PROPORTIONS

The Concrete mix of M25 grade is designed as per IS 10262-2009[11].The partial replacements of OPC with Mineral Admixtures are done based on weight basis.

Grade	water	cement	Fine aggregate	Coarse aggregate
M25	0.45	1	2.39	3.17

V. CONCRETE MIXES AND TEST RESULTS

C0: OPC 100%+ M-Sand +Coarse aggregate + Fibers (1% of weight of OPC)
C1: OPC 85%+M-Sand+ Coarse aggregate + Fibers (1% of weight of binder) + 5%GGBS +5% Fly ash + 5%Metakaolin
C2: OPC 70%+ M-Sand +Coarse aggregate + Fibers (1% of weight of binder) + 10%GGBS + 10% Fly ash + 10%Metakaolin
C3: OPC 55%+ M-Sand +Coarse aggregate + Fibers (1% of weight of binder) + 15%GGBS +15% Fly ash + 15%Metakaolin

A. Workability

Workability is shown as histograms vide Fig (1) for different mixes. It was observed that workability is decreased as the replacement of OPC is increasing

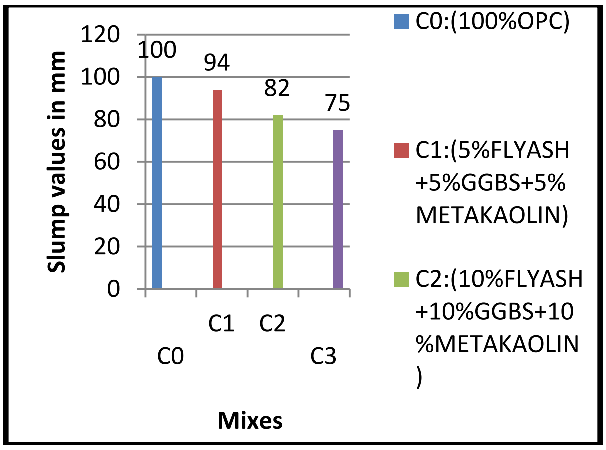


Fig (1): Workability

B. Compressive strength

For all the mixes 7days and 28 days age compressive strength is represented as histograms vide Fig(2) and Fig(3) respectively .Test results indicated that 28 days compressive strength of mixes of 15% and 30% replacement is optimum among all the replacements. It is clearly seen that the 28 days compressive strength of mix in which OPC was replaced by 15% is 22.7% more than that off controlled concrete at 28 days.

Compressive strength in N/mm^2				
Days	C0	C1	C2	C3
`7	26.8	25.48	24	20.19
28	36	44.2	38.04	31.5

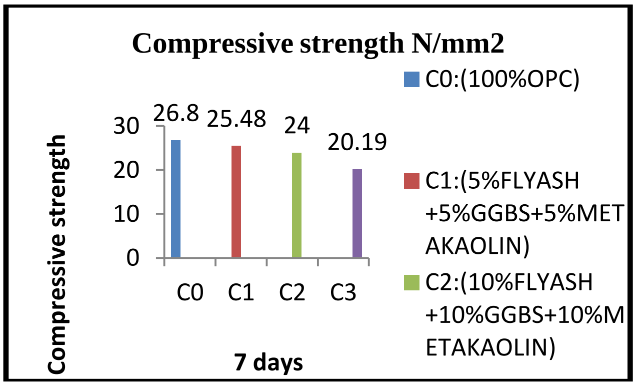


Fig (2):7 days Compressive strength N/mm2

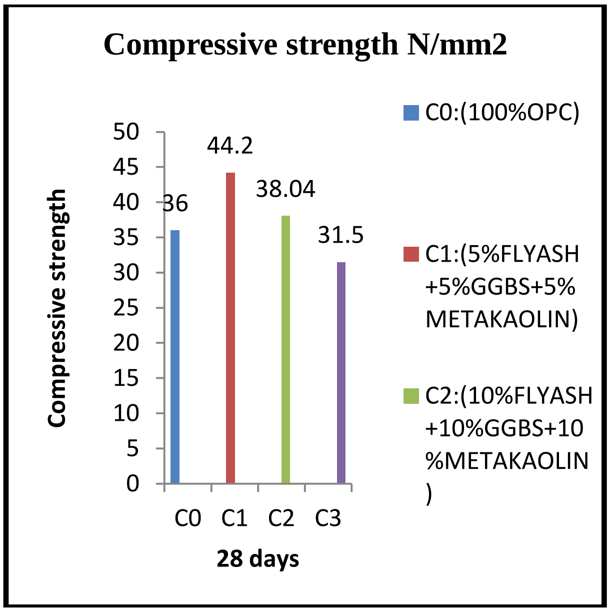
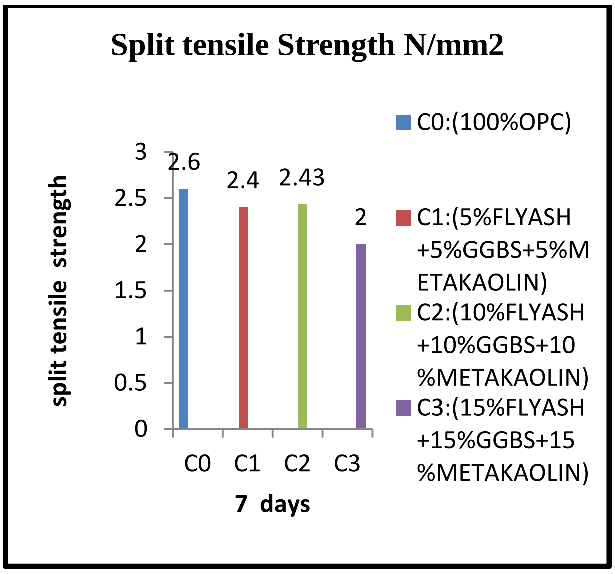


Fig (3): 28 days Compressive strength N/mm2

C. Split tensile strength

Split tensile strength values for all the mixes at 7 days and 28 days are represented as histograms vide Fig(4) and Fig(5) respectively . Split tensile strength is observed maximum at 15% replacement of OPC with mineral admixtures.

Split tensile test N/mm^2				
Days	C0	C1	C2	C3
7	2.6	2.4	2.43	2
28	3.57	4.6	3.9	3



Fig(4): 7days split tensile strength N/mm2

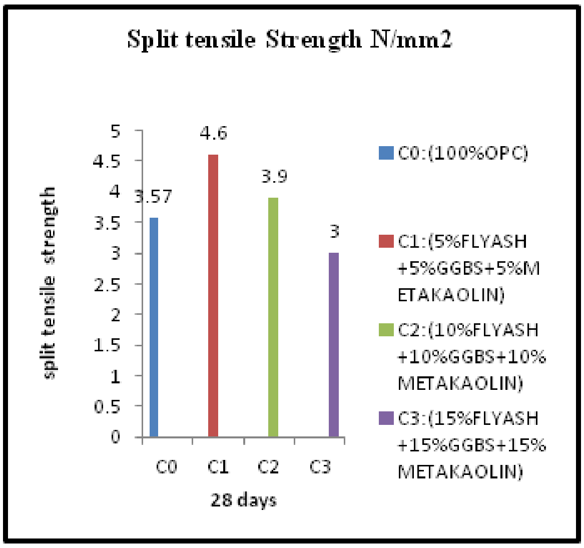


Fig (5): 28 days split tensile strength N/mm2

D. Sorptivity

Sorptivity values for all mixes are represented graphically as shown in Fig (6).Sorptivity values are found to be decreased as the percentage replacement of cement is increased.

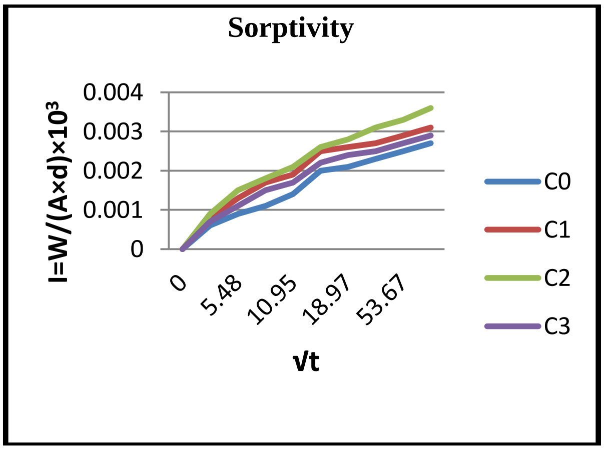


Fig (6):Sorptivity

E. Water Absorption

Water absorption test results for all mixes are represented graphically as shown in Fig (7). It was observed that water absorption was found decreased as the percentage replacement of cement increased.

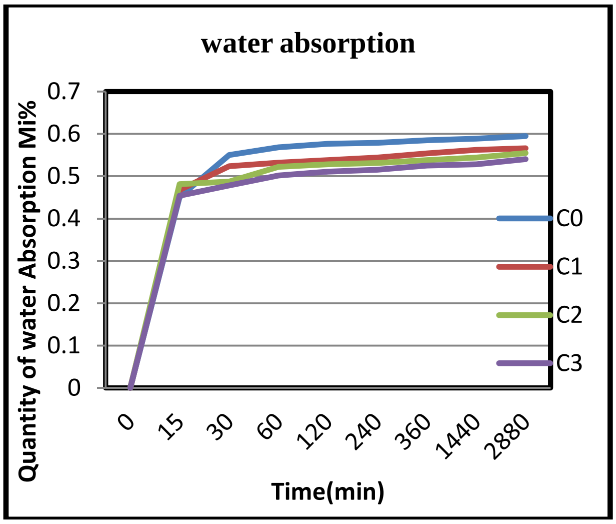


Fig (7): Water Absorption

VI. CONCLUSIONS

From this Experimental investigation the following conclusion are made

1. The workability of the Concrete was decreased from 100mm to 75mm when 45% of Cement was replaced by Fly Ash, Metakaolin and GGBS.
2. Maximum Compressive strength were attained at 15% replacement of cement by Fly Ash, Metakaolin and GGBS ,28 days compressive strength is 23% more than that off controlled concrete.
3. For 15%and 30% replacements the compressive strengths are more than the target mean strengths and for 45% replacement compressive strength is almost equal to target mean strength.
4. Split tensile strength was observed to be maximum when Cement was replaced by the Mineral Admixtures to an extent of 15%.
5. In the present Study there was significant improvement in the durability properties like water absorption and Sorptivity.

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AUTHOR'S PROFILE

Dr.N.Sanjeev, He got his first degree from NIT Warangal in 1983 Joined government of India through UPSC engineering services (so called IES)-1983 batch and was engineer in charge for the construction of longest runway in Asia near Chennai. After 21 years service retired from government service Served private and corporate construction industries for 6 years up to level of vice president. Worked as professor in KLU for 2 years and presently professor in civil engineering in Gokaraju Rangaraju institute of Engineering and Technology since November 2014.

Katta.Manoj, Completed engineering in Chaithanya Bharathi institute of echnology Obtained CGPA -7.2
Btech project is "Estimation of Temperature ,Humidity, Rainfall for next 70 years using Artificial neural networks". Presently pursuing masters in Structural engineering at Gokaraju Rangaraju institute of Engineering and Technology keenly interested to conduct experimental investigation on concrete made with different mineral admixtures.

Mechanical Properties of Concrete with Mineral Admixtures - an Experimental Programme

N. Sanjeev, T.Sairam

Abstract: Concrete is a general composite material used in construction industry over many decades. Due to rapid Growth of infrastructure, the demand of concrete is raising day by day. This composite material mainly made up of cementitious material such as cement and natural sand. This cement production results in release of large amount of CO_2 which directly effects environment pollution and Global warming and also, the usage of natural sand leads to environmental degradation. So, better way to reduction in CO_2 emission by minimizing cement content with some other puzolonic materials such as Metaakolin,Fly ash, Ground granulated blast furnace slag(GGBS) and This present Experiment is for to observe the cube and cylinder specimens strength of M40 grade of concrete at 7 days and 28 days with partial replacement of cement with ground granulated blast furnace slag ,Metakaolin and flyash @ 15%,30%,45% of binding material and natural sand with manufactured sand (M-sand).

Keywords: Concrete, Fly Ash, GGBS, Metakaolin, M-Sand, Compressive Strength, split tensile strength

I. INTRODUCTION

Concrete is a utmost adopted material in worldwide for construction works because of its main properties such as workability, compressive strength and durability etc. Concrete is a heterogeneous mixture made up of Cement, coarse Aggregate, fine aggregate and Water. The main ingredient being Cement, whose production involves emission of green house gases which causes the Environmental pollution and Global warming. Better way to reduce green house emissions by replacing cement with some materials known as puzolonas, like Ground granulated blast furnace slag(GGBS) ,flyash and Metakaolin. Flyash and GGBS are by-products of thermal, power and steel manufacturing industries respectively, whose usage in concrete reduces cement's utilization and eliminates disposal problems of mineral admixtures - Fly Ash and GGBS. During the past few decades, usage of natural sand in large amounts for manufacturing of Concrete degrades the environment as the depletion of natural resource, sand. To minimize the extraction of sand from river beds, manufactured sand (M-sand) is intended to use which is obtained by crushing the Granite and other stones. Th The aim of this research program is to observe the strengths of M40 grade of concrete with cubes and cylindrical specimens made in the laboratory with partial replacement of cement with Ground granulated Blast furnace slag,flyash and Metakaolin and also use M-sand in place of natural sand as fine aggregate .

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II. MATERIALS USED

The properties for various materials used in the present experiment are explained below:

A. Cement *:* OPC of 53 grade confirming to IS 12269:1987. compressive strength - 3, 7, 28 days are 25.3MPa, 36.8MPa, 53MPa respectively, initial and final setting time are 60 mins and 300mins respectively.

B. Fine Aggregate: M sand was used as fine aggregate confirming to Zone-II as specifications of IS:383-1970.

C. Coarse Aggregate: Crushed granite aggregates of size 20mm with angular shape were used confirming to IS 383:1970.specific gravity-2.80,water absorption -Nil.

D. Water: potable water suitable for concrete mixing and for curing .

E. Fly Ash*:* Type -Class F, color– Dark grey, Bulk density - 1041kg/m^3, fineness 336 m^2/kg, sp. gravity - 2.2.

F. GGBS: color-off white, Bulk density-1280 kg/m^3, sp. gravity -2.81, fineness-342m^2/kg,sp.gravity-2.8

G. Metakaolin: color-off white, Bulk density-790 kg/m^3,sp.gravity-2.6

III. EXPERIMENTAL PROGRAM

The research work is carried out on M40 grade concrete to observe the strength appraisals of cubes 15cm*15cm*15cm and cylinders 15cm dia*30cm height casted in laboratory with partial replacement i.e. 15%,30% and 45% of cement with Fly ash, ggbs and Metakaolin. For this work, the samples (one set of sample means 3 specimens) casted and tested for 7 days and 28 days respectively.

The following tests are performed on specimens as:

A. Compressive strength test

The compression test is carried out on3 specimens of cubes size 15cm*15cm*15cm at 7 &28 days curing age as per specifications of IS 516-1969.

B. Split tensile test

The split tensile strength test is carried out on 3 cylindrical specimens of size 15cm dia*30cm height at 7 &28 days curing age and are tested in accordance with IS:5816-1970

C. Mix Design

The mix design adopted for M40 concrete is as Per IS :10262:2009 and obtained proportion is cement:M sand:Coarse aggregate is 1:1.98:2.79 and water - cement ratio kept as 0.46 with Super Plasticizer(Master rheobuild920SH-naptha formaldehyde) dose is 1.2% weight of binder.

D. Concrete Mixes

The different type of concrete mixes with proportion are tabulated below:

Mix	Proportion
C1(conventional mix)	100%opc+M sand+coarse aggregate
M1	85%opc+15%admixtures(5%Each)+M -sand+coarse aggregate
M2	70%opc+30%admixtures(5%Each)+M -sand+coarse aggregate
M3	55%opc+45%admixtures(5%Each)+M-sand+coarse aggregate

IV. TEST RESULTS

Table-I : Cube and cylindrical strength values of various mixes

Mix	Cube strength(MPa)		cylinder strength(MPa)	
	7 days	28 days	7 days	28 days
C1	36.04	50.73	2.32	3.29
M1	37.92	51.42	2.74	3.61
M2	38.91	53.45	3.04	3.74
M3	39.31	56.41	3.29	4.06

A. Compressive Strength

The compressive strength of cubical specimens of four mixes at 7 days and 28days age are shown graphically in Fig.1

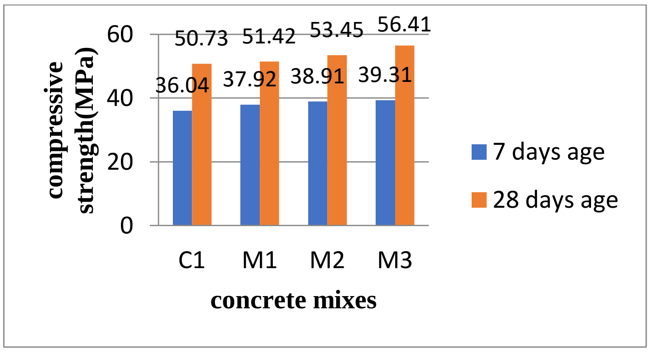

Fig.1

B. split tensile strength:

The split tensile strength of cylindrical specimens of four mixes at 7 days and 28 days are shown graphically in Fig 2.

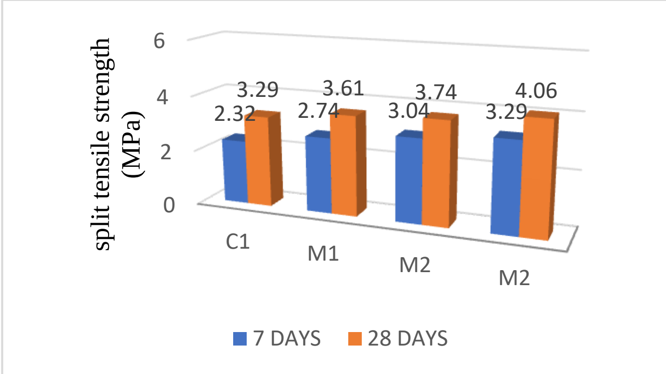

Fig.2

V. DISCUSSIONS

A. As compare the Conventional concrete mix(C1),with raise in Fly ash, GGBS and Metakaolin content in the mixes(M1,M2,M3) compressive Strength is increases by 5.21%,7.96% and 9.07 %for 7 days respectively.

B. As Compare the Conventional concrete mix(C1),with raise in Fly ash, GGBS and Metakaolin content in the mixes(M1,M2,M3) compressive Strength is increases by 1.36%,5.36% and 11.19% for 28 days respectively.

C. As Compare the Conventional concrete mix(C1),with raise in Fly ash, GGBS and Metakaolin content in the mixes(M1,M2,M3)split tensile Strength is increases by 18.10%,31.03%, 41.81% for7 days respectively.

D. As Compare the Conventional concrete mix(C1),with raise in Fly ash, GGBS and Metakaolin content in the mixes(M1,M2,M3)split tensile strength is increases by 9.72%,13.67% ,23.40% for 28 days respectively.

VI. CONCLUSION

A. workability of concrete decreases with addition of M-sand but it can be achieved by addition of super plasticizers.

B. From the past researches and with observed test results in this study ,the cube and cylinder strength values are increased with M-sand and with increase in content of mineral admixtures when compared with river sand and mineral admixtures.

C. Use of M-sand ,Flyash, GGBS and Metakaolin in concrete reduces usage of Cement ,solve the industrial waste disposal problems and prevent environmental problems.

D. Procuring M40 grade of concrete with M-sand and mineral admixtures is lesser when compared with concrete made up of river sand and mineral admixtures.

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Dr.N.Sanjeev[1] He is a master of structural Engineering program and obtained his masters degree in management(M.B.A) in 1996 and Doctorial degree in 2003 from Andhra University,vishakapatnam.He has started his career with central warehouse corporation as a sub divisional engineer in 1983.Later he joined military engineering services as an Indian defence service of engineers in 1996 and continued up to 2005.Later he has served engineering colleges for 10yrs in the capacity of professor and Indian private construction industry for 6yrs.His research areas include geopolymer concrete, Basalt fibre reinforced high volume flyash and pavements.

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STUDIES ON THE BEHAVIOUR OF SULPHATE ATTACK RESISTANCE OF LOW CALCIUM FLY ASH AND SLAG BASED GEOPOLYMER CONCRETE

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ABSTRACT

This paper presents an experimental result on the behavior of fly ash and slag based geopolymer concrete exposed to 5% sulphate solutions for 3.5 months of G30 and G50 which are equivalent to M30 and M50 grades respectively. The test specimens were cast and after one day rest period, half of the specimens were cured in an oven at 60°C for 24 hours and the remaining period cured in sun light until the testing is done and remaining half of the specimens were ambient cured. After 28 days the specimens were immersed in sulphates such as Na_2SO_4 and $MgSO_4$ for 15, 45, 75 and 105 days then tested on 15^{th,} 45th, 75th and 105th day according to codal procedures and the results are compared with the controlled concrete. From the test results, it is observed that the geopolymer concrete has better resistance to sulphates attack than controlled concrete.

Keywords: Fly Ash, Geopolymer Concrete, GGBS, Oven Curing, Sulphate Attack

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1. INTRODUCTION

Geopolymer is an inorganic polymer. Joseph Davidovits in 1979 proposed that an alkaline liquid could be used to react with silicon (Si) and aluminum (Al) as source material of geological origin or with byproduct materials such as fly ash, GGBS and rice husk ash etc; to produce binders. Since the chemical reaction that is taking place in this case is a polymerization process and the precursors are of geological origin, these binders were named as 'Geopolymer'

2. MATERIALS

2.1. Ordinary Portland Cement

The cement thus procured was tested for physical properties in accordance with the IS: 4031-1968 and found to be conforming various specifications of IS 12629-1987.

2.2. Fine Aggregate

The physical properties of fine aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS: 2386. Grain size distribution of sand shows it is close to Zone II of IS 383-1970.

2.3. Coarse Aggregate

The crushed angular aggregate of 20mm maximum size obtained from the local crushing plants is used as coarse aggregate in the present study. The physical properties of coarse aggregate such as specific gravity, bulk density, flakiness and elongation index are tested in accordance with IS: 2386-1963.

2.4. Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBS) is a by-product of the steel industry. About 15% by mass of binders was replaced with GGBS.

2.5. Water

Water free from chemicals, oils and other forms of impurities is to be used for mixing of concrete as per IS: 456:2000.

2.6. Constituents of Geopolymer

2.6.1. Source Materials

Any material that contains mostly Silicon (Si) and Aluminium (Al) in amorphous form is a possible source material for the manufacture of geopolymer. Several minerals and industrial by-product materials have been investigated in the past. Low calcium fly ash (ASTM Class F) is preferred as a source material than high calcium (ASTM Class C) fly ash.

2.6.2. Alkaline Activators

The most common alkaline activator used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).

2.7. Superplasticiser

High range water reducing super plasticizer PCE based (Master Glenium B233) for G50 and Naphthalene based for G30 was used in the mixtures at the rate of 1.5% and 1% by weight of fly ash respectively to improve the workability.

3. EXPERIMENTAL INVESTIGATION

3.1. General

This paper presents experimental results on the behavior of fly ash and slag based geopolymer concrete exposed to 5% sulphate solutions for up to 3 months of G30 and G50 which are equivalent to M30 and M50 grades respectively. The alkaline solution used for the present study is combination of sodium silicate (Na_2Sio_3) and sodium hydroxide. The ratio of Na_2SiO_3 to NaOH is 2.5 and SiO_2 to Na_2O is 2.09 has been used since the compressive strength is maximum at these ratios. In case of geopolymer concrete the cubes of size 100mm×100mm×100mm were cast and after one day rest period, half of the specimens were cured in an oven at 60°C (OC) for 24 hours and the remaining period cured in sun light until the specimens immersed in sulphates and remaining half of the specimens were ambient cured (AC) and in controlled concrete conventional method is adopted for preparing the same size of cubes and kept under water for curing (NC). After 28 days the specimens were immersed in sulphates such as Na_2SO_4 and $MgSO_4$ for 15, 45, 75 and 105 days then the sulphate attack resistance in terms of loss of compressive strengths and loss of weights of various grades of controlled and geopolymer concrete exposed to 5% concentrations of Na_2SO_4 and $MgSO_4$ sulphates. Acid Durability Factors (ADFs) and Acid Attack Factors (AAFs) of controlled and geopolymer concrete exposed to 5% concentrations of various sulphates are also evaluated to determine their resistance to sulphate attack and the obtained results have been studied and compared**.**

3.2. Mixing and Casting of Geopolymer Concrete

Geopolymer concrete can be manufactured by adopting the conventional concrete techniques used in the manufacture of Portland cement concrete. In the laboratory, the fly ash and the aggregates were first mixed together dry in a pan mixer for about three minutes. The alkaline liquid was mixed with the super plasticizer and extra water if any. The liquid component of the mixture was then added to the dry material and the mixing continued usually for another four minutes. The fresh concrete was cast and compacted by the usual methods used in the case of Portland cement concrete. The workability of the fresh concrete was measured by means of the conventional slump test.

4. TEST RESULTS

4.1. Weight Loss and Residual Compressive Strength

The loss of weight and compressive strength of controlled and geopolymer concrete in percentage when it is exposed to 5% concentration of Na2SO4 and $MgSO_4$ solutions for various curing methods are given in Figs 1 to 4**.**

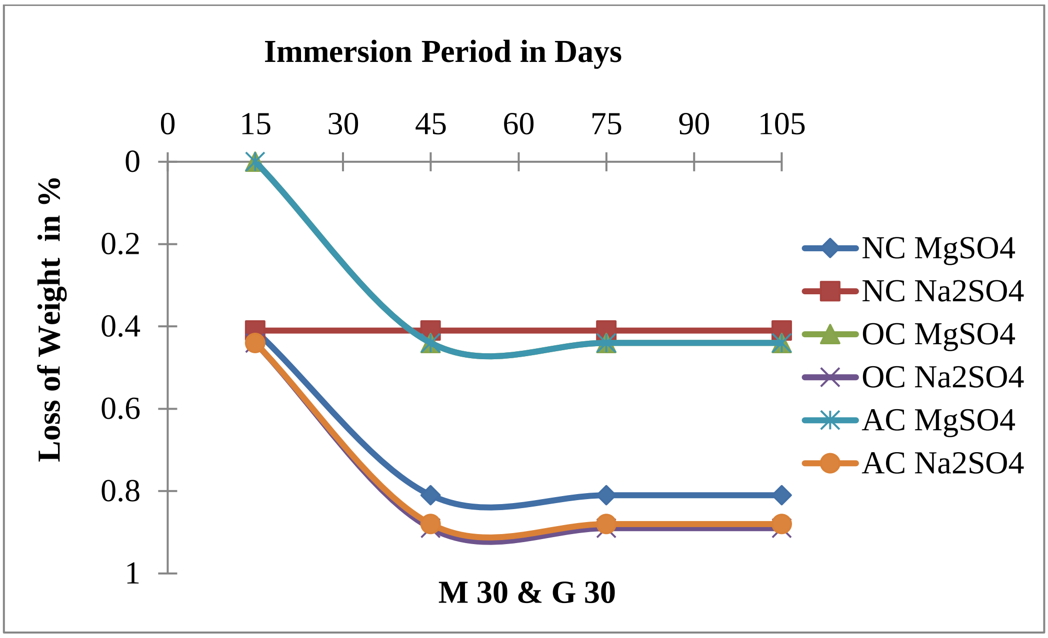

Figure 1 Weight Loss in Percentage of Controlled (M30) & Geopolymer Concrete (G30) when immersed in 5% concentrations of various Sulphates and Curing methods

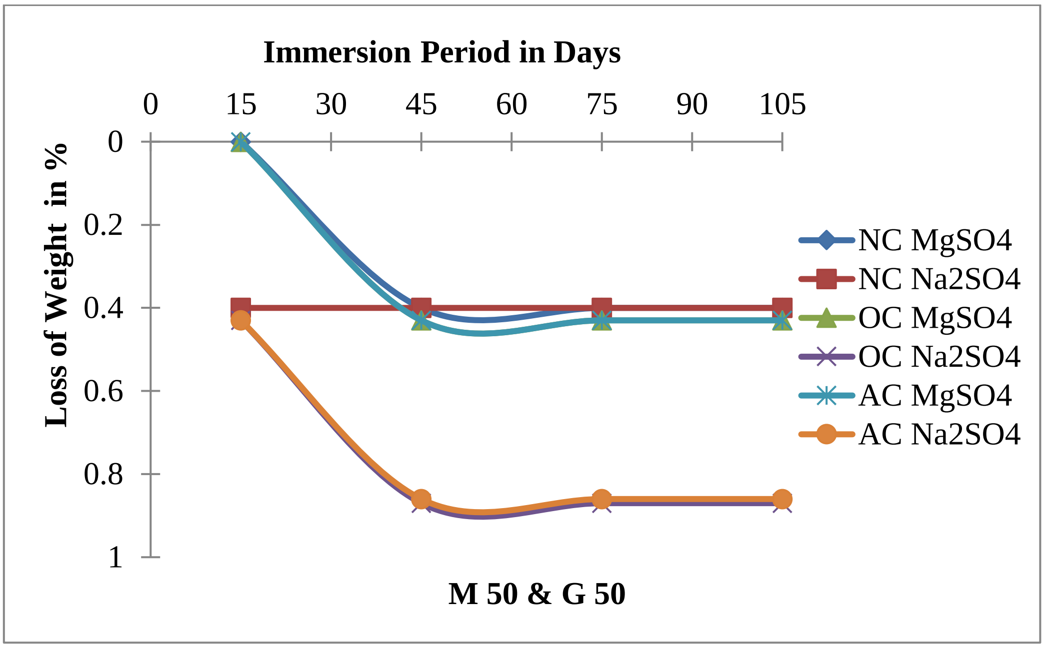

Figure 2 Weight Loss in Percentage of M50 & G50 when immersed in 5% concentrations of various Sulphates and Curing methods

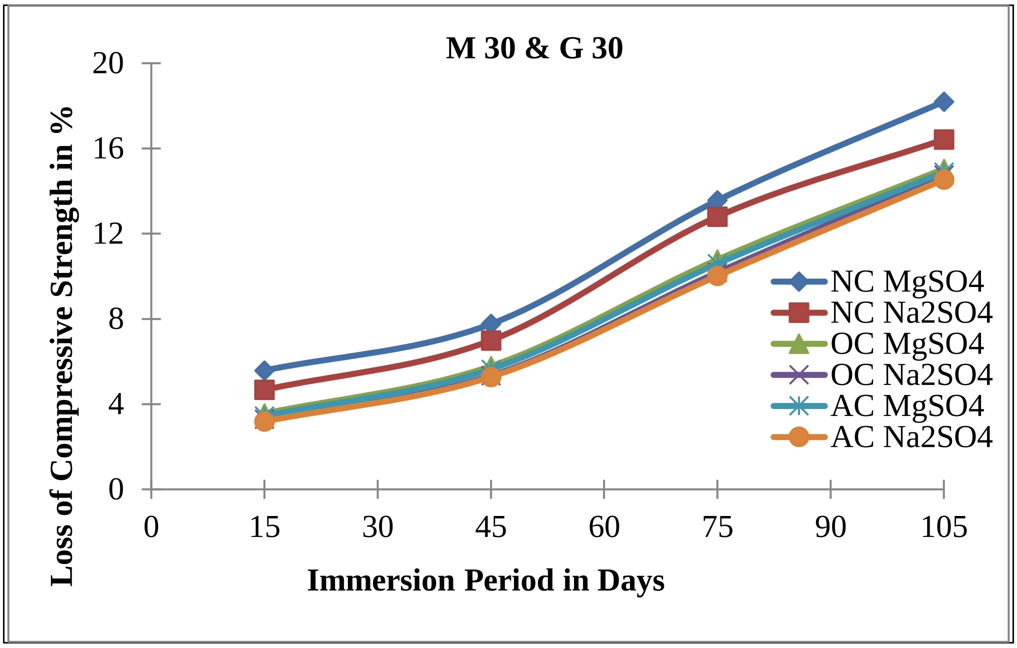

Figure 3 Compressive Strength Loss in Percentage of M30 & G30 when immersed in 5% concentrations of various Sulphates and Curing methods

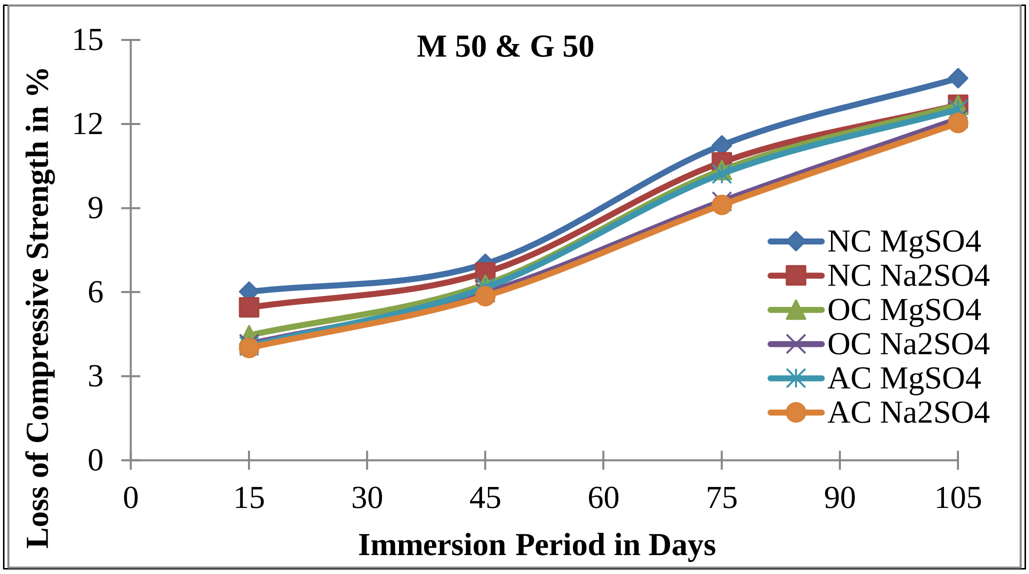

Figure 4 Compressive Strength Loss in Percentage of M50 & G50 when immersed in 5% concentrations of various Sulphates and Curing methods

4.2. Acid Durability Factors (ADFs) and Acid Attack Factors (AAFs)

4.2.1. Acid Durability Factors

The “Acid Durability Factors” (ADFs) can be designed as follows.

ADF = Sr (N/M)

where, Sr = relative strength at N days, (%)

N = number of days at which the durability factor is needed

M = number of days at which the exposure is to be terminated

Acid attack test was terminated at 105 days. So, M is 105 in this case

4.2.2. Acid Attack Factors

The extent of deterioration at each corner of the struck face and the opposite face is measured in terms of the solid diagonals (in mm) for each of the two cubes and the "Acid Attack Factors" (AAFs) per face is calculated as follows.

AAF = (Loss in mm on eight corners of each of 2 cubes) / 4

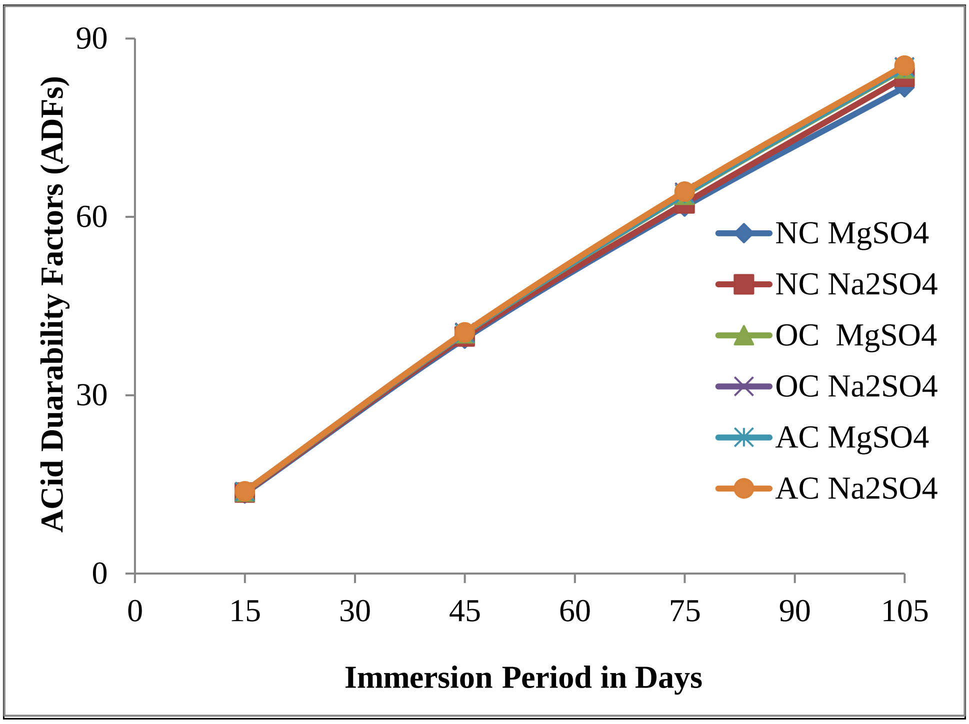

Figure 5 Acid Durability Factors (ADFs) of M30 & G30 when immersed in 5% concentrations of various Sulphates and Curing methods

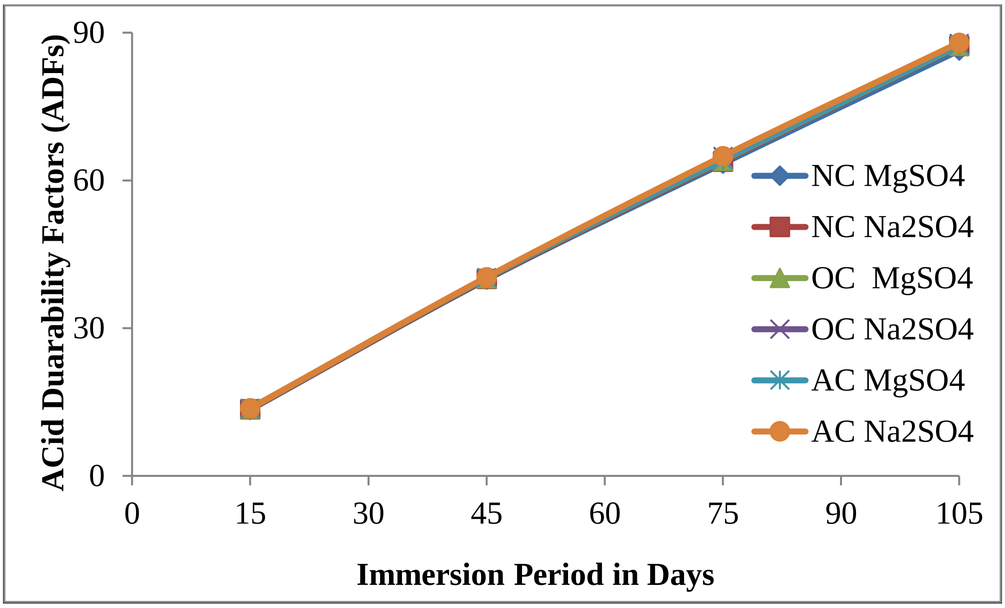

Figure 6 Acid Durability Factors (ADFs) of M50 & G50 when immersed in 5% concentrations of various Sulphates and Curing methods

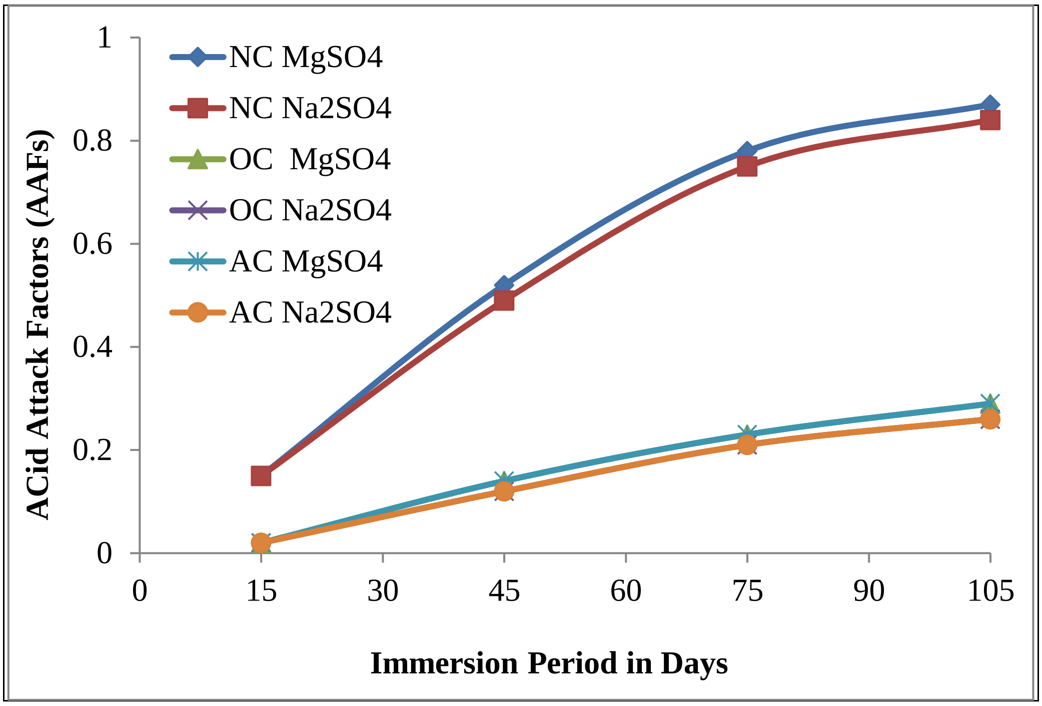

Figure 7 Acid Attack Factors (AAFs) of M30 & G30 when immersed in 5% concentrations of various Sulphates and Curing methods

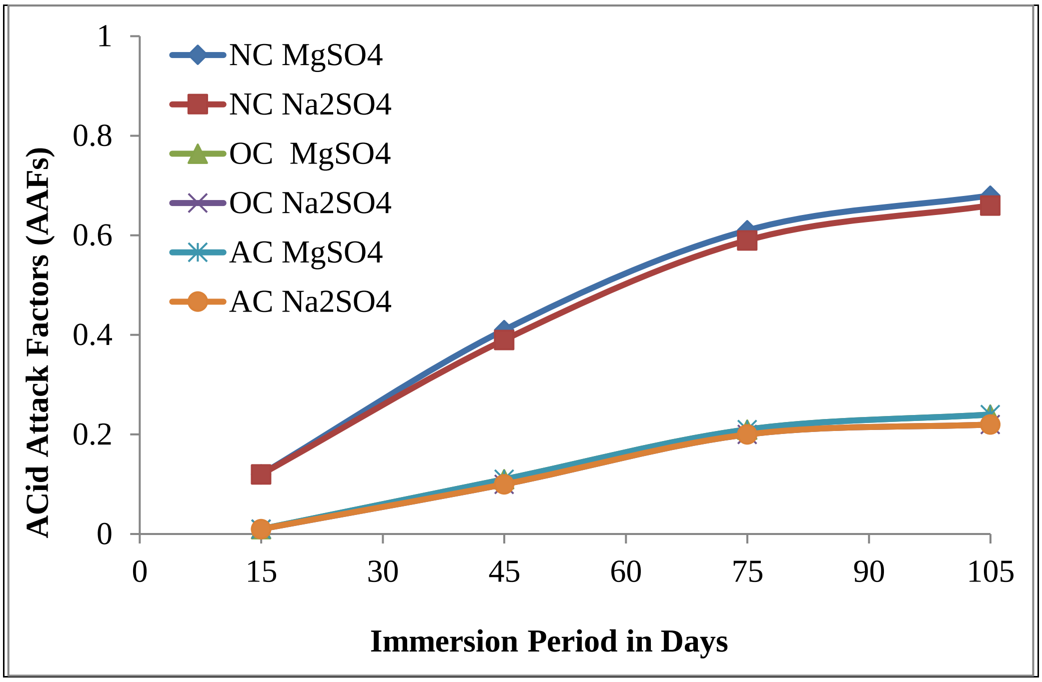

Figure 8 Acid Attack Factors (AAFs) of M50 & G50 when immersed in 5% concentrations of various Sulphates and Curing methods

Figs 5 to 8 shows the Acid Durability Factors (ADFs) and Acid Attack Factors (AAFs) of controlled and geopolymer concrete specimens exposed to 5% concentration of Na2SO4 and $MgSO_4$ solutions for various curing methods. From the graphs it is observed that the Acid Durability Factors (ADFs) increased, whereas the Acid Attack Factors (AAFs) decreased for geopolymer concrete when it is compared with controlled concrete for all the grades and in both the sulphate solutions such as Na_2SO_4 and $MgSO_4$.

5. CONCLUSIONS

1. The following specific conclusions can be drawn from the present experimental investigation
2. When the specimens are exposed to magnesium and sodium sulphates, the percentage loss of compressive strength and weights are increased as the immersion period increases for all the grades of controlled and geopolymer concrete.
3. The original compressive strength of M30 and M50 is 38.62MPa and 58.42MPa respectively then it lost by 4.67 to 16.42%, whereas in geopolymer concrete which is originally 38.45MPa and 59.75MPa lost by 3.19 to 12.03% when it is exposed to sodium sulphate for a period of 15 days to 105 days.
4. The loss of compressive strength of controlled concrete specimens when exposed to magnesium sulphate is in the range of 5.58 to 18.2%, where as it is about 3.44 to 12.52% in case of geopolymer concrete. Thus, geopolymer concrete is more resistant than controlled concrete.
5. The loss of weight of controlled concrete specimens when exposed to sodium and magnesium sulphates is more than that of geopolymer concrete. Therefore, it can be said that geopolymer concrete has more dimension stability than controlled concrete.
6. It can be inferred that geopolymer concrete is more durable in terms of 'Acid Durability Factors' and is less attacked in terms of 'Acid Attack Factors' than controlled concrete at all the ages for all grades and can perform better in severe aggressive environments due to its high impermeability and alkalinity of concrete mass.
7. It can be concluded that the magnesium sulphate environment is more severe than sodium sulphate, since the strength & weight loss are more and also the specimens received white deposits on the surfaces which gradually transformed from soft and flaky shape to hard and rounded shape during exposure to magnesium sulphate compared to sodium sulphate solution.
8. It is observed that the loss of compressive strengths and weights are decreased as the grade of concrete is increased in both controlled and geopolymer concrete.

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[14] Experimental Study on Coir Fibre Reinforced Flyash Based Geopolymer Concrete With 12m & 10m Molar Activator

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[16] Experimental Study on Plastic Fiber Reinforced Flyash Based Geopolymer Concrete

Seismic Effect on Design of Residential Multi-Storey Building (Stilt+17 Floors) In Zone-Iii and Zone-Iv using Etabs

T.srinivas, M.Abinay raj

Abstract*: : Structural Analysis is a branch which involves in the determination of behaviour of structures so as to predict the responses of different structural components due to impact of loads. ETABS (Extended 3 Dimensional Analysis of Building Systems) is a software which is incorporated with all the major analysis engines that are static, dynamic, linear and non-linear etc. The main purpose of this paper is to design Multi-storeyed building with a static method, since an effective design and construction of earthquake resistant structures are important all over the world. This project deals with seismic effect on "analysis, design and comparison of multi-storey residential building of stilt+17 floors in zone-iii and zone-iv using ETABS". It is an attempt to study the behaviour of a residential building using ETABS in different zones and areas with same soil bearing capacity. Analysis and design has been carried out as per IS1843-2002 (Part-1) and IS 456:2000. The more drifts and displacements have been noticed in zone 4 compared to zone 3.
Keywords: ETABS, static method, base shear, storey drifts, Diaphragm, storey stiffness

I. INTRODUCTION

ETABS is the present day leading design software in the market. Many design company's use this software for their project design purpose. So, this paper mainly deals with the comparative analysis of the results of zone-iii and zone-iv with same medium soil in both the zones. In this case, a 19.3 m x 22.6m, Stilt+17 storey structure is modelled using ETABS software. The height of each storey is taken as 3meter making the total height of the structure 57meter. Analysis of the structure is done and then the results generated by this software are compared in between zone-3 and zone-4 of the structure using IS 1893:2002.so why i have chosen this project is As our country is that the quickest growing country across the world that the need of shelter for highly inhabited cities like Mumbai and Delhi (the capital) which lies under zone-iii and zone-4 respectively.

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wherever the price of land is high and any horizontal growth isn't possible because of inaccessibility of area, so we the engineers taken a step forward and build buildings vertically After an earthquake happens it causes nice harm because of seismic motion when the peak of building is increased the wind load result conjointly acts on building. Structures are designed to resist these unforeseen forces and may have decent stiffness and strength to manage displacement at supports. Even the arrange configuration of building depends upon however the structure reacts on loading. For symmetrical building the deformation is lesser compared to a unsymmetrical arrange of columns and beam. So the first point we consider is the building should be symmetric Here a neighbourhood of structure is taken into account and also the centre line diagram is computed from AUTOCAD to ETABS. Then a model is been ready in ETABS The analysis of this structure is finished to match the bottom reactions once loading happens and deformation of various beams is observed. and compared the building in zone-iii and zone-iv with all the parameters like storey shear ,storey stiffness ,shear force and bending moments base shear and storey drifts are taken for seismic analysis according to Indian standards rules and regulations.

II. MODELING

Generally building consists of beams, columns and slabs for multi storey building we consider
shear wall including with columns due to heavy load
Modelling in 3D view in ETABS and centre line drawing

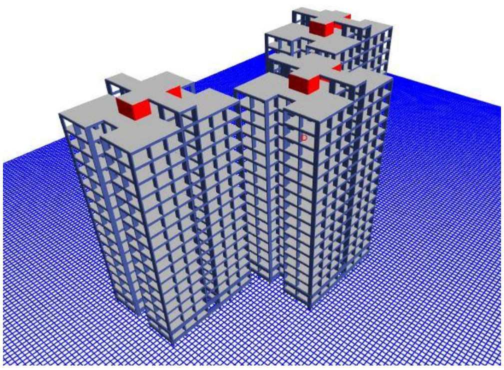

Fig no: 1 3D model in EATABS

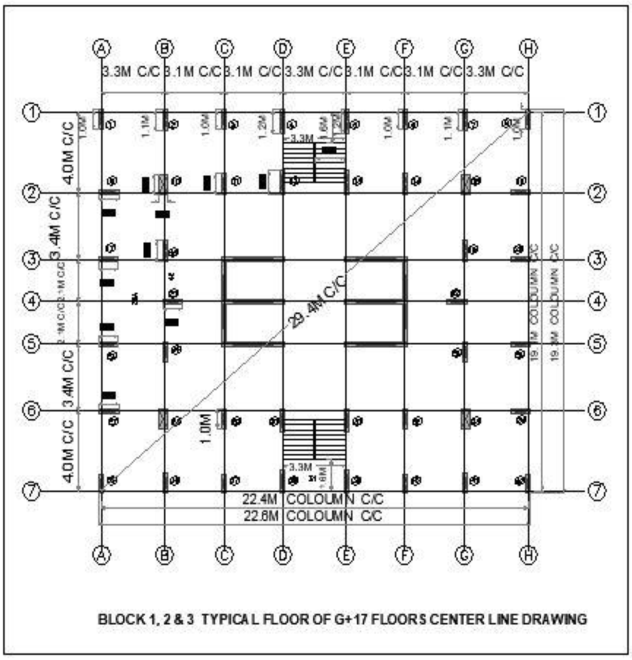

Fig no: 2 Centre line diagram of the building

Dimensions and centre line drawing is must for the execution of the building and analysis of the building in ETABS this values are taken form trial and error based theory. grades of concrete ,steel(rebar) and IS- codes are taken this are shown in table 1

table 1 general dimensions of the building

Sl. no	Specifications	NOTATION	Values
1.	Slab thickness	S1 S2	150mm 150mm
2.	Beam dimensions	B1 B2	300x750mm 230x750mm
3.	Column dimensions	C1 C2 C3	300x1000mm 300x1200mm 500x1000mm
4.	Shear wall	W1	300mm
5.	Block 1 Block 2 Block 3	22.6x19.3m 22.6x19.3m 22.6x19.3m	
6.	Building height	57m	
7.	No of storey's	STILT+17	
8.	Steel	Fe500D	
9.	Concrete	M35,M30,M25	
10.	Standards Seismic loads Load combinations	IS-CODE IS: 1893:200 IS:8751987 PART 3	
11.	Software Used	ETABS-2016,AUTOCAD-2014	

Seismic loads - Seismic zone: III (Z=0.16), Soil type: II, Importance factor: 1, Response Reduction factor: 3, in MumbaiSeismic loads - Seismic zone: IV (Z=0.24), Soil type: II, Importance factor: 1, Response Reduction factor: 3, in Delhi

Ultimate load combinations

1. 1.5(dead load +impose load)
2. 1.2(dead load +impose load ± earthquake load)
3. 1.5(dead load ±earthquake load)
4. 0.9 load ±1.5 earthquake load)

Services load combinations

1. load + impose load
2. load ± earthquake load
3. load +0.8 impose load ±0.8 earthquake load

III. RESULT AND DISCUSSION

We have different results for seismic in ETABS

3.1 Response plots

1) Storey drifts
2) Storey stiffness
3) Base shear

3.1.1 STOREY DRIFTS:-

"It is the displacement of storey with respected to the other storey"

Where in storey drifts we consider for earthquake loads that is EQ-X direction and EQ-Y direction from both

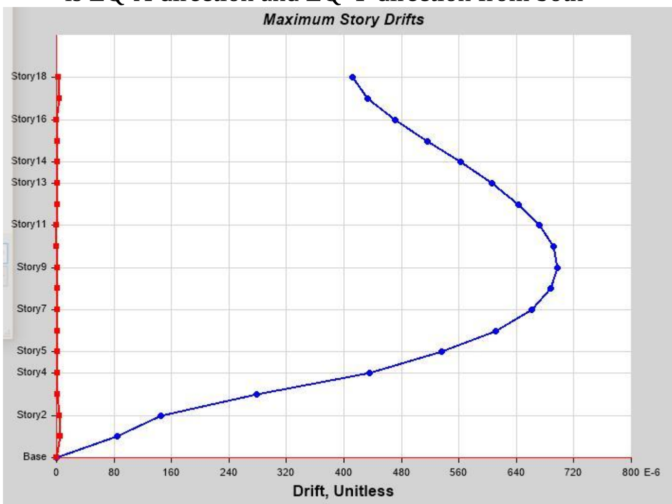

Fig no 3- Storey Drifts - ZONE III

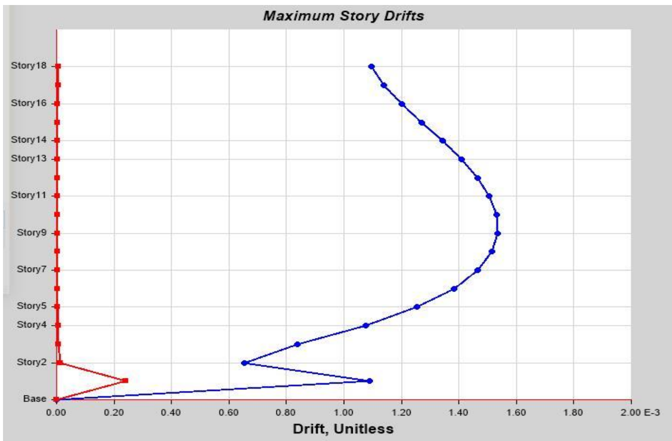

Fig no 4- Storey Drifts - ZONE IV

Storey drifts are high for zone 3 we can see in the images the 9th story have more displaced in both the cases where 0.000155 on 9th storey on zone -4 and 0.000697 on 9th storey that means we have more drift values in zone 3 .the drift limit according to the code IS:1893:2002 (PART 1) For seismic loads (0.01H) where H is height of the building and coming to our problem 0.01x57 that is 0.57 we did not cross the limit and our problem is safe .We have less in storey one more in top because of lateral loads and the design will change according to it and we can see the first floor is more displaced because of lateral forces at that storey one are high we can also see the values in tabular form given below

Table 2 storey drifts along x direction

			ZONE-III	ZONE-IV
Storey	**Elevation M**	**Location**	**X-Dir mm**	**X-Dir mm**
Base	**0**	**Top**	**0**	**0**
Storey1	**3**	**Top**	**0.000120**	**0.00109**
Storey2	**6**	**Top**	**0.000145**	**0.000652**
Storey3	**9**	**Top**	**0.000278**	**0.000842**
Storey4	**12**	**Top**	**0.000436**	**0.001076**
Storey9	**15**	**Top**	**0.000697**	**0.001554**

we can also see in tabular form at zone 3 we have more displacements at storey 1 and 2 because lateral forces and vibrations due to earthquake or seismic frequencies so the design will change according to the area

3.1.2. STOREY STIFFNES

comparison between zone-iii and zone-iv at earthquake-x axis in graph form for storey stiffness

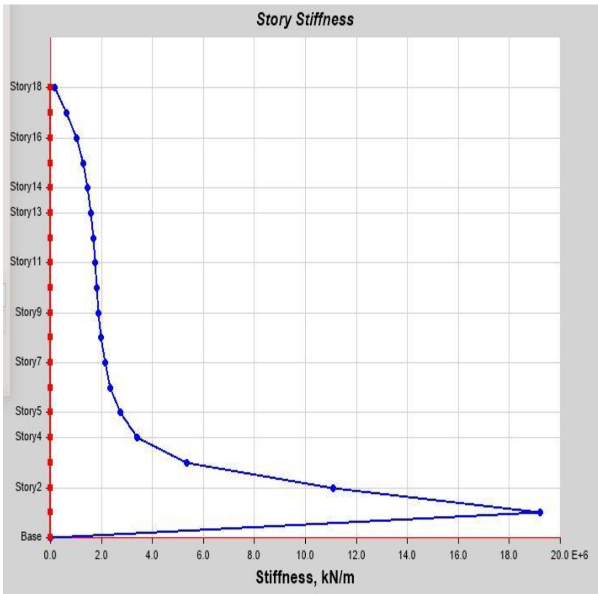

Fig -5 Storey stiffness x axis- zone iii

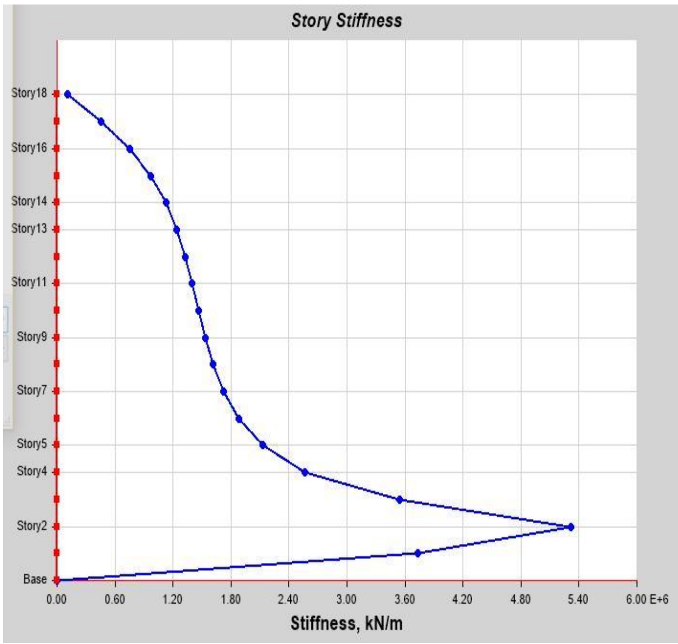

Fig -6 Storey stiffness- x axis- zone- iv

Comparison between zone- iii and zone-iv at earthquake-x axis in tabular form for storey stiffness

Table :3 storey stiffness x axis zone III

			ZONE-III	ZONE-IV	
Storey	**Elevation M**	**Location**	**X-Dir mm**	**X-Dir mm**	**% drop**
Base	**0**	**Top**	**0**	**0**	**0**
Storey 1	**3**	**Top**	**19200213.566**	**3729467.288**	**80.575**
Storey 2	**6**	**Top**	**11080862.271**	**5321393.635**	**51.976**
Storey 3	**9**	**Top**	**5344721.736**	**3542509.962**	**33.719**
Storey 17	**51**	**Top**	**633860.504**	**459894.151**	**27.445**
Storey 18	**54**	**Top**	**158231.849**	**113452.918**	**28.299**

From the above table we can see the difference between zone III and zone IV .zone III has more Stiffness than zone IV that is 19200213.566 in zone-3 and zone-4 as 3729467.288 it as decreed to 80% in zone III the more stiffness as we have more problem at storey one and as the storey's are increasing stiffness value is decreasing we have less storey in 17th storey because of head room so we can conclude that storey one at the bottom as more stiffness and we have to change the design and have tough reinforcement in storey 1 compare to each storey

3.1.3 BASE SHEAR

Comparison between base shear plotting in ETABS for zone iii and zone iv in x direction

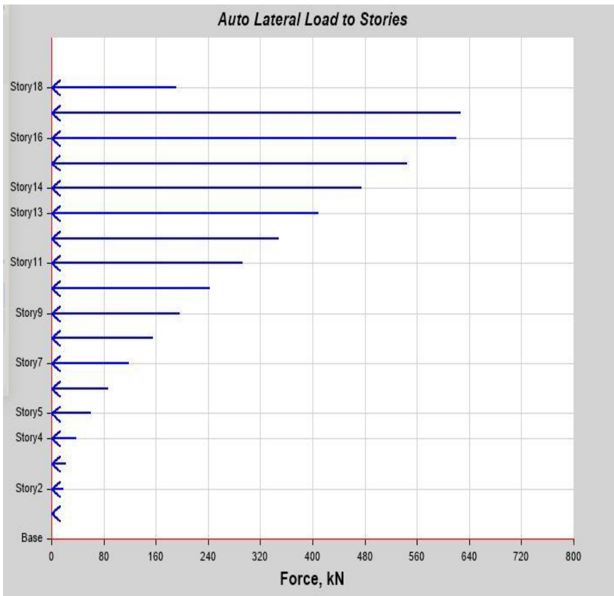

Fig -7 Shows ZONE III of base shear

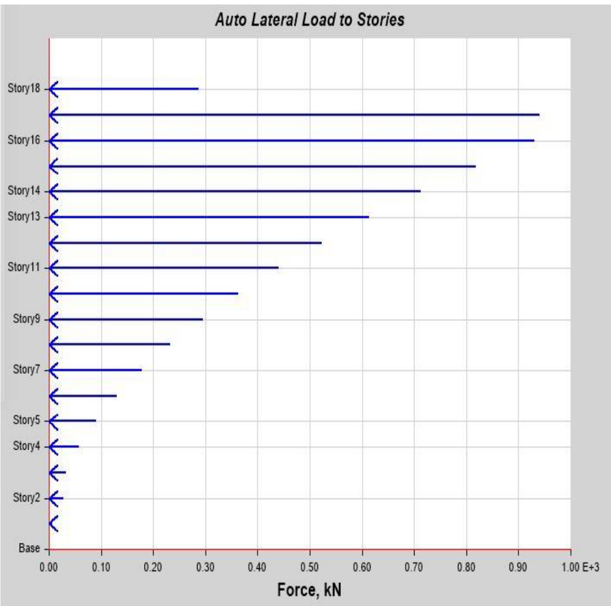

Fig -8 Shows ZONE III of base shear

Table :4 Base Shear- X- axis in zone III and zone IV

			ZONE - III	ZONE- IV	% Gain
Storey	Elevation m	Location	X-Dir mm	X-Dir mm	
Base	0	Top	0	0	0
Storey 1	3	Top	4.74	7.12	50
Storey 16	48	Top	620.6	930.99	50
Storey 17	51	Top	626.9	940.36	50
Storey 18	54	Top	191.2	286.94	50

We can see the base shear results for this building in x direction zone 4 has more shears we gain 50% because of more earthquake at zone 4 the values are less at storey one and we can see at the storey 18 has less because of head room of lift and head room of staircase so we get less shear in that place the values are given above in Tabular form because of less space I have shown only the critical sections and we can see the graph for more details. We can see the difference by calculating the base shear in manual by the code IS:1897:2002 (part1) By substituting in the formulas by calculating loads we got base shear in zone 4vb=13348.0312 In zone 3 and vb=20026.0843 we have a difference of 6678.0531. According to the results we have to Change The rebar sections and placement of three blocks because of less gap between the buildings can also change the displacement Comparison of the building of base shear of the building is done in ETABS it shown in graph and tabular representation

IV. CONCLUSION

1) It is observed that the support reactions have got maximum values in zone-4 than zone-3 due to forces and moments.
2) It is noticed that the drift in zone-4 has higher values when it is compared to the drift values in zone-3.
3) The storey drift is increased from top storey to bottom storey in both zone - 3 and zone - 4. At storey1, the drift is maximum as compared to other stories.
4) Zone-4 has more intensity of seismic wave's effect as compare to zone 3, because of less space between the blocks.
5) It is found that base shear values are more in zone-4 than zone -3 due to more earthquake forces. It is having 50% more displacement in 17^{th} floor compare to storey one.

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Sulphate attack Resistance of Geo-polymer Concrete made with Partial Replacement of Coarse Aggregate by Recycled Coarse Aggregate

T. Srinivas, R. N. Koushik

Abstract: ***The primary intent of this paper is to study replacement of coarse aggregate with RCA of M40 grade concrete in different proportions such as 0%,10%, 20%, 30% and 40% and also to collate the results of geo-polymer concrete made with recycled coarse aggregates(GPCRCA) with geo-polymer concrete of natural coarse aggregate(GPCNA) and controlled concrete of respective grade. Geo-polymer concrete (GPC) is observed to be more resistant towards sulphate attack, with both in (CA) and (RCA) to a replacement of 30%, when it is compared with the similar grade of controlled concrete(CC). The durability of the concrete cubes are analyzed by immersing in 5% concentration solutions for a time period of 15, 45,75 and 105 days, The change of weight and compressive strength towards resistance is evaluated . Results stipulated that Geo-polymer concrete is highly resistant to Sodium sulphate and Magnesium sulphate.***

Keywords: ***Geo-polymer Concrete, Recycled Aggregate, Alkaline Solutions, Controlled concrete Sodium sulphate and Magnesium sulphate***.

I. INTRODUCTION

Portland cement is the leading material for manufacturing of concrete around the world, an demand of over 1.5 billion tons is fulfilled annually. However, the Portland cement production is energy-intensive it also releases a notable volume of (CO_2) to the atmosphere. Thus, the development of geo-polymer concrete can play a very vital role in the context of sustainability and environmental issues. Geo-polymer binders can offer a similar performance to conventional cementitious binders in a range of applications and also reduce greenhouse gas emissions. The availablity of geo-polymers depends on materials factors such as availability, price, specific demand of user . Microstructure and properties of geo-polymers rely strongly on the character of the initial raw materials although the microscopic characteristics of alumino-silicate primarily based geo-polymers might seem similar. Using the coarse aggregate that is recycled from (C&D) waste, that reflects within the environment and economic benefit.

Durability of concrete is that the most essential property that evaluates the life of concrete. Exposure of concrete with external environment is one among the numerous factors that indicate the durability of concrete. There are several chemical attacks like acid attack, alkali attack etc. The extent of decay throughout sulphate attack of concrete rely on the chemical nature of anions present within it. Type of aggregate and concrete additionally influence the intensiveness of sulphate attack. Although OPC is that the wide used binder in the construction industry, the resistance for chemical attacks in sulphates is a major factor. When cement composites are extensively damaged by sulphates where as Ca(OH)2 is dissolved and the hydrated silicate and aluminium phases are decayed. In the past several few years geo-polymer binders have emerged together of the conceivable chance to OPC binders as a result of their resistance against sulphate attack

II. MATERIALS

A. *Ordinary Portland Cement*

The 53-grade of ordinary Portland cement is utilized and procured was tested in accordance for physical properties with the IS: 4031-1968 and ascertained to be conforming the numerous specifications of IS 12629-2009.

B. *Fine Aggregate(FA)*

In this, FA utilized is procured from local sources. The sand utilized is free away from clay matter, organic impurities silt and silt. The physical properties of fine aggregate like specific gravity, bulk density, gradation & fineness modulus were tested in accordance with IS: 2386. The sand is confirmed of Zone-II of IS 383-1970.

C. *Coarse Aggregate*

The angular crushed aggregate with maximum size of 20mm procured from the M.V crushing plant is utilizes in the present study. The aggregate particle size of 20mm is taken for this experimental setup. Properties of coarse aggregate are tested in accordance with IS: 2386-1963.The specific gravity of coarse aggregate is found to be 2.63.

D. *Fly Ash*

In this work, the low calcium Class F-fly ash is utilised, which is procured from Vijayawada thermal power station , Andhra Pradesh.

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E. *Ground Granulated Blast Furnace Slag*

GGBS is a by-product of the steel industry. GGBS comprises basically of calcium silicates and different bases in molten condition developed simultaneously with Fe in a blast furnace.

F. *Recycled Coarse Aggregate (RCA)*

RCA of C&D waste is gathered and it is a better replacement for Natural coarse aggregate NCA which is up to 40 percent of all waste generated worldwide. RCA and NCA are taken at a proportion of 40% and 60% for this study to validate cube strength, Split tensile strength, and flexural strength. By adding recycled coarse aggregate (RCA) it reduces foot print on environment by improving sustainable development. The strength of ordinary Portland cement concrete OPCC utilizing RCA depends greatly on the percentage of recycled aggregate used. Utilizing recycled aggregate can result in less mineral depletion

G. *Water*

Water free away from chemicals, other forms of impurities , oils are utilized for mixing of concrete as per IS: 456:2000.

H. *Sodium Hydroxide*

$Na(OH)_2$is one of the major ingredients of geo-polymer concrete which is most commonly used as an alkaline activator for geo polymerization. The following are the specifications of Sodium hydroxide and this material is procured from the local laboratory chemical vendors in Hyderabad. The physical appearance of sodium hydroxide pellets are in white solids Specifications are tabulated in table1 as given by the suppliers.

Table 1: Shows Physical properties of NaOH

Molar mass	40 gm/mol
Appearance	White solid
Density	2.1 gr/cc
Melting point	318^0c
Boiling point	1390°C
Amount of heat liberated when dissolved in water	266 cal/gr

I. *Sodium Silicate Solution*

Sodium silicate solution is a alkaline liquid participates a significant role as an activator in the geo-polymerisation process, it also reduces porosity. If excess amount of $Ca(OH)_2$ is present in concrete then it binds with surface thereby increasing durability and water resistance. This material is procured from the local laboratory chemical vendors in Hyderabad. Specifications are tabulated in table 2 as given by the suppliers.

Table 2: Properties of Na2SiO3 Solution

Specific gravity	1.57
Molar mass	123.06 gm/mol
Na_2O (by mass)	15.35%
SiO_2 (by mass)	30.00%
Water (by mass)	56.00%
Weight ratio (SiO_2 to Na_2O)	2.09
Molarity ratio	0.98

J. *Super Plasticizer*

Super plasticizer (MasterRheobuild920SH) was used as water reducing admixture, it increases workability. It is added in 1.5% to the binder.

K. *Table 3: Physical properties of Super plasticizer*

L. *State*	M. *Liquid*
N. *Colour*	O. *Dark Brown*
P. *Density*	Q. *1.20*
R. *Chloride content*	S. *0.074*
T. *Chemical name*	U. *Naphthalene formaldehyde polymers*
V. *Dry material content*	W. *39.38*
X. *P^H*	Y. *8.40*

III. EXPERIMENTAL INVESTIGATION

A. *General*

The main objective of this paper is to study the Durability properties of geopolymer concrete of grade G40 when natural coarse aggregate is replaced with recycled coarse aggregate in different proportions such as 0%,10%, 20%, 30% and 40% and also to compare the results of geo-polymer concrete made with recycled coarse aggregates with geo-polymer concrete of natural coarse aggregate and controlled concrete of respective grade. The specimens of size 100 mm cubes were casted the specimens were cured at 60°C for a period of 24 hours .

B. *Mixing and Casting of Geo-polymer Concrete*

Geo-polymer concrete is casted by utilizing the similar method which is employed within the conventional concrete. In the laboratory, the fly ash and also the aggregates were mixed along in dry by using a pan mixer for a time of two minutes, then the alkaline liquid was mixed with the super plasticizer and extra water if any required. An alkaline solution of Na(OH)2 &Na_2SiO_3 with molarity 10M are used alkali activators to synthesis the geo-polymer in this study. The alkaline liquid of the mixture was then added to the dry material and the mixing continued usually for additional two minutes. The fresh concrete was casted by the standard ways utilized in the case of conventional concrete. The workability of the fresh concrete was measured by means of the standard slump test.

IV. SULPHATE RESISTANCE

The Sodium sulphate and Magnesium sulphate attack resistance of geo-polymer concrete is evaluated. To carry the sulphate attack resistance test within the present investigation techniques of immersion is adopted. Specimens are immersed in acid solutions after casting and curing.

The concentration of Sodium sulphate and Magnesium sulphate solutions are 5%. The analysis is conducted after period of 15,45,75 and 105days from the date of immersion. Solutions are kept at room temperature. The solution is replaced at regular intervals of 15 days to takecare concentration of solution throughout the test period. The percentage weight loss, percentage cube strength loss is evaluated. The geo-polymer concrete decreases weight .when the sulphate concentration increases and the same effect is reflected after 105 days of immersion in sulphates. The weight of GPC specimen before and after immersion is shown in figure. The cube strength of geo-polymer concrete immersed in Na_2SO_4 and $MgSo_4$ concentrations are evaluated. The comparison of cube strength with Conventional M40 grade concrete is also shown below.

V. TEST RESULTS

The various weights, percentage of weight loss & cube strength loss of controlled concrete with RCA and geo-polymer concrete along with recycled aggregate is calculated at 5% concentration of HCL and H_2SO_4 is as shown below.

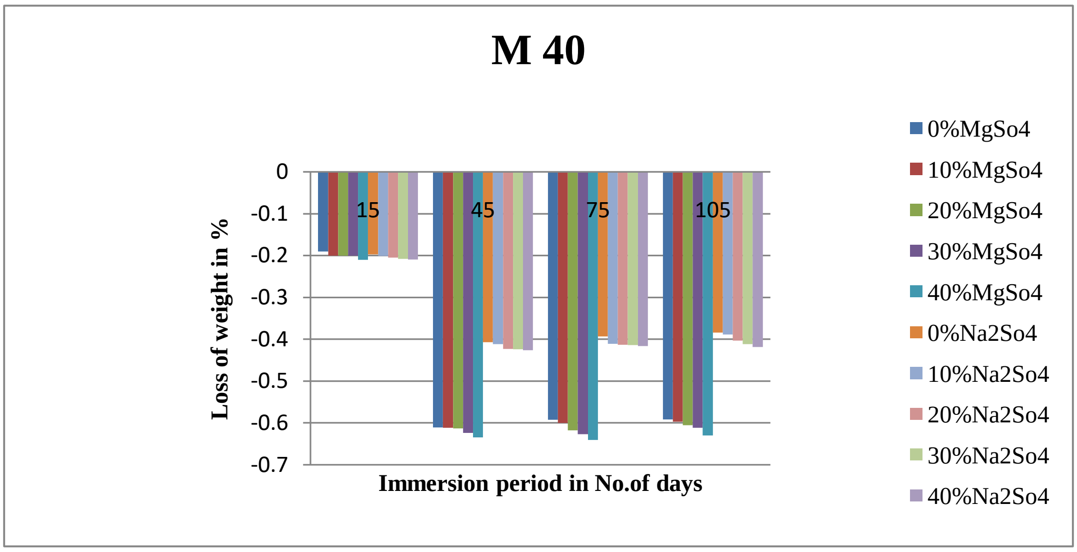

Fig : Percentage weight loss in controlled concrete (M40) when immersed in 5% concentration

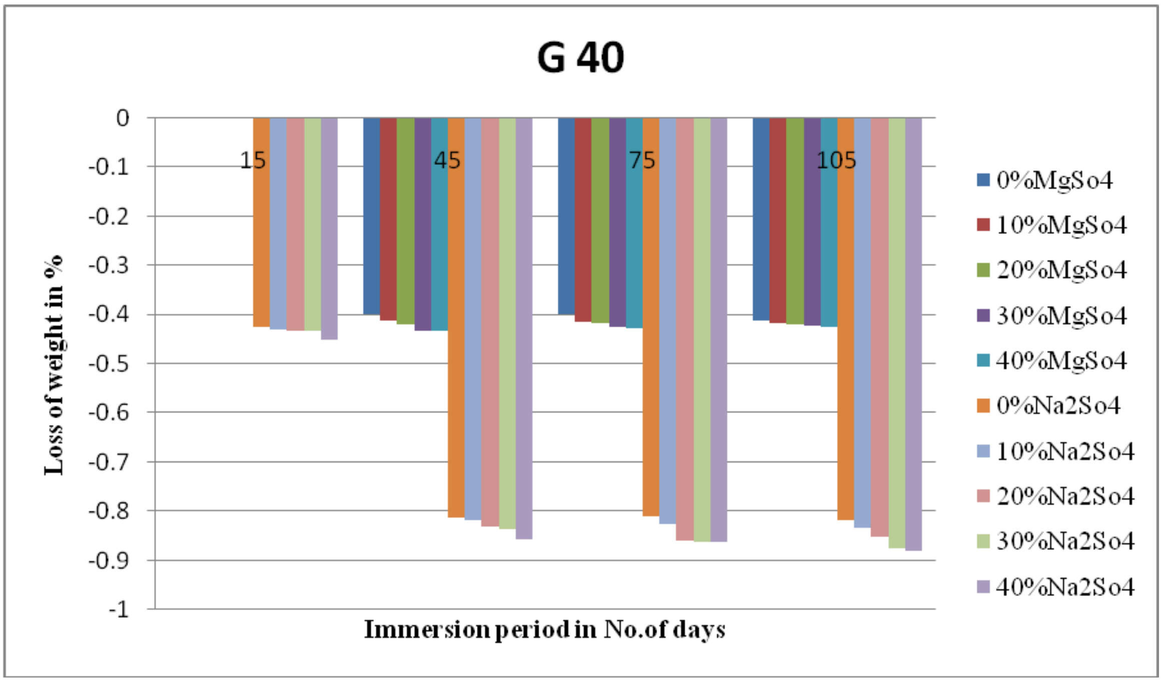

Fig : Percentage weight loss in controlled concrete (G40) when immersed in 5% concentration

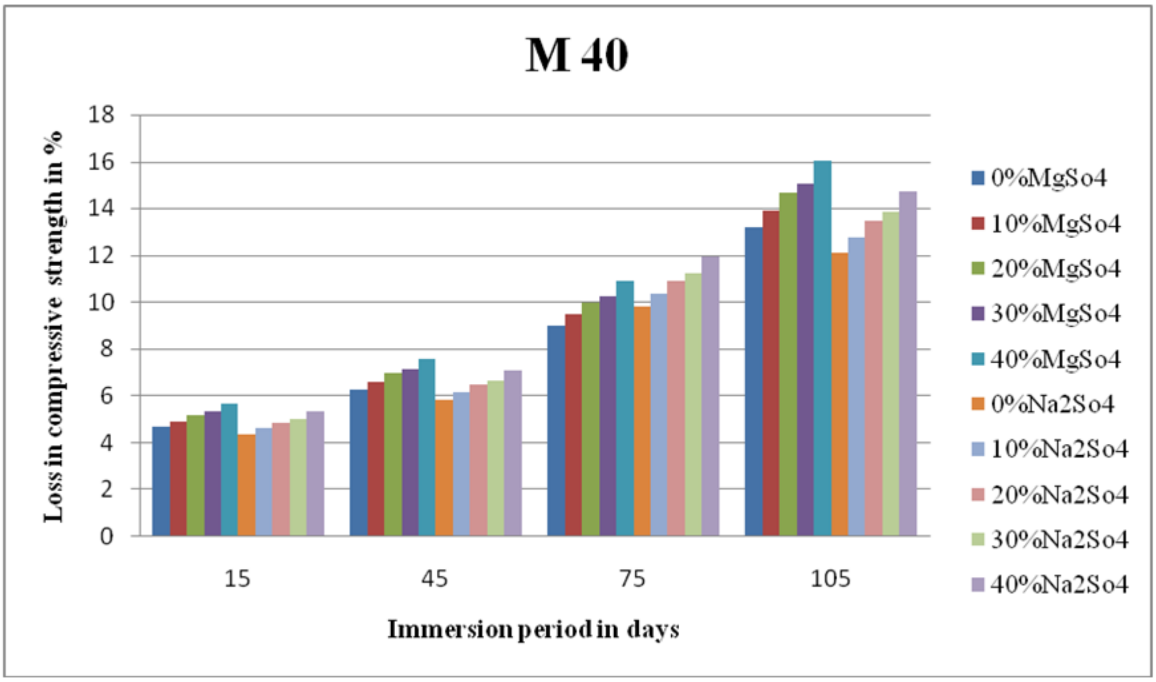

Fig : Percentage compressive strength loss in M40 when immersed in 5% concentration

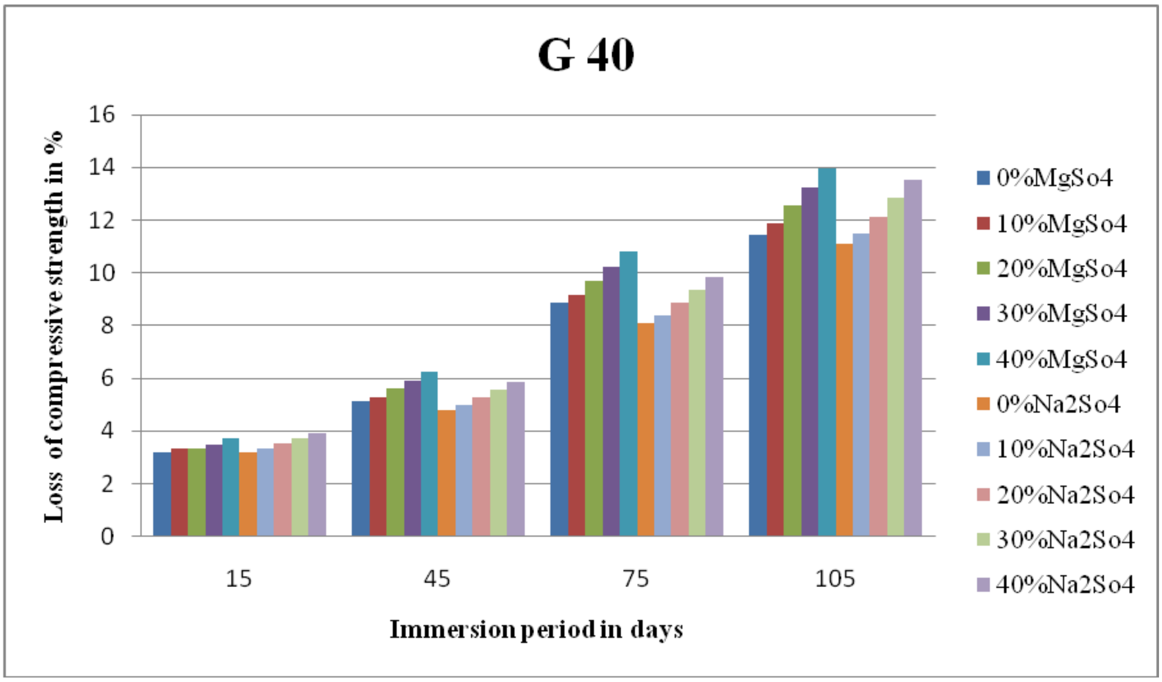

Fig : Percentage compressive strength loss in G 40 when immersed in 5% concentration

A. *Acid Durability Factors*

The (ADFs) can be calculated .

ADF = Sr (N/M)

Where, Sr = Relative strength at N days, (%)

N = No. of days the durability factor needs to be calculated.

M = No. of days the exposure of specimens to be terminated.

ATT was finished at 105 days. Thus M= 105

B. *Acid Attack Factors*

The decay of surface at each corner of the affected face and therefore the opposite face is measured in terms of the mm for each of the two cubes and the (AAFs) per face is calculated as follows.

AAF = (8 corners of every 2 cubes in loss) / 4

The Tables 5.15 to 5.16 shows the (ADFs) and (AAFs) of both grades of geo-polymer and controlled concrete specimens exposed to 5% concentration acids of NA2SO4 and MGSO4 solution at various days of immersion.

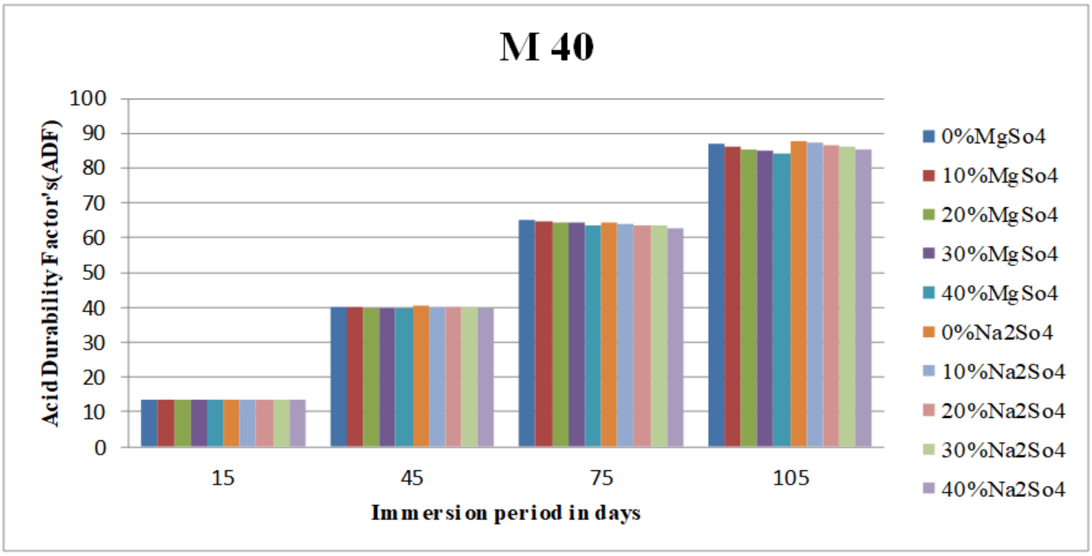

Fig : Acid Durability Factors of M 40 when immersed in 5% concentration of sulphates

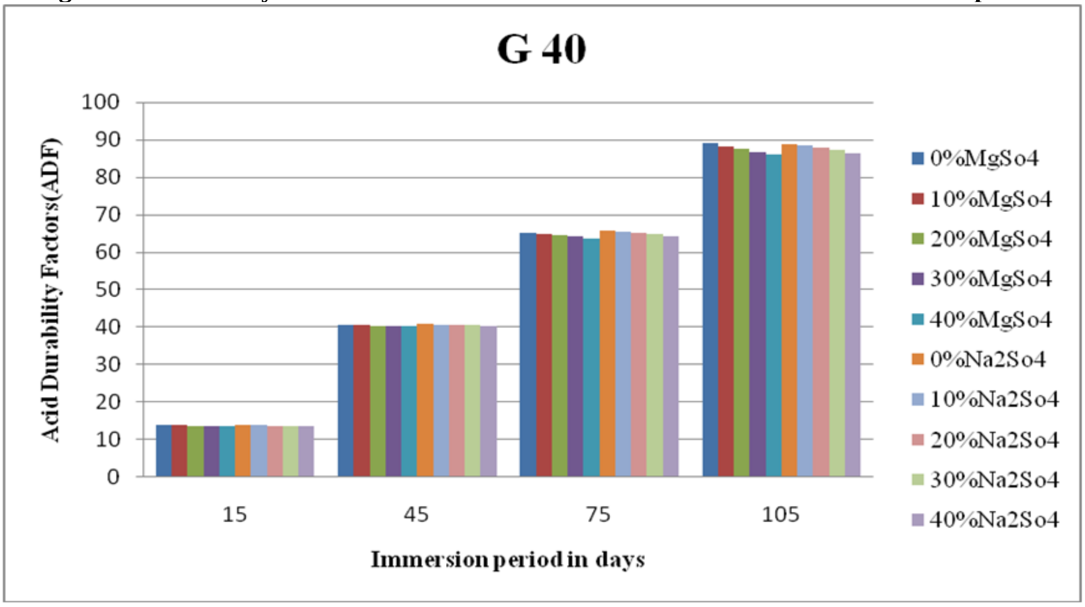

Fig : Acid Durability Factors of G 40 when immersed in 5% concentration of sulphates

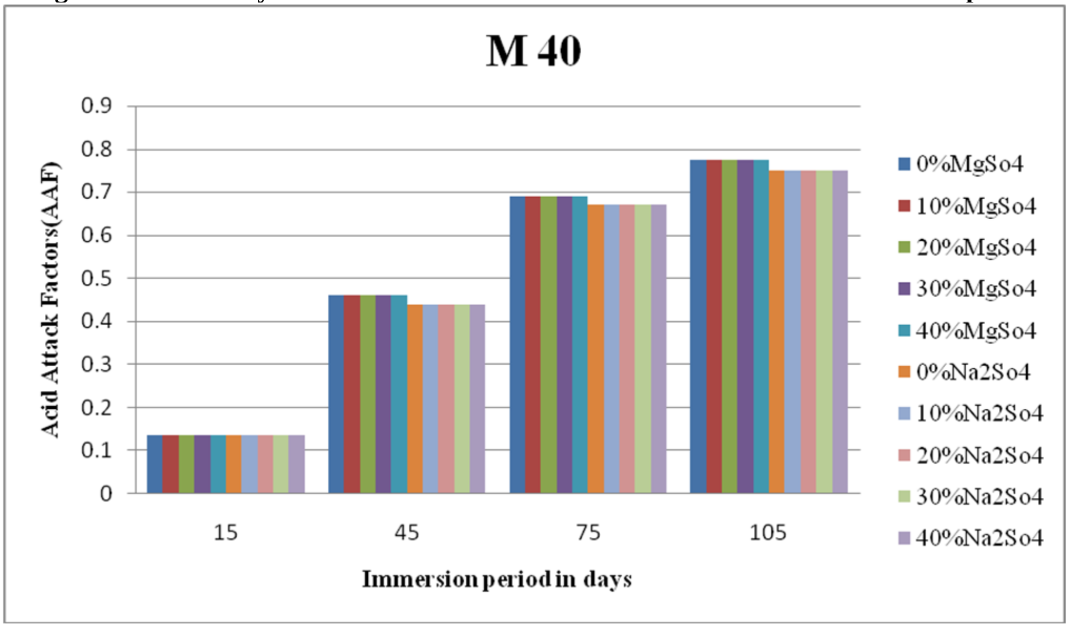

Fig : (AAFs) of M 40 when immersed in 5% concentration of sulphates

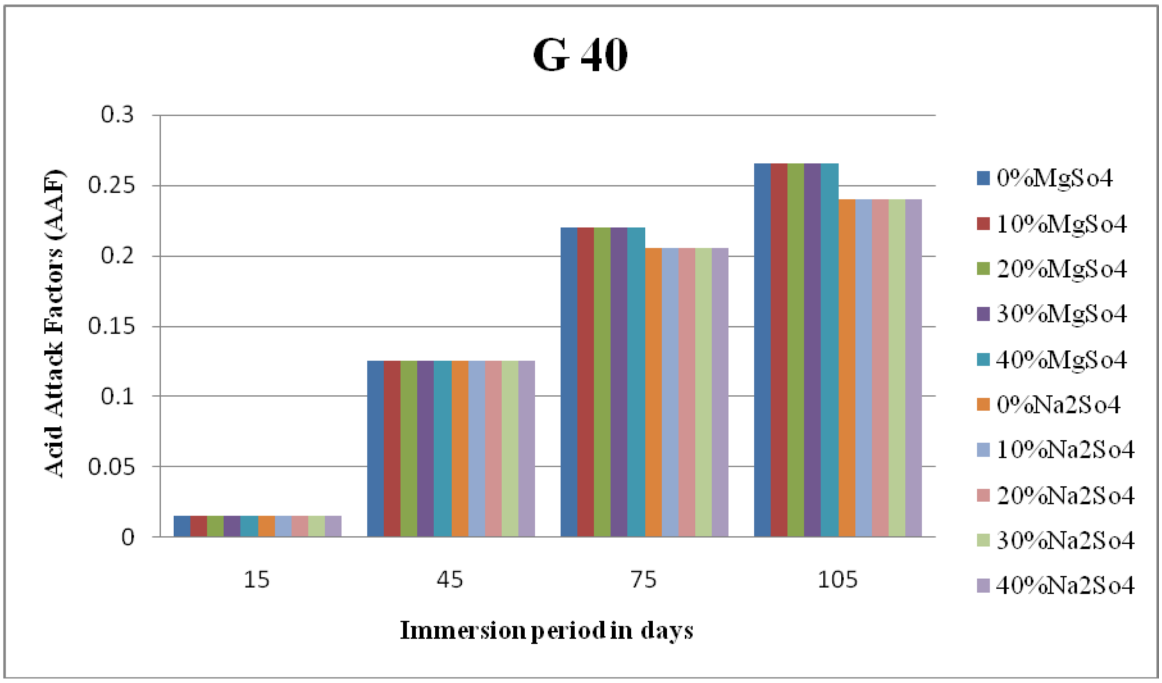

Fig : Acid Durability Factors of G 40 when immersed in 5% concentration of sulphates

VI. CONCLUSION

The conclusions can be drawn as follows :

i. The percentage loss of cube strength in CC, when subjected to $MgSo_4$ for 15 days to 105 days is in between 4.680 to 16.042, where as in geopolymer concrete it is in between 3.207 to 13.961. Thus GPC is more resistance to CC.

ii. The loss of percentage of compressive strength of CC, when exposed to Na_2So_4 for 15 days to 105 days is in between 4.389 to 14.726, where as in GPC it is in between 3.216 to 13.522. Therefore GPC is more resistance than controlled concrete.

iii. The % loss of weight is increased with increase in time of immersion for both conventional and geopolymer concrete when the specimens are subjected to $MgSo_4$ and Na_2So_4.

iv. When compared to CC, this GPC has better durability properties. Due to its outstanding cube strength, this GPC is suitable for structural application and GPC has no visible signs of surface deterioration.

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Permeation Properties of Geopolymer Concrete Made with Partial Replacement of Recycled Coarse Aggregates

T. Srinivas , P. Manoj Anand

Abstract: ***Concrete is themost generally used construction material inthe world due to, wonderful durability, straight forward accessibility of its constituent materials, its low price, straightforward formability to any shape, etc. There are many ecological problems connected with the manufacture of OPC, at a similar time accessibility of natural coarse aggregate is additionally changing into scarcity and on the other side, the disposal of C&D wastes is additionally changing into a significant environmental issue . Hence, it is unavoidable to find an alternative material to the existing most resource consuming Portland cement and natural aggregates. GPC is a construction material of innovation concrete which shall be produced by the chemical action of inorganic molecules and made up of fly ash, GGBS, FA, CA, and an alkaline solution of NaOH and Na_2SiO_3, plays a significant role in its environmental control of greenhouse effects. The main objective of this paper is to study the permeation properties such permeability, sorptivity etc.,of geopolymer concrete of grade G40 when natural coarse aggregate is replaced with recycled aggregate in different proportions such as 10%, 20%, 30%, and 40% and also to compare the results of geopolymer concrete made with recycled coarse aggregates with geopolymer concrete of natural coarse aggregate and controlled concrete of respective grade. It has been observed that the permeability and sorptivity properties are better in geopolymer concrete, both in natural coarse aggregate and recycled coarse aggregate up to 30% replacement when it is compared with the same grade of controlled concreterespectively.***

Keywords : Geo-polymer Concrete, Recycled Aggregate, Sorpitivity, Water permeability, Permeation Properties.

I. INTRODUCTION

Inthe previous few decades, PCC has been the highest-volumeof factory-made product within the world. These materials contain high reliable performance, min cost, skillfulness and widespread availableness of raw materials. Climate change and global warming are increasingly important issues. The most harmful greenhouse gases with 65th of worldwide warming caused by CO2. Portland cement contributes considerably to greenhouse gas emissions close to zero.8-1 ton of CO2 per ton of cement. Expanded focus is additionally being set on reusing as the universal resources are being depleted, drained and the measure of waste being discarded landfill is expanding comprehensively Therefore, as the industrial development process continues, the re-use of C & Dwaste is becoming increasingly important and for high volumetric use of recycled concrete various kind of solutions has been researched. For Portland cement geopolymer is a alternative promising binder. It is produced mostly from byproduct materials such as fly ash and blast furnace slag. There are several efforts are being created to reduce the use of Portlandcement in concrete by finding different binders to Portland cement this include the utilization of supplementary cementing materials fly ash, CA, Slag & metakaoline. The name geopolymer's is given by "Joseph Davidovits" in 1972.Geopolymer concrete can be made by the following pozzalona's like clays, metakaolin , fly ash or metallurgical slag along with alkalic solution.

II. MATERIALS

A. Ordinary Portland Cement

In this experimental investigation the cement used was OPC of 53-grade. The properties of cement are specific gravity 3.15and found to be conforming various specifications of IS 12629-1987.

B. Fine Aggregate

Locally available river sand which is passed through 475mm IS sieve and having a specific gravity of 2.67, water absorption 2.8% and grade zone-II as per IS: 383 – 1970 was utilized.

C. Coarse Aggregate

CA of crushed granite are obtained of max size 20 mm angular shaped were used. The specific gravity of coarse aggregate is 2.67

D. Fly Ash

In the present study of work, the fly ash is taken from thermal power station of Vijayawada in Andhra Pradesh

E. Ground Granulated Blast Furnace Slag

GGBS is a byproduct of the steel industry. Here binder replaced with GGBS about 15% by mass.

F. Recycled Aggregate Concrete (RCA)

For the replacement of the natural aggregate (coarse aggregate) the recycled concrete aggregate is used as it is the best possible substiute which is produced from demolished construction

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waste. Utilizing recycled aggregate can result in around 60 percent less waste and 50 percentages less mineral depletion per cubic metre of concrete produced. The strength of ordinary Portland cement concrete utilizing recycled aggregate depends largely on the percentage of recycled aggregate used.

G. Water

Water free from oils, chemicals and other forms of impurities is used for mixing of concrete as per IS:456:2000.

H. Sodium Hydroxide

Sodium Hydroxide is one of the major ingredients of geopolymer concrete. The following are the specifications of Sodium hydroxide and this material is procured from the local laboratory chemical vendors in Hyderabad, which is in the form of pellets. Specifications are tabulated in table 1 as given bythe suppliers

Table 1: Shows Physical properties of NaOH.

Molar mass	40 gm/mol
Appearance	White solid
Density	2.1 gr/cc
Melting point	318Oc
Boiling point	1390Oc
Amount ofheat liberated whendissolved in water	267 cal/gram

I. Sodium Silicate Solution

Sodium silicate solution is a type of alkaline liquid plays an important role in this polymerization process. This material is procured from the local laboratory chemical vendors in Hyderabad. Specifications are tabulated in table 2 as given by the suppliers

Table 2: Properties of Na2SiO3 Solution

Specific gravity	1.57
Molar mass	122.06 gm/mol
Na_2O (by mass)	14.35%
SiO_2 (by mass)	30.00%
Water (by mass)	55.00%
Weight ratio (SiO_2 to Na_2O)	2.09
Molarity ratio	0.97

J. Super Plasticizer

MASTER RHEOBUILD 920SH is additioned to improve the serviceability of concrete. In this study superplasticizer utilized was 1.5% of binder.

III. EXPERIMENTAL INVESTIGATION

A. General

An objective of this paper is to study the permissible properties of geopolymer concrete of grade G40, Where recycled coarse aggregate is replaced in natural coarse aggregate in different proportions such as 10%, 20%, 30%, and 40% and also to compare the results of geopolymer concrete made with recycled coarse aggregates with geopolymer concrete of natural coarse aggregate and controlled concrete of respective grade. The size of cubes were cast has 100mm×100mm×100mm and after 24hours rest period, the specimens were cured for a period of 24hours at 60°C in oven and the rest of the period cured under the ambient curing.

B. Mixing and Casting of Geopolymer Concrete

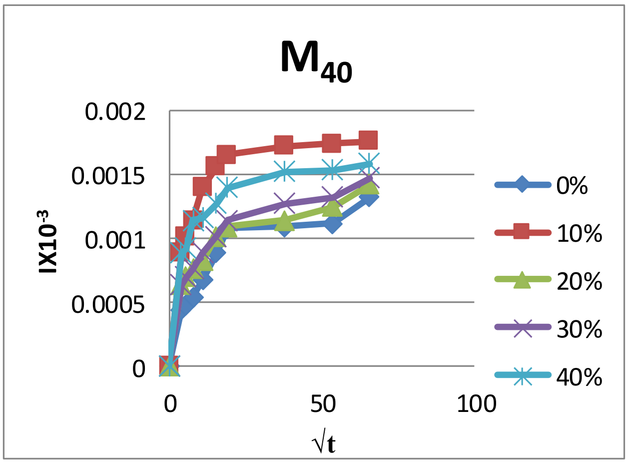
Geopolymer concrete is prepared byusing a similar procedure whatever is used within the conventional concrete. In the laboratory, the fly ash, GGBS and also the aggregates were mixed together in dry by utilizing a panmixer for 2minutes, thenthe alkaline liquid is added with the superplasticizer and additional water if needed. The liquid material is then added to the dry mix and also the mixture proceeded for 2minutes. The fresh concrete was casted by the standard strategies as of CC. The fresh concrete workability is measured by slumptest.

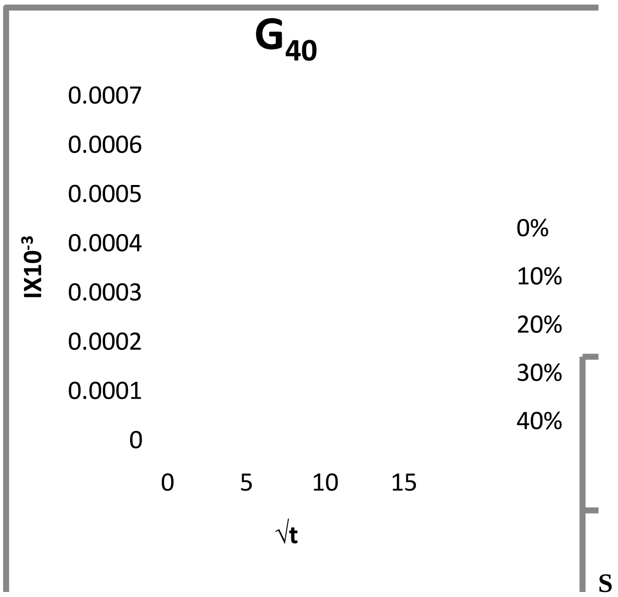
C. SORPITIVITY TEST

The objective ofthis test toworkout sorptivity of GPC of M40 grade. Sorptivity is that the accumulative modification in volume of W/A against the √t . The test was done on l specimen of size 100mm diameter and 50mm thickness. when 28 days of solidification, the specimens were oven dried at 110^{0}C for 24hrs. Edges of specimens are sealed with duct tape or sealing material. And suction face and also the opposite surface to it should be unbroken &opened. The specimens were arranged as shown within the figure below. The rate of water absorption or sorptivity

The rate of sorptivity K = slope of I vs√t graph

I = W/ (A x d); where W= the amount of water absorbed in kilogram A= C/S of the specimen is in contact with water, d = density of specimen when immersed (1000kg/m^{2}in case medium is water).





Sorptivity Coefficients of Controlled and Geopolymer Concrete

	Type of specimen	**Sorptivity Coefficient (k) x 10^{-3} m/min$^{0.5}$**	**Percentage Decreased**
0%	CC	0.083	-
	GPC	0.068	18.07
10%	RAC	0.087	-
	RAGPC	0.069	20.68
20%	RAC	0.089	-
	RAGPC	0.070	21.34
30%	RAC	0.092	-
	RAGPC	0.072	21.73
40%	RAC	0.094	-
	RAGPC	0.074	21.27

D. WATER PERMEABILITY

waterpermeability test of Concrete is carried out as per IS 3085:1965. The porosity tester was utilized a 3-cell tester consisting of 3testcell, a chamber of pressure and compressed air , water supply to the test samples below needed pressure. GPC specimens and CC specimens of dia& height 150mm are casted and cured for twenty eight days. Then they're the specially designed cells are loaded and a constant air pressure of 15kg/cm2 ismaintained byusing air compressor throughout the test for a given time interval. The pressure head to be applied is of standard to the water ought to be 10kg/cm^2. The quantity of percolated water collected is measured at periodic intervals. in the starting, the speed of water intake is larger than the rate of outflow, because the steady state of flow is approached, the 2 rates tend to become equal and therefore theoutflow reaches most andstabilizes. With additional passageof your timeeach flow and outflow typically register agradual drop. Porosity testshall be continued for regarding hundred hrs after the steady state of flow has been reached and also the outflow shall be thought-about as average of all the outflows measured throughout theperiod of 100hours.Then the constant of porosity supported Darcy's law of a falling water head, that is of steady state flow with applied conditions, may be calculated on 28days aged specimens, along subsequent formula

$$K = \frac{Q}{A \times T \times (H/L)}$$

Here
K=coeff of porosity inm/sec
Q = Quantity of water collected in ml over the complete test period
T = Time in seconds over that Q is measured = 100*60*60 sec = 360000 sec
A = Areaof the specimen face in m2 = 0.01767 m^2
Water pressure =10 kg/cm2 = 106 Pa
1Pascal of pressure = 0.0001m of pressure head
Pressure Head = 100 m (throughout the test it will be constant)
H/L = the ratio between Pressure head to thickness of the specimen each expressedin meter = 100/0.15 = 666.67

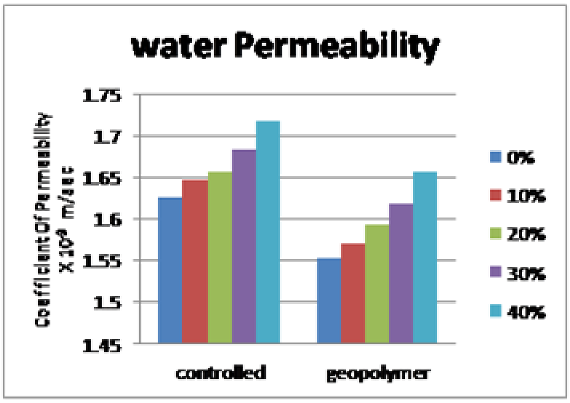
Table: Coef of Permeability for Controlled and Geopolymer Concrete at Age 28 days

	Type Of Specimen	**Pressure Head H (m)**	**Quantity Of Water Collected (m)**	**Coefficient Of Permeability X 10-9 m/sec**	**% Decreased**
0%	CC	100	6892	1.625	-
	GPC	100	6584	1.552	4.46
10 %	RAC	100	6984	1.646	-
	RAGPC	100	6676	1.57	4.41
20 %	RAC	100	7023	1.656	-
	RAGPC	100	6759	1.593	3.75
30 %	RAC	100	7143	1.684	-
	RAGPC	100	6865	1.618	3.89
40 %	RAC	100	7289	1.718	-
	RAGPC	100	7023	1.656	3.64

Table : Coef of Water Permeability Ranges as per IS: 3085-1965

Water Permeability	**Very Low**	**Low**	**Medium**	**High**
Coef ofpermeability (x 10^{-9} m/sec)	< 0.5	0.5-1.0	1.0-2.0	>2.0

Variation of Coefficients of Permeability for Controlled and Geopolymer Concrete Specimens of Age 28 days



IV. CONCLUSIONS

i. It is observed that the permeability of CC with RA is 3.5% more than that of Conventional concrete with Natural Aggregate at 30% replacement, but still it is in considerable range as per IS3085-1965.
ii. The permeability of GPC with RA is 4.08% more than that of Geopolymer concrete with Natural Aggregate at 30% replacement, but still it is in considerable range as per IS3085-1965.
iii. It is seen that the sorpitivity of Conventional concrete with Recycled Aggregate is 9.78% more than that of Conventional concrete with Natural Aggregate at 30% replacement, but still it is in considerable range as per IS3085-1965.
iv. The sorptivity of Geopolymer concrete with Recycled Aggregate is 5.55% more than that of Geopolymer concrete with Natural Aggregate at 30% replacement, but still it is in considerable range as per IS3085-1965.
v. The permeation properties such as sorptivity, water permeability of geopolymer concrete are affected to some extent with addition of Recycled Aggregates. However, these properties are better than Ordinary Portland Cement concrete containing same amount and type of RCA.
vi. The replacement of recycled aggregates in concrete gives better results till 30% replacement, so it is an alternative solution for disposal of C&D waste.
vii. The geopolymer concrete gives an early strength when cured in an oven, so it can be preffered wherever early strength is required.

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Mechanical Properties of Geopolymer Concrete Made With Partial Replacement of Coarse Aggregate by Recycled Aggregate

T. Srinivas, G. Sukesh Reddy

Abstract: Construction is the one the fast growing field in the worldwide. There are many environmental issues connected with the manufacture of OPC, at the same time availability of natural coarse aggregate is getting reduced. Geopolymer binder and recycled aggregates are promising alternatives for OPC and natural coarse aggregates. It is produced by the chemical action of inorganic molecules and made up of Fly Ash, GGBS, fine aggregate, coarse aggregate and an alkaline solution of sodium hydroxide and sodium silicate. 10 M sodium hydroxide and sodium silicate alkali activators are used to synthesis the geopolymer in this study. Recycled aggregates are obtained from the construction demolished waste. The main focus of this work is to find out the mechanical properties of geopolymer concrete of grade G40 when natural coarse aggregate(NCA) is replaced by recycled coarse aggregate in various proportions such as 0%, 10%, 20%, 30%,40% and 50% and also to compare the results of geopolymer concrete made with recycled coarse aggregates(RAGPC) with geopolymer concrete of natural coarse aggregate(GPC) and controlled concrete manufactured with recycled aggregates(RAC) and controlled concrete of natural coarse aggregates(CC) of respective grade. It has been observed that the mechanical properties are enhanced in geopolymer concrete, both in natural coarse aggregate and recycled coarse aggregate up to 30% replacement when it is compared with the same grade of controlled concrete.

Key words: Geopolymer Concrete, Recycled Aggregate, Alkaline Solutions, controlled concrete.

I. INTRODUCTION

Carbon dioxide (CO_2) is the inimical greenhouse gas in the world.one ton of OPC releases one ton of CO_2 into atmosphere. Now a day's natural resources like coarse aggregate are depleted and construction and demolish waste increased. this cause to increase the land filling globally.

Geopolymer is a promising alternative binder to Portland Cement. Recycled aggregate are promising alternative for coarse aggregateThis paper presents experimental results of geopolymerconcrete of grade G40 when natural coarse aggregate is replaced by recycled coarse aggregate up to 50% at the interval of 10% and also to compare the results of geopolymer concrete made with recycled coarse aggregates with geopolymer concrete of natural coarse aggregate and controlled concrete of respective grade.

II. MATERIALS

A. Ordinary Portland Cement(OPC)

In this program, 53-grade of OPC is used. The physical properties of cement tested in accordance with the IS: 4031-1968.

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B. Fine Aggregate

In this investigation, fine aggregate used is collected from the local suppliers. It belonging to Zone-II IS 383:1970. The physical properties are tested in accordance with IS: 2386-1963.

C. Coarse Aggregate

Locally available aggregate 20mm size were used in this study. The physical properties were tested in confirming to IS: 2386-1963.

D. Fly Ash

In this study of work, low calcium Fly Ash is used, which is acquired from Dr Narla Tata Rao Thermal Power Plant from Andra Pradesh.

E. Ground Granulated Blast Furnace Slag(GGBS)

GGBS acquired from the Lafarge RMC plant from bachupally Telangana. It is replaced by 15% of weight of binder.

F. Recycled Aggregate Concrete (RAC)

Recycled aggregates are collected from the CT lab, Osmania university. Utilizing RCA can result in 50 percentages less mineral depletion per m^3 of concrete produced.

Fig 1: Recycled Coarse Aggregate (Source: Laboratory)

G. Water

Portable water is used for the curing in this work. which is easily available in the lab environment.

H. Sodium Hydroxide

NaOH is one of the major ingredients of geopolymer concrete. The following are the specifications of Sodium hydroxide pellets and this material is procured from the local laboratory chemical vendors in Hyderabad. Specifications of sodium hydroxide are shown in table1.

Table 1: physical properties of NaOH

Molar mass	41 gm/lit
colour	White
Density	2.2 gm/cc
Melting Point	319°C
Boiling Point	1392°C

I. Sodium Silicate Solution

This material is procured from the local laboratory chemical vendors in Hyderabad. Specifications of sodium silicate solution are tabulated below.

Physical properties of Na_2SiO_3

Molar mass	121.16 gm/lit
Specific Gravity	1.59
Na_2O(by mass)	14.53%
SiO_2(by mass)	31%
Water(by mass)	56%

J. Super Plasticizer

Super plasticizer GLENIUM B233 of Fosroc chemical India Ltd. was used as water reducing admixture, it increases workability.

III. EXPERIMENTAL INVESTIGATION

A. General

The main aim of this program is to find out the mechanical properties of geopolymer concrete of grade G40 when recycled aggregate takes the place of natural coarse aggregate in different proportions such as 0%, 10%, 20%, 30%, 40% and 50% and also to compare the results of geopolymer concrete produced by recycled coarse aggregates (RAGPC) with geopolymer concrete of natural coarse aggregate (GPC) and controlled concrete manufactured with recycled aggregates (RAC) and controlled concrete of natural coarse aggregates (CC) of respective grade.

B. Geopolymer Concrete

In the preparation of geopolymer concrete firstly alkaline solution was prepared by mixing the sodium hydroxide(NaOH) and sodium silicate(Na_2SiO_3). Mix the all ingredients in pan mixer to get uniform mix. Cast the fresh concrete into cubes, cylinders and beams. In this study the samples were cured in an oven at a temperature of 60°C after one-day rest period for 24 hours and the samples are kept in a atmosphere until testing. The samples were cast testing at 3days and 7 days and 28 days to analyze the mechanical properties.

IV. TEST RESULTS

A. Compressive Strength

i. Compressive Strength of CC and GPC

This experiment is the direct measure of the strength of concrete. Compressive strength test has been conducted on the cubes of sizes 100mmx100mmx100mm accordance with IS 516-1969. Compressive strength of CC and GPC are shown table3.

Table 2: Compressive strength of CC & GPC

	CC (N/mm^2)	GPC (N/mm^2)
3 days	28.75	46.71
7 days	40.25	53.91
28 days	56.72	58.30

ii. Compressive Strength of Conventional Concrete manufactured with Recycled Aggregate (RAC)

Compressive strength test is performed on conventional concrete made with recycled aggregate up to 50% replacement at the interval of 10%. In this regard, The compressive strength value has been slightly decreasing up to 30% of replacement with recycled aggregate and there on it started to decrease drastically. From table 3, it can be summaries that, 30% replacement is the optimum percentage of utilization of recycled aggregate in the concrete, because at this percentage the strength is higher than target mean strength.

Table 3: Compressive strength (N/mm^2) of RAC

percentage	DAYS		
	3	7	28
0%	28.45	39.51	56.72
10%	26.80	37.66	53.81
20%	24.91	35.50	51.04
30%	**24.56**	**34.65**	**49.75**
40%	23.26	32.70	46.72
50%	21.98	31.50	45.08

iii Compressive Strength of Geopolymer Concrete made by Recycled Aggregate (RAGPC)

Compressive strength test is performed on RAGPC up to 50% at the interval of 10%. In this regard, the compressive strength value has been slightly decreasing up to 30% of replacement with recycled aggregate and thereon it started to decrease drastically. From the results given in table 4, it can be summaries that, 30% replacement is the optimum percentage of utilization of recycled aggregate in the concrete, because at this percentage the strength is higher than target mean strength.

Table 4: Compressive strength (N/mm^2) of RAGPC

percentage	DAYS		
	3	7	28
0%	46.71	53.91	58.30
10%	45.56	51.18	56.25
20%	43.65	48.44	53.24
30%	**40.77**	**46.31**	**50.34**
40%	38.24	43.98	47.81
50%	38.02	42.72	46.95

iv. Compressive Strength Test Results

From Table 5, it is evident that the strength of GPC is more than that of Conventional concrete. When the conventional and geopolymer concrete replaced with recycled aggregate the strengths have been slightly decreased up to 30% and there on decreased drastically. In RAC and RAGPC, the strength has been decreased slightly but still it is above the target mean strength, so optimum strength results at 30% replacement of recycled aggregate geopolymer concrete can be considered.

Table 5: Compressive Strength Test Results

	DAYS		
	3	7	28
CC	28.75	40.25	56.72
GPC	46.71	53.91	58.3
RAC -30%	24.17	34.52	49.75
RAGPC -30%	40.15	46.31	50.34

Table 6: Split Tensile Strength Test Results

	DAYS		
	3	7	28
CC	3.34	4.9	6.81
GPC	5.97	6.62	7.28
RAC -30%	2.81	4.28	6.12
RAGPC -30%	5.3	5.82	6.54

B. Split Tensile Strength

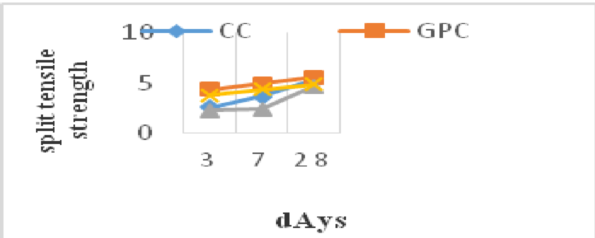
It is the experiment to know the tensile strength of the concrete in the indirect way. This test has been conducted on the cylinders of sizes 100 mm x 200 mm accordance with IS 5816-1970.

i. Comparisons of Split Tensile Strength Test Results

From Table 6, the tensile strength of GPC is more than that of CC. When the conventional and geopolymer concrete replaced with recycled aggregate the strengths have been slightly decreased up to 30% and thereon decreased drastically. The results shows that 30% is the optimum replacement among all replacements.

Table 7: Flexural Strength Test Result

	DAYS		
	3	7	28
CC	2.59	3.67	5.39
GPC	4.36	4.92	5.59
RAC -30%	2.29	2.39	4.68
RAGPC -30%	3.82	4.34	4.87



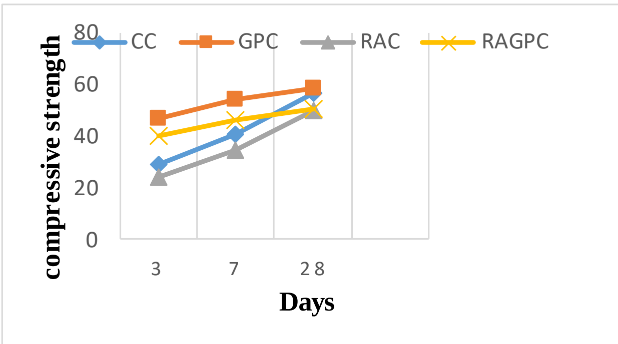
Comparison of Split Tensile Strength Test Results

C. Flexural Strength

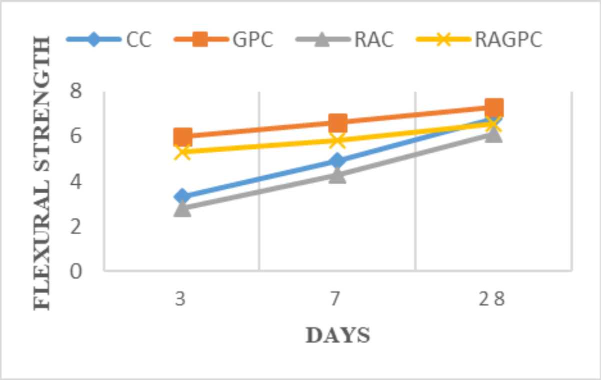
It is the experiment to know the bending strength of the concrete in indirect way, it was conducted on the prisms of sizes 500mmx100mmx100mm accordance with the IS 519-1959. The systems of loading used in finding the flexure strength was central point loading and third point loading. In this study third point loading is used.

i. Comparison of Flexural Strength Test Results

From Table 7, bending strength of GPC is more than that of CC. from the results it is observed that 30% replacement is optimum among all replacements.



Compressive Strength Test Results



Comparison of Flexural Strength Test Results

V. CONCLUSIONS

The conclusions are drawn from the above results are as follows

i. From the results, it is concluded that the compressive, tensile and flexural strength of Geopolymer concrete made with Natural Aggregate (GPC) is 2.79%, 3.5% and 6.9% greater than that of Conventional concrete made with Natural Aggregate (CC) respectively.

ii. It is distinguished that the compressive, tensile and flexural strength of RAC is 12.29%, 13.17% and 10.13% less than that of CC respectively at 30% replacement. However, it can be considerable, since compressive strength is still above the target mean strength.

iii. The compressive, tensile and flexural strength of RAGPC is 13.65%, 12.89% and 10.16% less than that of GPC respectively at 30% replacement. However, it can be considerable, since compressive strength is still higher than the target mean strength

iv. The replacement of recycled aggregate in concrete gives better results till 30% replacement, so it is an alternative solution for disposal of C & D waste.

v. The geopolymer concrete gives an early strength when cured in an oven, so it can be preferred wherever early strength is required.

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Impact of Ground Water Due to The Solid and Liquid Dump and Evaluating Various Parameters in The Leachate

S. Venkat Charyulu

Abstract: ***Dumping of solid waste, garbage is very new science to local places and surrounding areas which It effects the ground water and nearby places . In this paper, important of leachate effects and the it rate pollutions interns of chemical tests. Here it is discussed about the Jawaharnagar local area which is situated in medchal village , Hyderbad city Telangana state India In this venture, the nature of groundwater around the Jawahar nagar GHMC dumping yard, fully effected which is situated in Medchal-Malkajgiri locale , close Kapra, India., the rate of plootion is has been explored via completing Physical and chemical investigation on groundwater and leachate tests gathered from the site, done to BIS standard. The technique incorporates computing the dissolved solids, pH, electrical conductivity, total disintegrated solids, Alkalinity, all out hardness, chlorides and nitrates in (ppm) parts per Million (aside from pH), along these lines it is trailed by depicting ventures for structuring the reasonable landfill according to standard rules alongside different methods to neutralize supporting issue. finally it conclude the pollution intensity which has effected surrounding area with different chemical effects and measures to carried for the same. Finally evaluated values are expressed in the form of tabular column The ground water pollution in the jawahar nagar observed physical and chemical values are that polluated and need design of land fill***

Index Terms: Groundwater, Leachate, Physical And Chemical Parameters, Jawahar nagar

I. INTRODUCTION

Fast industrialization, growing populace and changing lifestyle are the foundation causes for Increasing charge of solid waste generation which results in health hazards and an environmental burden. no longer only the waste has increased in amount, but the traits of waste have also modified tremendously over a period, with the creation of such a lot of new gadgets and equipment. The quantum of municipal solid waste generated in India is approximately 62 million tons yearly out of which less than 60% is accumulated and round best 15% is processed. Therefore management of stable waste and related environmental affects presents a massive assignment to both growing and evolved nations.

A. Waste Generation in India

According to the Press Information Bureau, 62 million tones of waste is generated annually in the country , out of which 5.6 Million Tones is plastic waste, 0.17 Million Tones (MT) is biomedical waste, hazardous waste generation is 7.90 Million Tones per annum and 15 lakh tone is e-waste. In india an average of waste generated 200 M grams to 600 M grams per day.

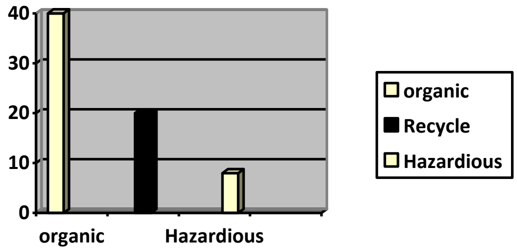

Figure 1.0

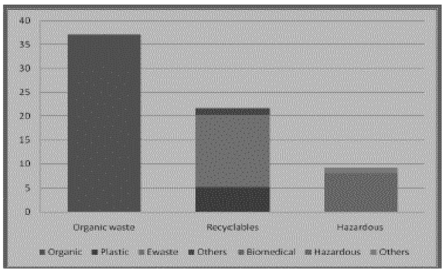

Figure 2.0

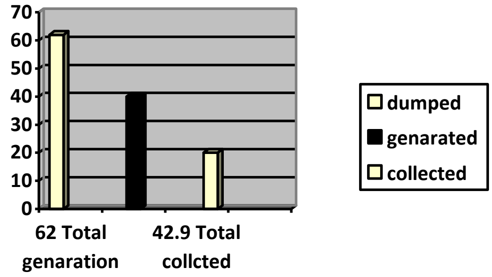

Figure 3.0

Figure 1, Figure2 and Figure 3: Collection vs Dumped Statistics (numbers in Million Tones(MT) per annum) (Source: PIB, Government of India) PIB 2016

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Fig 3 : Jawahar nagar Leachate lake near dump yard, Hyderabad

If a confining barrier beneath or surrounding the waste disposal site is absent, this leachate can migrate and contaminate subsurface and surface waters surrounding soils, vegetation, livestock and ultimately groundwater, which is a major source of water supply for drinking and domestic purpose in India.

- Several agro chemicals like DDT, fluorine, arsenic, lead compounds and organ phosphorus compounds found in polluted groundwater are super toxic and cause symptoms like nausea, vomiting, diarrhea, sweating, salivation and muscular tremors.
- Location of Jawahar Nagar dump yard, Jawahar Nagar village, Hyderabad, R.R.Dist.,Telangana, India.

B. Methodology

Very initial step was to select the location and visit the site, which in our project is Jawahar nagar dump yard located in Jawahar nagar village, Ranga Reddy district of Telangana, India.Leachate sample was collected in 1 litre pre-cleaned high density polyethylene bottle (HDPE) during pre onsoon. Similarly, ground water samples were collected from 4 stations during pre-monsoon within 5kmradius from the dumpsite employing random sampling method.The groundwater characterization has been carried out for the parameters like pH, alkalinity, total dissolved solids (TDS), total hardness (TH), chloride (Cl-), and nitrate (NO3 -) by following the standard methods prescribed as per Bureau of Indian Standard 10500 (BIS 2012).The physical and chemical characteristics like TDS, TH, CH, Cl- and NO3 - of collected leachate around the dumpsite during pre-monsoon were analyzed.WQI (Water Quality Index) for the water samples collected was calculated by considering abovementioned parameters. (Weighted Arithmetic Index method has been used).

C. Objectives of Present Study

● To analyze various physicochemical parameters including heavy metals in the leachate.

● Effect of the impact of leachate percolation on groundwater quality.

● scope of design and operate the suitable landfill for the selected site.

D. *Location* of Study Area

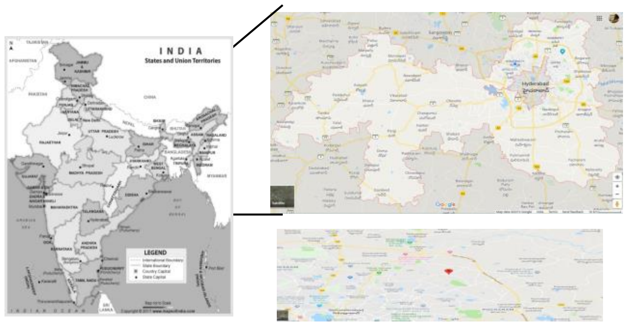

Fig 5 : Location Of Jawahar Nagar Dump Yard, Jawahar Nagar Village, Hyderabad, Telangana

II. LITERATURE REVIEW

A number of researches have been conducted on MSW management and Designing of Landfills during the recent years. The work of various researches have been studied and presented below:

1. Reducing the over-all cost of planning, design, operations and maintenance of landfill facilities while ensuring the protection of public health and the environment.-Rakesh Kumar Dutta 1,V. Gayathri2 et.al discussed about the environmental effect

2.. Building appropriate I nstitutional framework along with policy-level directions will help facilitate the necessary change. - Mathangi Swaminathan et al

3. The high concentration of Total Dissolved Solids, Electrical Conductivity and Chemicals , in ground water near landfill decreasing day by day . The threat to groundwater comes from un controlled landfills .-P. Vasanthi 1 & S. Kaliappan 2 & R.Srinivasaraghavan $_3$ et.al

Table 1: Geographical Details of the Study Area

S. No	Sample	Station	Latitude	Longitude	D
	GW1	Malkaram	17 31 38	78 34 52	1km
	GW2	Y.S.R.Nagar	17 31 02	78 34 57	1km
	GW3	GabbiLalpet	17 31 01	78 34 45	2km
	GW4	Dammaiguda	17 30 12	78 35 27	2km

GW1, GW2,GW3 and GW4 are the notation which represents the ground water collection from the samples. D is distance Collected from the sample site in km. Each of the leachate and groundwater samples were analyzed for 6 parameters viz., pH, TDS, TH, TA, Cl- and NO3 -using standard procedures. The pH was recorded on site at the time of sampling with digital pH meter. The physicochemical parameters like Total Dissolved Solids (TDS), Total alkalinity (TA) , Total Hardness (TH) and Chlorides (Cl-) of leachate, and ground water samples were analyzed titrimetrically. Chlorine is added to identify the ground water quality. Nitrates determination was carried out using spectrometer. The main

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physical properties of water are color, taste, odor, turbidity, pH. These values should be within the permissible limits otherwise it is harmful. So tests have been conducted to find the quality of water present in and around Jawahar Nagar.

III. PHYSICAL AND CHEMICAL PARAMETERS

A. *PH*

In science, pH (capability of hydrogen) is a numeric scale used to indicate the causticity or basically of a fluid arrangement. It is around the negative of the base 10 logarithm of the molar fixation, estimated in units of moles per liter, of hydrogen particles. All the more unequivocally it is the negative of the base 10 logarithm of the action of the hydrogen particle. Arrangements with a pH under 7 are acidic and arrangements with a pH more prominent than 7 are fundamental. Unadulterated water is nonpartisan, at pH 7 (25 °C), being neither a corrosive nor a base. In opposition to prevalent thinking, the pH worth can be under 0 or more prominent than 14 for solid acids and bases separately. It is estimated utilizing pH meter.

B. Total Hardness (TH)

Hard water will be water that has high mineral substance (interestingly with " delicate water "). Hard water is framed when water permeates through stores of limestone and chalk which are to a great extent comprised of calcium and magnesium carbonates. Hardness in the drinking water is having less advantage. Where water hardness is checked to evade expensive breakdowns in boilers , pots and water warmers and so on. Any place water hardness is a worry, water mellowing is regularly used to diminish hard water unfriendly impacts

C. Total Dissolved Solids (Tds)

Absolute broke down solids (TDS) is a proportion of the broken up consolidated substance of all inorganic and natural substances present in a fluid in sub-atomic, ionized or miniaturized scale granular (colloidal sol)suspended structure. The main use of TDS is in the investigation of water quality for streams,rivers and lakes, in spite of the fact that TDS isn't commonly viewed as an essential toxin (for example it is not deemed to be related with well being impacts. This strategy is utilized as it is the best yet time-expending.

D. *Total Alkalinity (TA)*

Alkalinity is the capacity to cradle acids. The proportion of alkalinity is vital in distinguishing the level of buffering water has experienced against unexpected pH changes. In spite of the fact that consumption is for the most part a consequence of low pH in water, expanded alkalinity decreases calcium carbonate solvency, bringing about scaling

E. Chloride Ions (Cl-)

Regular chlorides incorporate sodium chloride (NaCl) and magnesium chloride (MgCl2). Chlorine alone as Cl2 is very poisonous and it is frequently utilized as a disinfectant.

In mix with a metal, for example, sodium it winds up basic forever. Limited quantities of chlorides are required for ordinary cell works in plant and creature life. hlorides can erode metals and influence the flavor of sustenance items. In this manner, water that is utilized in industry or handled for any utilization has a suggested greatest chloride level. Chlorides can debase new water streams and lakes. Fish and sea-going networks can't get by in elevated amounts of chlorides.

F Nitrate ions (NO_3 -)

Nitrate-nitrogen (NO_3- N) in groundwater may result from point sources, for example, sewage transfer frameworks and animals offices, non-point sources, for example, prepared cropland, parks, greens, yards, and plant enclosures.. The nitrite oxidizes the iron in the hemoglobin of the red platelets to shape methanol globing, which comes up short on the oxygen-conveying capacity of hemoglobin. This makes the condition known as methemo globinemia (now and again alluded to as "blue infant disorder"), in which blood does not have the capacity to convey adequate oxygen to the individual body cells making the veins and skin seem blue. The measure of nitrate particles present

IV. LEACHATE

The physical and chemical characteristics of collected leachate around the dumpsite during pre monsoon were analyzed and presented in the (Table number 2). From the results, it can be observed that pH is more in alkaline. Alkaline pH is normally available at landfills. one value of leachate 9.6 shown more alkaline. 10 years after disposal. Other analyzed parameters like TDS, TH, Cl- and NO_3 - were found to have higher concentrations in the leachate collected during pre-monsoon season when compared to post monsoon leach ate sample.

Table 2 Obtained Sample Values With World Health Organization

Ground points Sample collected	pH value	TDS mg/l	TH Value	TA Value	Cl- Value	NO3-
GW1	7.8	383	205	298	78	28
GW2	7.3	640	1000	427	126	174
GW3	7.2	512	275	222	138	165
GW4	7.1	960	465	394	355	196
LEACHATE	9.6	35200	2900		45319	1012
WHO Standards	7 to 8.5	500	200	200	250	50

V. EXPERIMENTAL RESULTS AND CONCLUSION

Result of the studies are carried out in the mode of ground water pollution by the impact of leachate expressed various Quanities

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VI. GROUNDWATER AND VARIOUS QUANTITIES

Ground water after effects of physico-substance examinations of groundwater tests gathered during pre storm of 2019 were contrasted and the World Health Organization (WHO:2006) as appeared (Table:2). The pH estimations of all the ground water tests gathered around dumpsite fall inside the WHO (2006) limits demonstrating the basic nature. The TDS estimation of the ground water tests extended from 383-960mg/l during pre-rainstorm season and from 528-1260 mg/l which surpassed the admissible furthest reaches of WHO(2006). Total hardness values of water samples ranged from 205-465 mg/l during pre-monsoon were also above the permissible levels of WHO (2006) except one sample collection.

The chloride values ranged from 78-355mg/l during pre-monsoon were above the permissible levels of WHO (2006). Highest chloride concentration was observed in GW4 station. The high chloride present in groundwater basically from sewages, fertilizers, septic tanks, and leachates. Nitrate values ranged from 28-196 mg/l during pre-monsoon. Most of the water samples exceeded the WHO (2006) limits. It is further require to calculate the water quality index for the same area. Further its need of design and operate the suitable landfill for the selected site.

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AUTHORS PROFILE

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Mechanical Behaviour of Self Compacting Concrete by using M-sand & Rice Husk ash

Mallikarjuna Reddy V, Bhaskar B

Abstract:- Rice husk ash (RHA) is an agricultural based pozzolanic material, which contains high amount of silica content. This experimental research was conducted on Self Compaction Concrete (SCC), to generate an economical concrete by using Manufactured Sand (M-sand) and Rice Husk Ash. Natural River sand usage is damaging the river beds, causing the drastic changes in ground water table and cost of river sand increasing day by day. To overcome this problems manufactured sand is used in SCC production. Rice husk Ash is very cheaper when compared to the Cement. It is extracted from Rice Husk which is a waste of Agricultural product. This material can be useful to generate a sustainable construction material. This paper presents the experimental results on development of mechanical properties of SCC with M-sand and Rice Husk Ash. Experiment conducted on 6 different mixes. i.e Partial Replacement with RHA (0%, 5%, 10%, 15%, 20%, 25%). For each mix Fresh properties (Slump flow & L-Box Test) & mechanical properties (Compressive strength, Split Tensile strength and Flexural strength) for 7days, 28days and 60days along with Density comparisons are compared.

Keywords:- Self compacting Concrete, Rice Husk Ash, M-sand.

I. INTRODUCTION

Self-Compacting Concrete was first developed in japan in 1988 for dense reinforced, Skin reinforced structures and deep shafts. SCC can flow through dense reinforcement under its own weight without any segregation and bleeding. It does not require any vibration. Due to its own weight it can flow and spread uniformly throughout the enclosed area.

Sand is major construction material. Day by day usage of concrete is increasing, accordingly sand mining is also increasing. This is also a threat to the biodiversity. Due to the heavy usage of sand, River beds losing their natural properties and ground water level decreasing. Manufactured sand is an alternative material to the Natural sand. It was more angular in shape and also cubical, which gives better strength and more interlocking capacity than natural sand. Its cost is very less when compared to the natural sand. 100% Replacement of Natural river sand is replaced by M-sand showing 19% more compressive strength & other mechanical properties also increasing [1]. Rice husk ash is highly reactive pozzolona which is a bi-product of Agriculture waste. Rice Husk contains high silicon during burning process it produces silica with oxygen. Silica is responsible for strength.

RHA has high amount of Silica content. Using of RHA economize the construction materials. RHA having less density so concrete density also decreases. RHA improving the Strength properties within 90 days and giving acceptable results for workability tests as for EFNARC Guidelines [2].

II. II. MATERIALS USED

A. Cement

In this work Ordinary Portland Cement of 53 grade is used. It confirmed to requirements of IS:1229-1987. Physical properties of cement is as shown in Table.1.

Table.1 Physical properties of Cement

S.No	Property	Details
1	Specific gravity	3.12
2	Fineness	8%
3	Normal consistency	28%
4	Initial Setting time	37min
5	Final Setting time	450min

B. Mineral Admixture

Rice Husk Ash:-

It is collected from brick Manufacturers, Grinded and Sieved to required size. Specific gravity of RHA is 1.83 and grey in colour. Loss on ignition is 5%. Chemical properties of RHA is as shown in Table.2

Fig.1 Rice Husk Ash

Fig.2 GGBS

GGBS:-

GGBS is obtain by grinding Blast furnace slang. It is collected from nearest steel plant.

Its Specific Gravity is 2.8. Chemical properties of GGBS is as shown in Table.2

Table.2. Chemical Properties of RHA & GGBS

S. No	Compound	% By total mass	
		RHA	GGBS
1	SiO_2	92.39	35.4
2	Al_2O_3	0.54	13.97
3	Fe_2O_3	0.91	0.87

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4	MgO	0.87	8.65
5	CaO	1.32	39.37
6	Others	3.97	1.74

C. Fine Aggregate

M-sand is used as Fine aggregate. Their properties are as shown in Table.3.

D. Coarse Aggregate

Maximum 12mm size Crushed aggregate is used for the preparation of SCC. Properties of Coarse aggregates are as shown in Table.3

Table.3 Properties of M-sand & Coarse Aggregates

Property	M-sand	C.A
Bulk Density (kg/m^3)	1580	1502
Specific Gravity	2.83	2.6
Surface water (%)	0.5	0.5
Water Adsorption (%)	5	0.2

All test on aggregates are conducted as per IS:2386(Part-3)-1963.

E. Super Plasticizer

MasterEase 3709 super plasticizer was used in this experiment. This plasticizer is the product of BASF. This plasticizer also contain viscosity modifying agents (VMA). VMA reduces the friction between particles and give high workability. It is available in liquid form and brown in colour.

F. Water

For mixing water should be free from impurities, oils, salts and acids. pH value should not be less than 6. It fulfil the requirements of IS:456-2000.

Fig.3 Super Plasticizer

III. III. MIX DESIGN

Nan-Su method of mix design is used for the SCC mix. It is a trial and error method. The mix which satisfy the requirements of fresh concrete are cured for 28days. Final mix design decided by its 28days Strength.

Final mix Design:-

Grade of concrete = M40

Cementitious material = 350+110 Kg/m^3 (Cement+GGBS)

Fine Aggregate (M-sand) = 920 Kg/m^3

Coarse Aggregate (10mm) = 807 Kg/m^3

Super plasticizer =1% of Total Binder

w/c ratio =0.3

Mix Proportions:-

Six mixes with 0%, 5%, 10%, 15%, 20%, 25% replacement of Cementitious material by RHA is used. They are designated as M-1, M-2, M-3, M-4, M-5 & M-6. Mix-1 is used as Conventional mix when comparing strength properties. Cementitious material contents are as shown in Table.4.

Table.4 Cementitious material contents

Mix	Cement (Kg/m^3)	GGBS (Kg/m^3)	RHA (Kg/m^3)
M-1	350	110	0
M-2	332.5	104.5	23
M-3	315	99	46
M-4	297.5	93.5	69
M-5	280	88	92
M-6	262.5	82.5	115

For each mix coarse aggregate is 920Kg/m^3 and M-Sand is 807Kg/m^3 are fixed. Percentage of Super Plasticizer dosage is 1% and w/c ratio is 0.3.

Specimen Used:-

A total of 162 specimen are casted where 54 no. of cubes are used to conduct the Compressive Strength, 54 no. of Cylinder used for Split Tensile Strength and 54 no. of Beams are used for the Flexural Strength

IV. IV. EXPERIMENTAL RESULTS

Each mix tested for Fresh concrete properties and Hardened properties. Fresh properties of SCC are tested as per EFNARC Guidelines. Fresh properties of SCC are Flowing ability, passing ability & Filling ability which are decided by slump flow test, V-funnel test & L-box test respectively. Fresh properties are as shown in Table.5.

Table.5 Fresh Properties of SCC

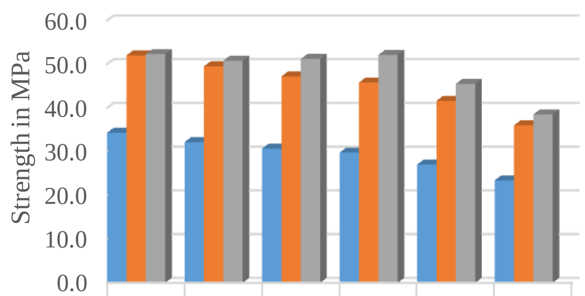
Property	M-1	M-2	M-3	M-4	M-5	M-6
Slump (mm)	650	630	615	590	570	555
L-box (ratio)	0.9	0.86	0.81	0.75	0.7	0.64
V-funnel (sec)	10	11	12.5	14	16	18

Hardened Properties:-

Strength test on concrete are conducted as per IS:516-1959. Compressive Strength, Split Tensile Strength and Flexural Strengths are shown graphically below. Each property tested for 7day, 28days and 60 days.

Compressive Strength

Compressive strength of concrete is strength of 150mm cube. It is calculated from 100mm cube by multiplying 100mm cube strength by conversion factor 0.9. At specified curing day cubes are tested by CTM and get compressive load from that compressive Strength calculated. Resulting Compressive strength data is as shown in the Fig.4.



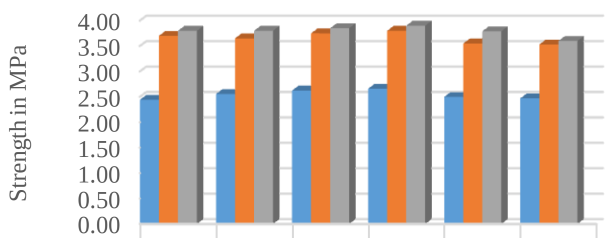
	MIX-1	MIX-2	MIX-3	MIX-4	MIX-5	MIX-6
7days	34.3	32.175	30.68	29.77	27.04	23.4
28 days	52	49.5	47.2	45.8	41.6	36
60 days	52.3	50.8	51.2	52.1	45.5	38.5

Fig.4 Compressive Strength of concrete

Reactivity of Mix-4 is high after 28 days, and it gained full strength as much of conventional one when compared with all other mixes Compressive Strength.

Split Tensile Strength

Cylinder with 100mm diameter and 200mm height is used for Split tensile test because maximum size of coarse aggregate used is 12mm. Cylinder casted and cured for 28 days. At specified curing day Cylinder tested by CTM and get load. From that loads Split Tensile Strengths are calculated by using Specified formula. Split tensile strength data is as shown in the Fig.5.



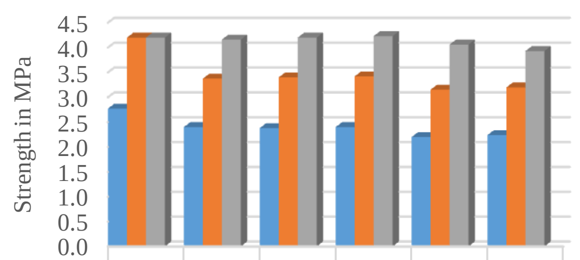
	MIX-1	MIX-2	MIX-3	MIX-4	MIX-5	MIX-6
7days	2.44	2.56	2.63	2.66	2.50	2.47
28 days	3.7	3.65	3.75	3.8	3.55	3.53
60 days	3.8	3.8	3.85	3.9	3.79	3.6

Fig.5 Split Tensile Strength of concrete

Split Tensile strength of all mixes are in one range but 15% replacement showing slightly more strength for 28 & 60 Days.

Flexural Strength

Beam with 100mm Square cross section and 500mm length are casted and cured for specified days for Flexural strength and tested for four point loading using Flexure Testing Machine. The obtained Flexural strengths are as shown in the Fig.6.



	MIX-1	MIX-2	MIX-3	MIX-4	MIX-5	MIX-6
7days	2.8	2.4	2.38	2.4	2.2	2.24
28 days	4.2	3.375	3.4	3.42	3.153	3.2
60 days	4.2	4.16	4.2	4.23	4.06	3.93

Fig.6 Flexural Strength of concrete

Flexural strength of Mix-4 got more Strength than conventional mix for 60 days and 28 day strength also in allowable range only.

V. CONCLUSION:

1. Workability of SCC decreases with an increase in percentage Replacement of Cementitious material with RHA. All mixes except M-6 satisfying the SCC fresh properties as per EFNARC guidelines.
2. By using RHA Self weight of structure also decreases because each 5% replacement of RHA, 0.56% weight is decreasing.
3. Strength variations clearly showing that the Mix -4 is better for long term strength requirements.
4. The mix with 15% replacement is most suggestible and weight of this mix is 1.7% less compared to the conventional mix.
5. 15% replacement of cement by RHA giving light weight and economical concrete.

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List of codes:-

[1] IS12269:1987 Specification For 53 Grade Ordinary Port Land Cement
[2] IS 2386-3 (1963)_ Methods of test for aggregates for concrete, Part 3
[3] IS 12269 : 2013 Ordinary Portland Cement, 53 Grade — Specification
[4] IS : 516 - 1959 Methods Of Tests For Strength Of Concrete
[5]
[6] The European Guidelines for Self-Compacting Concrete (EFNARC Guidelines)

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B.Bhaskar,has completed Engineering from JNTUH College of Engineering, Manthani, Telangana, in the batch of 2012-2016 with first class degree. Presently pursuing masters in Structural Engineering Gokaraju Rangaraju Institute of Engineering and Technology (Hyderabad) attentively interested to conduct mechanical behaviour of self-compacting concrete by using M-sand & Rice Husk Ash.

Mechanical Properties of Fibre Reinforced Self Compacting Concrete using Rice Husk Ash

V Mallikarjuna Reddy, S Manikanta

Abstract: Self-compacting concrete (SCC) is relatively a recent development in the construction world. SCC can flow through dense reinforcement under its own weight without any segregation, bleeding, and vibration. The use of steel fibers is being encouraged to increase mechanical characteristics of SSC. However, adding fibers to fresh concrete results in loss of workability. Steel fibers operate as crack arrestors in concrete and extend the span of structures. In the present study, the mechanical properties of SCC with cement is partially replaced by rice husk ash (RHA) & P500 (ultra-fine fly ash). A total of 5 mixes with 0.3 W/C ratio were cast for 7, 28 and 56 days water curing. The replacement of fibres is considered as 0%, 0.5%, 1%, 1.5%, and 2% by weight of cement. Workability, Compressive, Split Tensile and Flexural strength is studied in this investigation. Superior strength was observed at optimum dosage of steel fibers at 1.5% by weight of cement.

***Keywords*: SCC, Husk Ash, P500 (ultra-fine fly ash) , steel fibres**

I. INTRODUCTION

This paper gives a review on Self Compacting Concrete (SCC) to be made using various Mineral Admixtures and steel Fibres. Due to the difficulty in placing the concrete in congested reinforcement where there is no possibility for the vibrator to compact manually so an invention of new type of concrete is done and named as self-compacting concrete (SCC)[1]. This concrete can pass through congested reinforcement easily and to all corners of shuttering SCC can compact by its own weight without requirement of any manual compaction [2].

Rice Husk Ash (RHA) is produced after burning of Rice husks (RH) which has high reactivity and pozzolanic property. RHA having less density so concrete density also decreases. Strength development can be increased& durability of the structure is improved. Due to its large surface area and has a high amount of silica content the pores in the concrete are neglected and seepage of liquids through concrete is minimized. Use of rice husk ash economize the construction materials. Proper consumption of these RHA contributes to solving environmental pollution and also produces cost-effective concrete. Greenhouse gases can be decreased to a greater extent when we use RHA in concrete with partial replacement of cement [3].

Steel fiber is a metal reinforcement. A certain amount of steel fiber in concrete can cause qualitative changes in concrete's physical properties. Steel fibers are well known to improve the resistance to crack growth thereby improves the mechanical properties. But the problem with steel fibers reduces the workability [4]. To control plastic shrinkage cracking and drying shrinkage cracking fibres are used. They also lower the permeability of concrete and thus reduce bleeding of water[5].

II. MATERIALS

2.1 Cement- Ordinary Portland Cement of 53 grade confirming to be12269 is used and the physical properties are as shown in table.1**.**

Table.1 Physical properties of Cement

S.No	Property	Details
1	Specific gravity	3.12 gm/cc
2	Fineness	8%
3	Normal consistency	28%
4	Initial Setting time	37min
5	Final Setting time	450min

2.2Rice Husk Ash: - Rice Husk Ash is collected from brick Manufacturers after that it is Ground in ball mill and Sieved to required size. Ignition loss is found to be 5% and the Specific gravity of RHA is determined as 1.83. Chemical properties of RHA is as shown in Table.2

Table.2. Chemical Properties of RHA

S.No	Compound	% By total mass
		RHA
1	SiO_2	92.39
2	Al_2O_3	0.54
3	Fe_2O_3	0.91
4	MgO	0.87
5	CaO	1.32
6	Others	3.97

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2.3 P500 (Ultrafine fly ash): -ultrafine fly ash is produced from pure class F fly ash by grinding and specific gravity is 2.18, mean particle size is 3.9-5.0, the surface area is 13000sqcm/kg.

Fig.1 Rice husk ash **Fig.2 Ultrafine fly ash**

2.4Fine Aggregate (F.A)

Locally available river sand used in SCC with particle size less than 0.125mm. which is confirming to zone II.

2.5 Coarse Aggregate (C.A)

Coarse aggregate used for the preparation of SCC was 12mm in size and their Properties are as shown in Table.3

Table.3 Properties of F.A& C.A

Property	F.A	C.A
Bulk Density (kg/m^3)	1550	1502
Specific Gravity	2.63	2.6
Surface water (%)	0.5	0.5
Water Adsorption (%)	0.4	0.2

2.6 Super Plasticizer

The superplasticizer used in the mix was Master Ease 3709. This plasticizer is the product of BASF. This plasticizer also contains viscosity modifying agents (VMA). The workability of concrete is high due to the presence of VMA.

Fig.3 Super Plasticizer

2.7 steel fibers

The fibers used are hooked end steel fibers of aspect ratio 40.which are randomly oriented and uniformly distributed. This study is carried out by changing the fiber proportions from 0% to 2% with 0.5% increment.

2.8 Water

Portable water is generally considered for mixing concrete which was free from oils, impurities, acids and salts and also That should fulfill the requirements of IS:456-2000.

III. MIX DESIGN

Grade of concrete = M40

Cementitious material = 470 Kg per m^3 (Cement+RHA+P500)

Fine Aggregate (M-sand) = 920 Kg per m^3

Coarse Aggregate (10mm) = 808 Kg per m^3

Superplasticizer =1% of Total Binder

w/c ratio =0.3

3.1 Specimens Used

A total of 135 specimens were cast where 45 no. of cubes are used to conduct the Compressive Strength, 45 no. of Cylinder used for Split Tensile Strength and 45 no. of Beams are used for the Flexural Strength.

IV. RESULTS AND DISCUSSIONS

Initially, a test was conducted for 28 days of compressive strength to know the optimum percentage replacement of rice husk ash with four different mix proportions 5%,10%,15%,20%.

To determine the compressive strength for 28 days 3 cubes for each mix is prepared.

Table.4 compressive strength for 28 days

RHA %	28 days compressive strength(N/mm^2)
5%	45.1
10%	46.73
15%	48.21
20%	47.25

From table 4 it is observed that 15% replacement of rice husk ash is giving more strength and further increasing the RHA% decreases the strength. So therefore 15% RHA is taken as the optimum replacement and further experiments with different proportions of fibers are determined.

Five mixes with 0%, 0.5%, 1.0%, 1.5% and 2.0% replacement of fibres with weight of binder is considered and remaining materials are kept constant . They are designated as Mix-1, Mix-2, Mix-3, Mix-4 & Mix-5. Mix-1 is considered a conventional mix when comparing mechanical properties.

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V. EXPERIMENTAL RESULTS

Each mix tested for Fresh concrete properties and Hardened properties. Fresh properties of SCC are tested as per EFNARC Guidelines. Fresh properties are as shown in Table.5.

Table.5 Fresh Properties of SCC

Property	M-1	M-2	M-3	M-4	M-5
Slump (mm)	640	628	615	602	588
L-box (ratio)	0.89	0.85	0.79	0.76	0.71
V-funnel (sec)	11	15	18	21	25

5.1 Hardened Properties

The strength test on concrete is conducted as per IS 516-1959. Compressive, Split Tensile and Flexural Strengths are shown graphically below. Each property tested for 7days, 28days and 56 days.

5.1.1 Compressive Strength

Compressive strength of concrete is considered with the strength of 150mm cube but I have used 100mm cube and then the obtained strength is multiplied with the conversion factor 0.9. The cubes are cast and cured for 7 days, 28days and 56 days. Compressive strength results & percentage gain according to a conventional mix are shown in table 6.

Table 6: Compressive Strength results

Mix	7days	% gain	28 days	% gain	56 days	% gain
Mix1	28.26	0	48.2	0	51.2	0
Mix2	29.3	3.68	48.83	1.31	52.43	2.4
Mix3	30.47	7.82	49.16	1.99	53.66	4.8
Mix4	32.01	13.27	50.03	3.8	54.63	6.7
Mix5	31.05	9.87	49.3	2.28	53.9	5.27

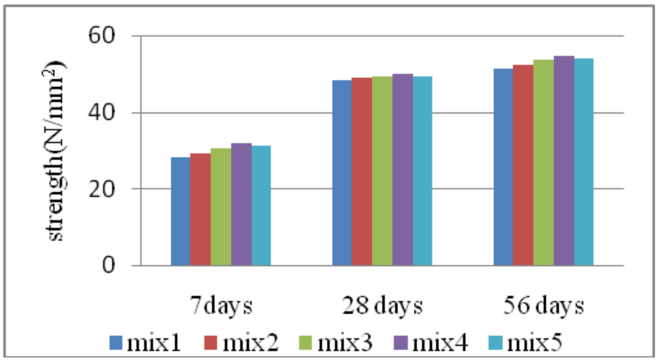

Fig 4: compressive strength results

The percentage variation in the strength is compared with the conventional mix and it was observed that %gain in strength is increased from 0 to 3.80 for 28days and 0 to 6.70 for 56 days. Further increase in fibers decreases strength.

5.1.2 Split Tensile Strength

Split tensile strength is done by using 100mm diameter and 200mm height cylinders. It is one of the important properties of concrete. Split Tensile strength of concrete is much lower than its compressive strength. Totally 45 cylinders are cast to 5 mixes for 7, 28 and 56 days. Split tensile strength results & percentage gain according to the conventional mix are shown in table 7.

Table 7: Split tensile Strength results

Mix	7days	% gain	28 days	% gain	56 days	% gain
Mix1	2.86	0	3.18	0	3.82	0
Mix2	2.55	-10.8	3.32	4.4	3.9	2.09
Mix3	2.91	1.75	3.5	10.06	4.14	8.38
Mix4	3.5	22.38	3.82	20.13	4.45	16.49
Mix5	3.18	11.19	3.55	11.64	4.2	9.95

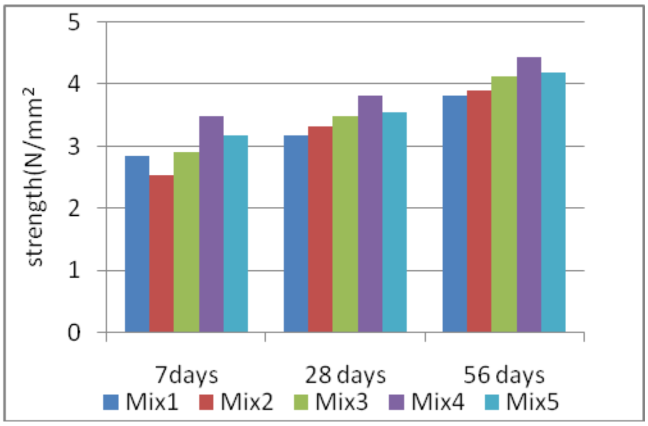

Fig 5: Split tensile Strength results

The percentage variation in the strength is compared with the conventional mix and it was observed that %gain in strength is increased from 0 to 20.13 for 28days and 0 to 16.49 for 56 days. Further increase in fibers decreases strength.

5.1.3 Flexural Strength

It is a measure of an un-reinforced concrete beam to resist failure in bending. The flexural strength of beam is tested on two-point loading and the cross-section of beam used was 100mm Square cross-section and 500mm length. The obtained Flexural strength values & percentage gain according to conventional mix are shown in table 8.

Table 8: Flexural strength results

Mix	7days	% gain	28 days	% gain	56 days	% gain
Mix1	4.4	0	4.8	0	5	0
Mix2	4.6	4.55	5	4.17	5.2	4
Mix3	4.72	7.27	5.2	8.33	5.4	8
Mix4	5	13.64	5.4	12.5	5.6	12
Mix5	4.8	9.09	5.28	10	5.52	10.4

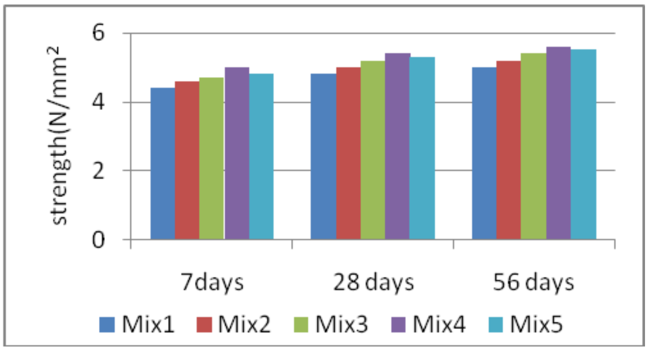

Fig 6: compressive strength results

The percentage variation in the strength is compared with the conventional mix and it was observed that %gain in strength is increased from 0 to 12.50 for 28days and 0 to 12.00 for 56 days. Further increase in fibers decreases strength.

VI. CONCLUSION

Based on the above experimental results the following conclusions were drawn;

- Compressive strength for 28 days is optimum when 15% of cement is replaced by rice husk ash and that is considered as the optimum RHA replacement.
- The increase in the percentage of fibers decreases the workability.
- From the results, it is observed that the compressive strength, split tensile strength and flexural strength increases with the increase in Steel fibers up to 1.5%.
- The cost of the construction can be minimized because rice husk ash cost is low compared to cement

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S.Manikanta, has completed engineering from ST.MARTINS engineering college, Hyderabad, Telangana, in the batch of 2013-2017 with first class degree. Presently pursuing masters in Structural Engineering Gokaraju Rangaraju Institute of Engineering and Technology (Hyderabad) attentively interested to conduct mechanical properties of fiber reinforced self compacting concrete using rice husk ash.

Effect of Polyethylene Glycol in Self-Curing of Self Compacting Concrete

V Mallikarjuna Reddy, Rathod Praveen

Abstract—The objective of this research is to evaluate the strength characteristics of self-compacting concrete as self-curing material by using water soluble Polyethylene Glycol 400. The objective of self-curing agent is to decrease concrete water disposal, thus increasing concrete's water retention ability in comparison with conventional curing. Self curing Concrete is a modern method, which performed to meet the water needs of the concrete without external curing. This research discusses the compressive, flexural, and split tensile strength of the concrete having the self-curing agent. Polyethylene glycol (PEG) of Molecular Weight 400 (PEG 400).The percentage of self-curing used from 0.5, 0.1, 1.5 and 2 percent by weight of cement. From the experimental results it is observed that optimal dosage PEG 400 is achieved at one percent being maximum strength. It is also found that the increase in PEG dosage decreases the strength of concrete.

Keywords—Self-Curing, Conventional-curing, Polyethylene Glycol, Self-compacting concrete.

I. INTRODUCTION

Internal curing (or) self-curing plays a significant part in the development of the concrete pore structure. The idea of internal curing is to improve the hydration method to preserve temperature evenly [1].Curing helps ongoing hydration of cement and subsequently ongoing boost in strength. Water is the highest commodity used as a result, the water table's daily level drops, if for building works water has to be bought the building price will rise much higher. Continuous curing is also extremely difficult for concrete work on vertical extremities, sloping roofs and floors. Concrete is subjected to the setting, water evaporation occurs and the humidity reduces original Cement proportion of water, incomplete hydration of the concrete [2]. Evaporation in the original phase contributes to cracking plastic shrinkage and it contributes to drying contraction in the final setting phase. Cracks are formed between two heat-incompatible materials, i.e. Paste and aggregates of cement, ordinary concrete loses energy at elevated temperatures. Self-curing agents primarily assist in concrete water retention by decreasing evaporation during concrete hydration. Water soluble Poly Ethylene Glycol (PEG) can be used in concrete as self-healing agents for self-healing. One of the self-curing agents is also Super Absorbent Polymer. Most Super Absorbent Polymer (SAP), are poly electrolytes that are cross-linked. Because of their ionic nature and interconnected composition, they absorb huge amounts of water without dissolving. In today's condition, where water becomes an important asset that cannot be wasted for curing, self-curing admixtures play a crucial role.

II. LITERATURE REVIEW

1. M V Jagannadahakumar et al.,Concluded that the use of self-healing specialists (polyethylene glycol) in concrete improves the performance features of concretes under the air-healing system that can be ascribed to better maintaining of water and caused further watering of the concrete paste which results in fewer emptying and pores. [4].
2. R. SubrahmanyaPavanet al.,studied two specific self-healing operative such as Polyethylene Glycol 600 and Super Absorbent Polymer, the present subject is invented on the toughness characteristics of self-curing based on the above research. [5]
3. R Udhayan et al., 2017 concluded that self-curing agent PEG can promote effective hydration of cement without any externally applied curing procedure [6]
4. ShaileshVetal et al., 2016 observed that noted increasing the PEG-400 rate increases the weight decrease for the reduced w / c ratio. Hence lower measurement indicating better water maintenance for lower w/c proportion. [7]
5. B.Mohan et al., 2016 concluded that the self-curingself-compacted concrete shows better results compares to conventional, self-curing and self-compacting concrete. [8]

III. EXPERMENTAL METHODOLOGY

A. *Cement*

Ordinary 53 grade Portland cement was used for all IS12269:1987[9] confirmed concrete mix, Physical substances of cement are presented in table 1

TABLE 1. Physical substances of cement

S.NO.	SUBSTANCE	RESULT
1	Specific gravity	3.16
2	Initial setting time	35 min
3	Final setting time	460 min
4	Fineness modulus	8%

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B. *Coarse aggregate (ca) and Fine aggregate (fa)*

Sand from river locally accessible is confirming to IS383:1970 [10]. Crushed angular aggregates used conformist to IS383:1970. Properties are presented in table 2.

TABLE 2. Physical properties of fine and coarse aggregate

S.NO.	SUBSTANCE	CA	FA
1	Specific gravity	2.6	2.7
2	Bulk density	1505	1560
3	Surface water	0.6	0.7
4	Water absorption	0.3	0.4

C. *Fly ash*

Fly ash is a by-product of the burning of pulverised carbon by energy stations. The chemical reaction between the cement and water to the formation of other cement products which enhance many of the desired concrete properties reacts with calcium hydroxide. Properties of fly ash are presented in table3.

TABLE 3. Physical properties

S.NO	PROPERTY	RESULT
1	Specific gravity	2.8
2	Fineness modulus	350 m^3/kg
3	colour	Gray

D. *Super plasticizer*

To increase the workability of concrete by super plasticizer is used. The super plasticizer used in the experiment was Master EasEe-3705 from BISF Bangalore, was used... As per IS9103-1999[11]. Properties of EasEe are presented in table 4.

TABLE 4. Properties of chemical admixtures.

S.NO.	PROPERTY	RESULT
1	Specific gravity	1.20

E. *Polyethylene glycol(peg)400*

Atomic weight 400 polyethylene glycol (PEG) is selected as a self-curing specialist. Polyethylene-glycol is an ethylene oxide and water buildup material with the overall equation $HO(C_2H_4O)$ nH, where n is the regular amount of rehashing ox ethylene group from 4 to about 180. Polyethylene glycol 400 is emphatically hydrophilic. Properties are presented in table 5.

TABLE 5. Property of peg 400

S.NO	PROPERTY NAME	PROPERTY VALUE
1	Molecular weight	400
2	Appearance	Clear liquid
3	Nature	Water soluble

F. *Water*

Drinking water is used to test the experimental work to the mixing properties.

G. *Mix proportion*

The mixed concrete design is available for self-compacting concrete (SCC). The blend design for the M60 grade is accomplished using the Nansu method. Super plasticizer is added to the mix weight of cement at a dosage of 1.2 percent in this layout. The fly ash admixtures are added to the blend at 4.87% and PEG 400 at 0, 0.5 to 2% by weight of concrete. Mix properties used for the concrete production are conferred in table 6

TABLE 6. Mix proportion for M60 grade concrete for 1m3

Cement (kg/m^3)	Fly ash (kg/m^3)	FA	CA	Water (lit/m^3)	Super plasticizer (%)
390	120	1100	810	163	1.2

IV. RESULT AND DISCUSSION

I. Workability test

Workability is easy evaluation to place and compact new concrete. it is a complicated combination mix of fluidity, uniformity, transportability, compactness, and stickiness characteristics.

TABLE 7. Test result of workability test

Test	M_1	M_2	M_3	M_4	M_5	M_6
Slump flow test	630	630	635	640	645	650
L-box	0.7	0.7	0.72	0.75	0.78	0.8
V-funnel	15	15	14	13	12	10

II. Mechanical properties

The test outcomes will be conducted for the next 7 days and 28 days. The test results for both water curing (WC) and air curing (CA) at various specimens are observed. The 2000-kn compressors test machine has been used for compression testing, tensile strength and flexural strength.

*i. **Compressive strength***

Table 8 shows compressive strength test results of various dosages of Polyethylene Glycol.

TABLE 8. Test result of compressive strength

Details of the specimen		Compressive strength (N/mm^2)	
		7 days	*28 days*
PEG 0% (WC)	Traditional curing(Water Curing)	47	70.5
PEG 0% (AC)	Traditional curing (Air Curing)	25	37
PEG 0.5%	Self curing	32	46
PEG1%	Self curing	48	71
PEG 1.5%	Self curing	43	63.5
PEG 2%	Self curing	37	55

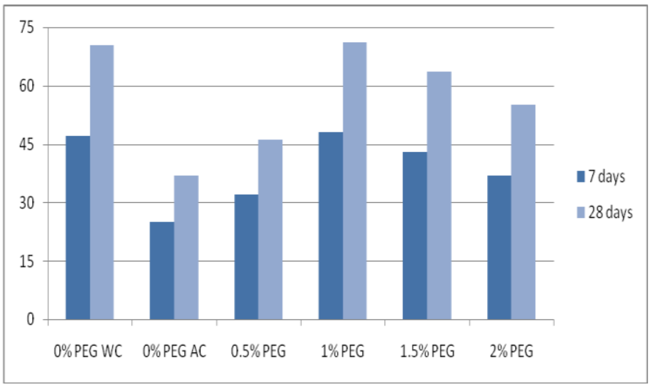

FIG 1. Graphical view for Compressive strength test results

*ii. **Split tensile strength***

Table 9 shows the split tensile strength test result of various dosages of Polyethylene Glycol at 7 days and 28 day.

TABLE 9. Test result of split tensile strength

Details of the specimen		Split tensile strength (N/mm^2)	
		7 days	*28 days*
PEG 0% (WC)	Traditional curing(Water Curing)	4.5	6.5
PEG 0% (AC)	Traditional curing (Air Curing)	3.3	4.6
PEG 0.5%	Self curing	4.2	5.7
PEG1%	Self curing	4.9	6.6
PEG 1.5%	Self curing	4.3	5.9
PEG 2%	Self curing	3.7	5.1

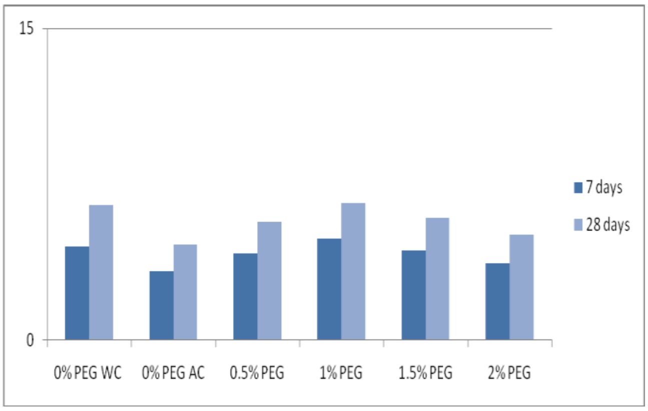

FIG 2. Graphical view for split tensile strength test results.

iii. ***Flexural strength***

Table 8 shows compressive strength test results of various dosages of Polyethylene Glycol.

TABLE 10. Test result of flexural strength

Details of the specimen		Flexural strength (N/mm^2)	
		7 days	*28 days*
PEG 0% (WC)	Traditional curing(Water Curing)	4.79	5.85
PEG 0% (AC)	Traditional curing (Air Curing)	3.5	4.2
PEG 0.5%	Self curing	4.3	4.8
PEG1%	Self curing	4.9	5.89
PEG 1.5%	Self curing	4.5	5.89
PEG 2%	Self curing	4.2	5.21

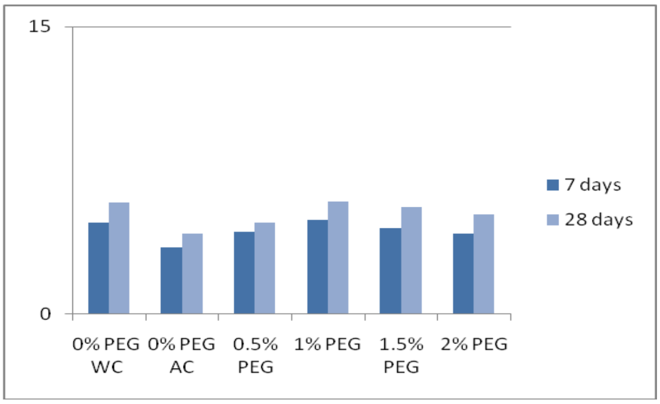

FIG 3. Graphical view for flexural strength test results.

V. CONCLUSION

From the outcomes of this research, the following findings can be observed:

1. The use of self-curing agent in concrete blends increases the strength characteristics of concrete under an air curing system that can be ascribed to better retention of water and causes continuing hydration of cement paste resulting in reduced voids and pores.
2. It has been observed that 2% PEG provides a lower compressive, split tensile and flexural strength compared to 1% PEG, so it is found that adding PEG at a high dose of over 1% of cement would not produce expected strength and would not be practically applicable,
3. Compared to standard curing concrete, setting time of self-compacting self-curing concrete is slow when percentage of PEG increases.
4. In this experiment 1 percent PEG gives better result when compared to 0.5%, 1.5%, 2% of PEG as a self curing agent.
5. Self-curing concrete is an option to conventional cured concrete in desert regions where water shortages are a major problem.

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Durability Properties of Self Compacting Concrete by using M-Sand as Fine Aggregate

V Mallikarjuna Reddy, R Sucharitha

Abstract: ***Self-compacting concrete is also called as self consolidated concrete which does not require vibration for placing and compaction. In the present trend scarcity of natural sand become a huge problem to construction industry, inorder to reduce this problem alternatives are used, one of the alternative material is Manufactured sand. Manufactured sand is produced from hard granite stone by crushing. There are two reasons to M-sand i.e, availability & transportation. An attempt was made to evaluate the workability and strength characteristics & durability properties of self compacting concrete with river sand and manufactured sand as fine aggregates. For each replacement level, constant workability was maintained by varying the dosage of superplasticizer. Sulphate attack and chloride attack of the specimens were determined. Different proportions of solution are used for durability study.***

Keywords: Self compacting concrete, Manufactured sand, Durability.

I. INTRODUCTION

Theconcept of selfcompacting concrete was proposed in 1986 by professor hajime okamura**.** Self-Compacting Concrete was first developed in japan in 1988 .One of the most outstanding advances in the concrete technology over the last decade is “Self Compacting Concrete” (SCC). Self Compacting Concrete is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. To achieve this mineral admixtures such as flyash, GGBS and chemical admixtures like, viscosity modifying agent are used in the mix design of the concrete.

River sand availability is depleting and also affects the ecological balance of the rivers. Manufactured sand is an alternative material to the Natural sand. It was more angular in shape and also cubical, which gives better strength and more interlocking capacity than natural sand. In this experimental work SCC of M60 Grade has been used.

II. MATERIALA

Cement:-

This work is done with Ordinary Portland Cement of 53Grade is used. It confirmed to requirements of IS:12269-1987. Specific Gravity of this Cement is 3.15, fineness of cement is 7.5%, Normal consistency is 29% and initial setting time is 36minuts.

Mineral Admixture:-

Ground Granular Blast furnace Slag (GGBS) is used as mineral admixture for the present work. It is collected from the JSW steel plant which is located near Nadyala. GGBS is highly pozzolanic material. Specific gravity of GGBS is 2.85.

Fig.1 GGBS

Aggregates:-

For conventional mix Natural River sand used as fine Aggregate. M-sand used for replaces the Natural river sand as fine aggregate.

Crushed aggregates of 12mm maximum Size is used as Coarse Aggregate which are angular in shape. Properties of M-sand, River sand and coarse aggregate are as shown in Table.1.

Table.1 Properties of Aggregates:-

Property	River Sand	M-sand	Coarse Aggregate
Bulk Density(kg/m^3)	1530	1580	1505
Specific Gravity	2.65	2.83	2.6
Surface water (%)	0.5	0.5	0.5
Water Adsorption (%)	0.4	5	0.2

Chemical Admixture:-

Super plasticizer from BASF company is used for experimental work. Master Ease 3705 is the Super Plasticizer which is a mixer of Plasticizer and Viscosity Modifying Agent. Viscosity modifying Agents is useful in reduces the Friction between particles and improve Workability of concrete. Super plasticizer is useful to reduce water content as well as improving workability.

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Fig.2 Superplasticizer

Water:-

Portable Water is used in concrete work. Its pH value should not be less than 6 and it should satisfy the requirements as per IS:456-2000.

III. MIX DESIGN

Nan-Su method of mix design is used for SCC mix design. As per final mix design 100% river sand mix is used as conventional mix. Total 5 mixes are test with varying Fine aggregate ratios of River sand and M-sand. M-sand Replaced 25%, 50%, 75% & 100%. Mix ingredients for these mixes are tabulated in Table.2.

Table.2 Material calculation for each mix

Mix	Cement (kg/m^3)	GGBS (kg/m^3)	RS (kg/m^3)	MS (kg/m^3)	C.A (kg/m^3)
100%RS+0%MS	430	150	1012	0	820
75%RS+25%MS	430	150	759	253	820
50%RS+50%MS	430	150	506	506	820
25%RS+75%MS	430	150	253	759	820
100%MS	430	150	0	1012	820

For all mixes water to binder ratio is 0.3 and Super plasticizer content is 1%.

Detailing of Specimen Used:-

A total of 150 specimen are casted where 120 no. of cubes of 100mm side are used for the tests like acid attack & sulphate attackand 30 cubes for both water absorption 28 days normal compressive strength.

IV. EXPERIMENTAL RESULTS

Experimental results consist of both Workability properties and durability properties. Workability tests are conducted as per EFNARC Guidelines and tests are conducted for filling ability, passing ability and Flowing ability and the test results are as shown in Table no.3.

Table.3 Workability test results

Property	Slump (mm)	L-box (ratio)	V-funnel (sec)
100%RS+0%MS	630	0.75	15
75%RS+25%MS	635	0.78	14
50%RS+50%MS	639	0.82	13
25%RS+75%MS	644	0.86	12
100%MS	650	0.89	11

Above showed Workability test results informing that the M-Sand improving the fresh properties of SCC it is due to the presence of high amount of fine particles in manufactured sand.

Durability test:-

All specimens which are casted for this work are cured for 28days in water and then compressive strength of cubes are tested by using the CTM.

Compressive test is conducted on cubes by using CTM and the compressive test results after 28 days curing period are tabulated in Table.4.

Table.4 28days Compressive strength

Mix	strength(MPa)	% increase in strength
100%RS+0%MS	78.2	0.0
75%RS+25%MS	86.6	10.7
50%RS+50%MS	91.3	16.8
25%RS+75%MS	95.1	21.6
100%MS	97.8	25.1

Compressive Strength of Self Compacting Concrete increasing with increasing in %of replacement of River sand with M-sand and 100% replacement of River sand by M-sand is more preferable according to the compressive strength resluts.

Water absorption:-

Water absorption test conducted on all mixes which are various percentages of M-sand as per the code ASTM C1585-13. The cubes which prepared for water absorption test are cured for 28days in water at room temperature. After 28 days of curing cubes are tested various time intervals and their relative increment with respect to initial weights of cubes.The experimental data of water absorption is as shown in below Fig.1. Total 8 different specified time intervals are used.

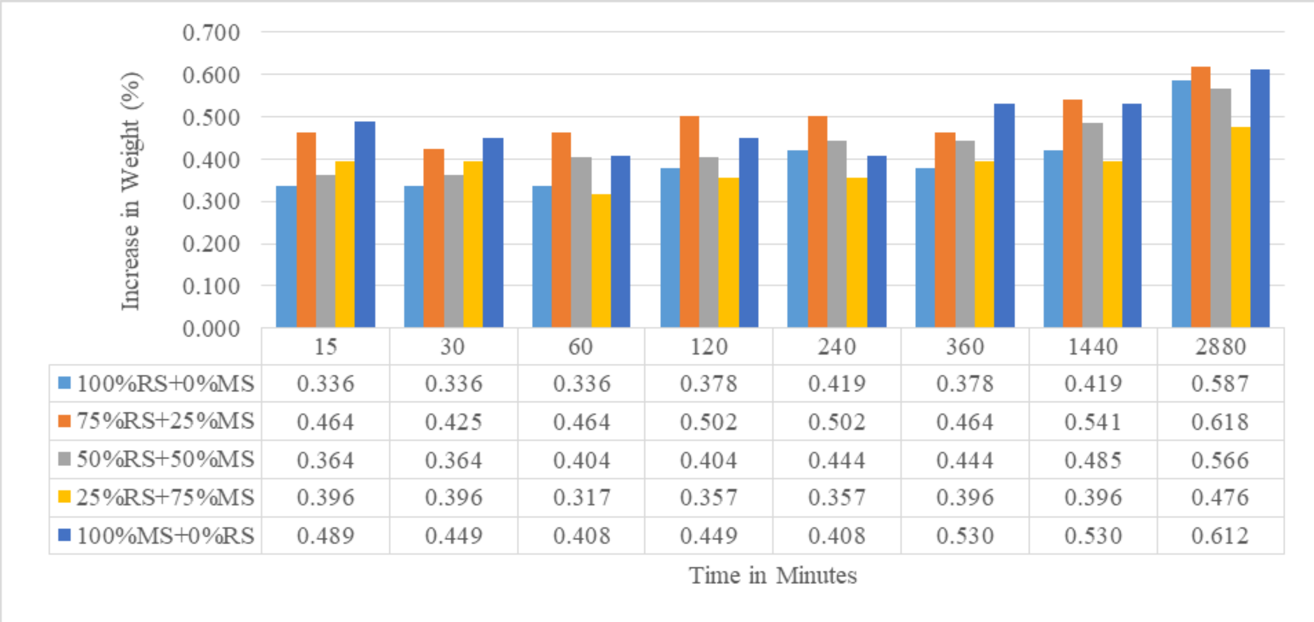

Fig.3Water absorption test data

Acid attack:-

Due to high pH value of concrete in react with acids and loses its cementitious materials. In this process concrete lose its weight and strength. To conduct acid attack test two different acids that are more aggressive acid(H_2SO_4) and less aggressive acid (HCl) with 5% concentration are used. In each acid 28days water cured cubes are immersed for next 28day and 56days. After that specified duration calculated their weight loss and Strength loss according to their 28 days compressive Strength of their corresponding mix. 28days acid attack results are as shown in Table.5& 56days acid attack results are as shown in Table.6.

Table.5 28days acid attack results

Property	5% H_2SO_4		5%HCl	
	Weight loss (%)	Strength loss (%)	Weight loss (%)	Strength loss (%)
100%RS+0%MS	2.721	50.3	0.972	26.06
75%RS+25%MS	4.462	41.14	1.388	26.29
50%RS+50%MS	3.544	51.41	1.149	22.03
25%RS+75%MS	7.983	51.35	1.774	20
100%MS	5.255	40.74	1.213	15.87

According to the 28days acid curing weight loss of mixes increasing when compared to conventional mix where as strength loss decreasing compared to conventional mix. For 28 days curing in both acids conveys that the mix with 100% M-sand as fine aggregate is most suggestible mix.

Table.6 56days acid attack results

Property	5% H_2SO_4		5%HCl	
	Weight loss (%)	Strength loss (%)	Weight loss (%)	Strength loss (%)
100%RS+0%MS	4.02	60.00	1.47	29.94
75%RS+25%MS	6.58	49.14	2.00	32.00
50%RS+50%MS	5.08	55.93	1.71	25.99
25%RS+75%MS	11.25	60.00	2.62	24.00
100%MS	8.00	48.68	1.82	20.00

According to the 56days acid curing weight loss of mixes increasing when compared to conventional mix where as strength loss decreasing compared to conventional mix. For 56days curing in both acids conveys that the mix with 100% M-sand as fine aggregate is most suggestible mix.

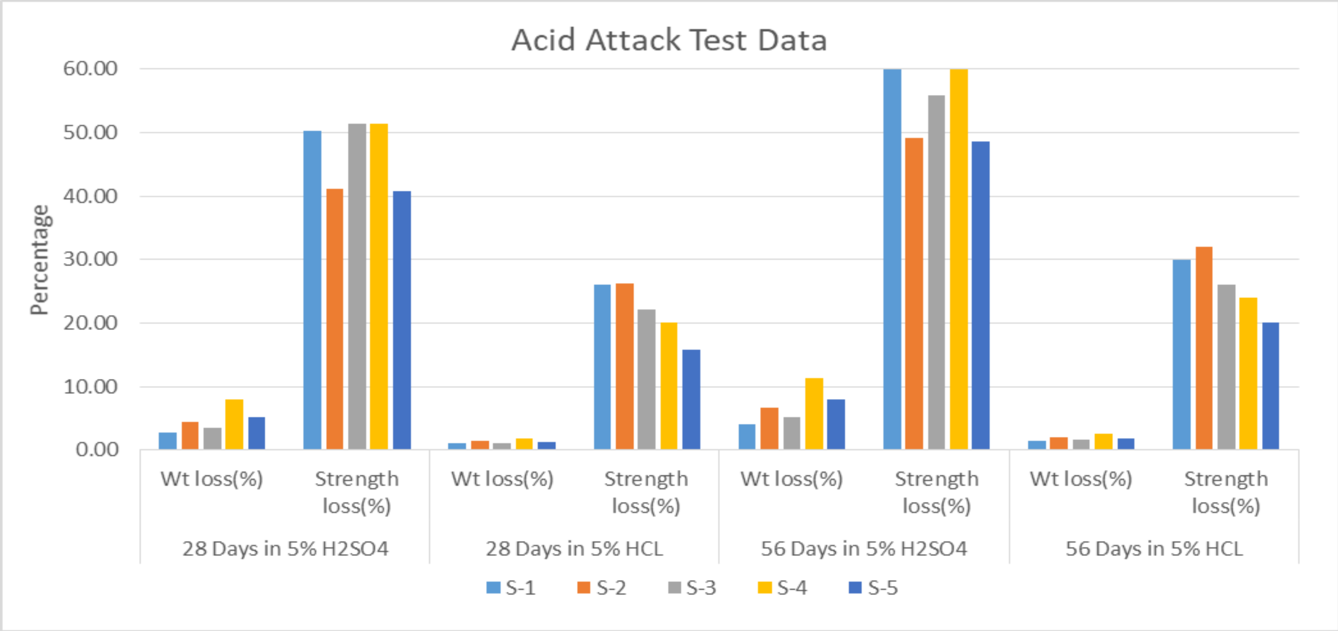

Fig.4 Acid attack Test Data

Sulphate attack:-

Due to Sulphate attack on concrete, cracks produced in concrete and that cracks are filled by the gypsum which is formed by the reaction between sodium sulphate and calcium hydroxide.

Magnesium sulphate ($MgSO_4$) and Sodium sulphate (Na_2SO_4) with 5% concentration are used to conduct sulphate attack. After 28days of water curing cubes are immersed for next 28day and 56days in sulphate solution and then calculated their weight loss and Strength loss according to their 28days water cured compressive Strength. 28days sulphate attack results are as shown in Table.7 &28days sulphate attack results are as shown in Table.8.

Table.7 28days Sulphate attack results

Property	5% Na_2SO_4		5% $MgSO_4$	
	Weight loss (%)	Strength loss (%)	Weight loss (%)	Strength loss (%)
100%RS+0%MS	-0.894	12.12	-0.299	10.91
75%RS+25%MS	-0.308	22.29	-0.289	12.57
50%RS+50%MS	-0.267	1.69	-0.344	16.95
25%RS+75%MS	-0.196	12.43	-0.386	9.19
100%MS	-0.176	4.76	-0.403	8.99

"-ve" sign indicates gain in weight

According to the 28days acid curing test data mixes gained the weight and gain percentage is high for 100% river sand mixed concrete and very low for 100% M-sand mixed concrete for 5% Na_2SO_4 solution where as weight gain is more for 100% M-sand mixed concrete when the solution is 5% $MgSO_4$. Strength loss is decreasing with increasing percentage of replacement of river sand by M-sand for both the sulphate solutions.

Table.8 56days Sulphate attack results

Property	5% Na_2SO_4		5% $MgSO_4$	
	Weight loss (%)	Strength loss (%)	Weight loss (%)	Strength loss (%)
100%RS+0%MS	-0.65	14.55	-0.33	14.91
75%RS+25%MS	-0.32	19.43	-0.41	19.43
50%RS+50%MS	-0.30	6.21	-0.20	5.54
25%RS+75%MS	-0.24	14.70	-0.28	13.73
100%MS	-0.26	5.50	-0.20	5.61

"-ve" sign indicates gain in weight

According to the 56days acid curing test data mixes gained the weight and gain percentage is high for 100% river sand mixed concrete and very low for 100% M-sand mixed concrete for 5% Na_2SO_4 solution where as weight gain is more for 100% M-sand mixed concrete when the solution is 5% $MgSO_4$. Strength loss is decreasing with increasing percentage of replacement of river sand by M-sand for both the sulphate solutions.

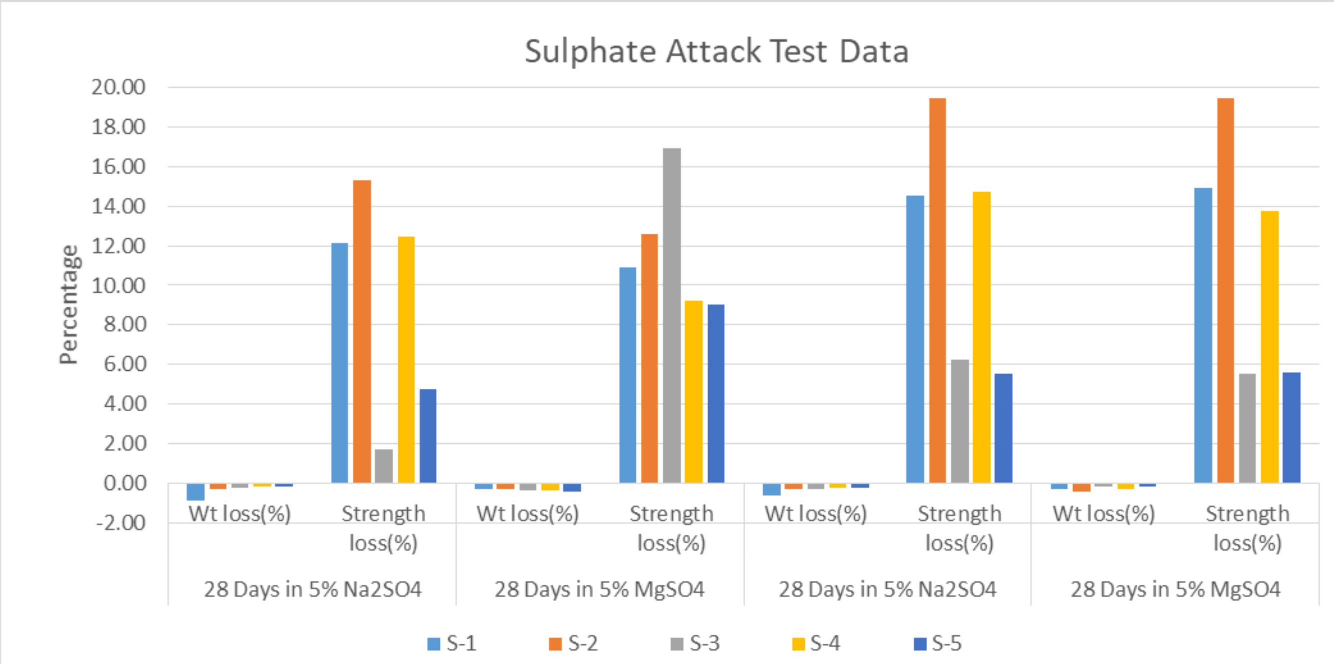

Fig.5 Sulphate attack test data

V. CONCLUSION

Based on the above experimental results the following conclusions were drawn;

- Compared to River sand, M-sand having high amount of fine particles and it increasing workability of SCC.
- Strength of concrete increasing with increasing percentage replacement of river by M-sand due to its interlocking capacity.
- Water absorption is slightly more for M-sand mixed SCC when compare to River sand mixed SCC
- M-sand providing better resistance against both acid attack and sulphate attack when compare to river sand.
- All durability test are providing the info that SCC mix with 100% M-sand as fine aggregate is preferable.

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Effect of Elevated Temperatures on Fiber Reinforced Self Compacting Concrete

V. Mallikarjuna reddy, S. Vasanthi

ABSTRACT: The present investigation is mainly focused on study the temperature effects on SCC reinforced with steel fibers on M40 grade of concrete. The main objective of the investigation is inspired from the real world - to know the strength of a concrete after subjected to an elevated temperature. Steel fibres with an aspect ratio of 40varied at a fibre dosage of 0, 1, and 1.5%by the weight of the cement used in this investigation. In this study concrete is exposed to five different residual conditions. In addition to the room temperature there are four different temperatures of 100˚c, 300˚c, 500˚c and 800˚c are considered at a retention period of 1, 2, 3 and 4 hours in muffle furnace. Compressive strength conducted after 28 days of curing. From the experimental results it is observed that SCC with steel fibres reduced the workability on the contrary there is increase in compressive strength observed with the addition of fibres. It is also observed that SCC with steel fibres has shown the better performance compared to control mix at elevated temperatures. This is mainly due to fibres are participated in delaying the cracks.

Keywords: Self compacting concrete, Steel fibres, High Temperatures.

I. INTRODUCTION

The difficulties in concreting at congested reinforcement areas can be achieved by self-compacting concrete (SCC) due to SCC has an ability to flow under its own weight [1]. SCC usually considered as high performance concrete due to its properties like low yield stress, high deformability, good segregation resistance and moderate viscosity [2]. Shortcoming of SCC like poor resistance to crack growth and spalling tendency under fire conditions are limiting the usages in structures like buildings, bridges and tunneling etc., [3]. These shortcomings can be achieved by the addition of polypropylene (PP) fibres to the concrete. Because of low reinforcing efficiency PP fibres can arrest the crack growth and spalling effect of concrete subjected to elevated temperatures [4]. SCC reinforced with PP fibres improve the properties of concrete but the improvement is limited in extent. Because of low young's modulus and low tensile strength these fibers can only effective in low stress levels only [5].

Concrete reinforced with steel fibers known to improve the crack resistance and energy absorption capacity at pre-peak and post-peak portions of concrete [6]. But the effect of steel fibers at elevated temperature to be studied. since the most of the studies are conducted on SCC reinforced with PP fibers [7]. Thus the study is aimed to investigate the mechanical properties of SCC reinforced with steel fibers. Steel fibers of length 20mm and diameter 0.5mm used in this study.

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II. EXPERIMENTAL PROGRAM

2.1Materials used for SCC

2.1.1 Cement:

Ordinary Portland cement of 53 grade confirming to IS 12269 [8] is used for the entire work. Cement having a Specific gravity, fineness and normal consistency are 3.15, 7% and 28% respectively. Initial and final setting time is 35min and 450min

2.1.2 Fly ash:

Ultra-fine pozzolana which is called as P500 is used as a mineral admixture shown in figure 1. Specific gravity of P500 is 2.18, mean particle size is 3.9-5.0, surface area is 13000sqcm/kg.

Fig.1 Ultra-fine pozzolana (P500)

2.1.3 Aggregates:

Locally available Crushed angular aggregate confirming to IS 383 [9] of maximum size 12mm used as coarse aggregate. Natural river sand is used as fine aggregate which is confining to zone-2. Properties of fine and coarse aggregates represented in Table.1

Table.1 properties of aggregates

Property	Fine aggregate	Coarse aggregate
Bulk Density(kg/m^3)	1560	1502
Specific gravity	2.7	2.6
Surface water (%)	0.5	0.5
Water adsorption (%)	0.4	0.2

All the above tests are conducted as per IS: 2386(part-3)1963 [10].

2.1.4 Chemical admixture:

Glanium B-233 is used as super plasticizer to develop SCC Mix. which is having specific gravity of 1.1, density is 1090kg/m3. It is a product of BASF Company. It is in light brown color. It is a mixture of VMA (viscosity modifying agent) and plasticizer. For all the mixes water binder ratio fixed as 0.3 and the super plasticizer is fixed as 1% by the weight of cementious material is used.

Fig.2 Superplasticizer

2.1.5 Fibres:

Steel fibres of length 20mm with a diameter of 0.5mm used as a reinforcing material to arrest the growth of micro and macro cracks. The percentage of steel fibre is considered as 0, 1 and 1.5% by the weight of cement.

2.1.6 Water:

Portable water is used for mixing of concrete which is free from impurities and having P^H should not be less than 6, it should be satisfy the requirements as per IS:456-2000 [11].

2.1.7 Mix design

The mix design for M40 grade is obtained by using nansu method of mix design. The final mix is used as conventional mix (without fibres). By adding fibres of 1% and 1.5% by weight of cementious material to the conventional mix to develop mix1 and mix2. Mix proportions are presented in table 2.

Table.2 Mix proportions for M40 grade per cubic meter

s.no	Material	Control Mix	MIX 1	MIX 2
1	Cement(kg/m^3)	350	350	350
2	P500 (kg/m^3)	120	120	120
3	F.A (kg/m^3)	920	920	920
4	C.A (kg/m^3)	808	808	808
5	Steel fibres(kg/m^3)	0	4.7	7.05

III. EXPERIMENT METHODOLOGY

3.1 Workability:

There are three properties to be achieved for SCC i.e., filling ability, passing ability, flowing ability as per the guidelines of AFNOR specifications. Different tests are conducted to determine the workability they are slump flow, L-box, V-funnel tests. It is observed that The addition of steel fibres to fresh SCC will slightly reduce the flow ability or workability.

3.2 Casting and specimens used

The 100×100mm cubes were used for the compressive tests. The fibres were added gradually to attain a uniform distribution with a mix. For three mixes total 153 specimens are used. Samples were demoulded after 24hrs and stored in a curing tank for 28 days. Finally, concrete samples were stored at room temperature to maintain humidness and temperature conditions until they were submitted to a testing.

3.3Thermal treatment

The samples were weighted before placing in the furnace. The samples with and without fibres are tested. In addition to room temperature there are four different temperatures were considered namely 100^{0}c, 300^{0}c, 500^{0}c and 800^{0}c along with various intervals i.e., 1hr, 2hrs, 3hrs and 4hrs are tested. The rate heating maintained as 200c/min is shown in figure.3.

Fig.3 Muffle Furnace

3.4 Results and discussion:

Mass loss

The samples were weighted before and after subjected to elevated temperatures. Weight loss is calculated at 100^{0}c, 300^{0}c, 500^{0}c and 800^{0}c respectively. The weight loss of concrete mix is shown in table.3 and figure.4.

Table.3: Mass loss in % for Various durations at different Temperatures

		Mass loss in %			
Mix	**Duration**	**100**	**300**	**500**	**800**
C.M	1 Hour	1.74	4.43	4.87	5.8
	2 Hour	2.84	1.98	4.67	6.11
	3 Hour	2.56	4.31	4.69	5.9
	4 Hour	0.4	0.04	4.85	5.58
Mix-1	1 Hour	1.18	3.68	3.31	4.73
	2 Hour	1.5	4.03	3.59	5.21
	3 Hour	2.02	3.91	3.79	5.46
	4 Hour	2.38	4.12	4.28	4.82
Mix-2	1 Hour	0.62	3.53	4.43	4.31
	2 Hour	0.62	4.25	4.5	4.57
	3 Hour	1.44	4.25	4.63	6.68
	4 Hour	1.59	3.6	4.43	3.42

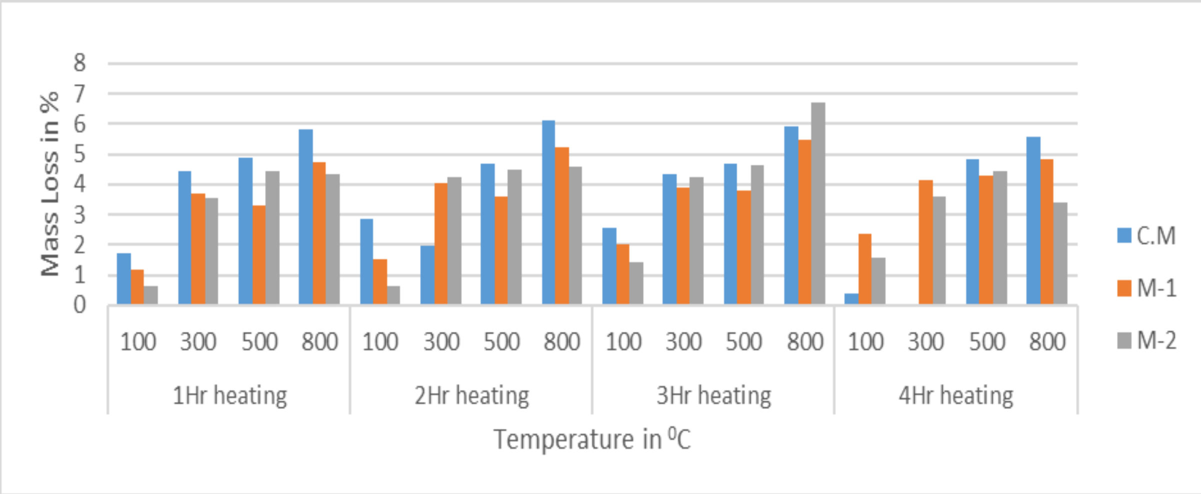

Fig.4 Mass loss in % for Various durations at different Temperatures

The experimental results show that mass loss in conventional mix is more than the other two mixes & mix-1 with 1% fibres having less variation in mass loss for varying high temperatures from 300^0c and 800^0c at any duration whereas mix-2 with 1.5% fibres having irregular variations.

Strength loss

For each mixture up to 300^0c the strength loss of the specimen is decreasing. It is also observed that strength loss of a concrete mix is more when specimen is subjected elevated temperature greater than 300^0c. If the exposure of the specimen is below 300^0c then the preferable mixture is C.M and if it is exposed to more than 300^0c the preferable mixture is M-2. Results are presented in figure 5 and table 4.

Table.4: Strength loss in % for Various durations at different Temperatures

Strength loss in %					
Mix	Duration	100	300	500	800
C.M	1 Hour	0.79	42.86	38.89	80.95
	2 Hour	3.97	7.94	0	82.54
	3 Hour	-3.97	-3.17	33.33	79.37
	4 Hour	-4.76	-11.11	0	76.19
Mix-1	1 Hour	7.69	-2.31	19.23	58.46
	2 Hour	3.85	4.62	11.54	63.08
	3 Hour	16.15	6.92	26.15	76.15
	4 Hour	-5.38	7.69	34.62	73.85
Mix-2	1 Hour	16.67	2.9	26.09	52.9
	2 Hour	21.01	-2.9	32.61	67.39
	3 Hour	25.36	-5.07	39.13	70.29
	4 Hour	8.7	-4.35	34.78	73.91

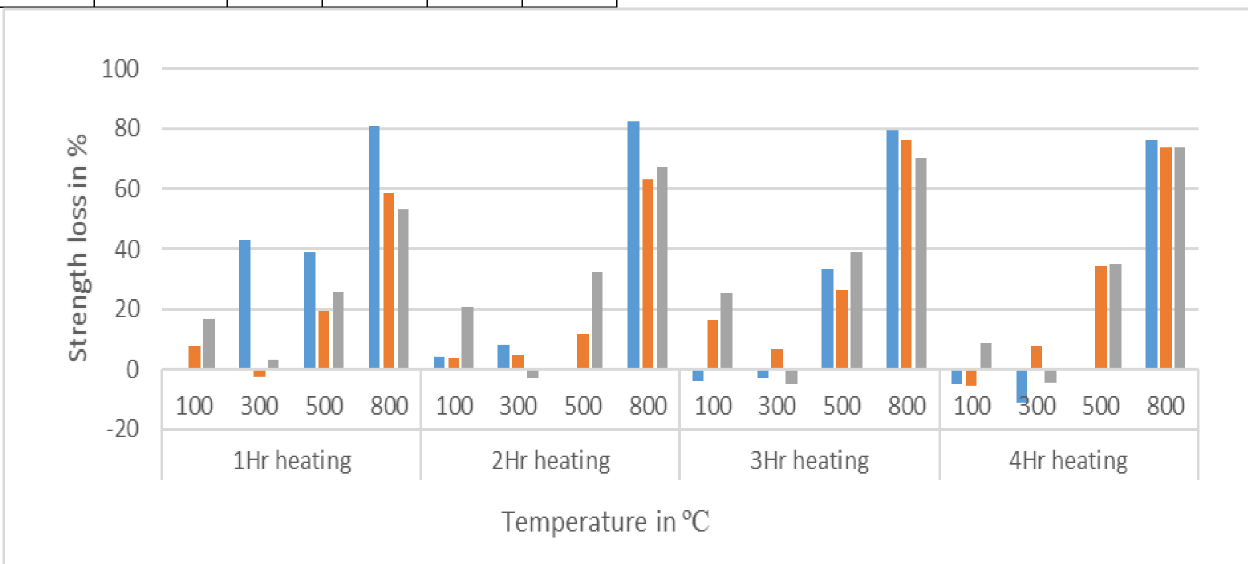

Fig.5 Strength loss in % for Various durations at different Temperature

Up to 300^{0}c Conventional Mix Strength is increasing with duration and further increasing in Temperature strength is decreasing drastically where as other two mixes losing their strengths gradually with increasing Temperature for each duration.

IV. CONCLUSION

As per the study and the experiments conducted to know the compressive strength of fibre reinforced self-compacting concrete with respect to the elevated temperatures. The fibres are mixed at a rate of 0%,1%, and % with binder materials. Thus three mixtures are formed which are conventional mix, Mix-1 and Mix-2. When these three mixtures are exposed to elevated temperatures such as 100^{0}c, 300^{0}c, 500^{0}c and 800^{0}c at an interval of 1,2,3,4.

Upon the processing the same the conclusions regarding the weight loss and strength loss are- it is observed that the weight loss is relative with respect to the temperatures mentioned. Regarding compressive strength loss- strength loss is decreasing when the specimen is exposed to up to 300^{0}C and increasing when the specimen is exposed to more than 300^{0}C. And so the preferable mixtures would be varying with respect to the exposure.

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Pcc Constituents Quantification Through Partial Replacement of Fine Aggregate And Cement

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Abstract: ***The paper aim is to acknowledge the use of Quartz Sand (silica sand) & Metakaolin in replacement of natural sand and cement. As the natural sand is depleting at an alarming rate due to perpetual mining and on other side the emission of co2 from production of cement causing global warming. The M30 grade is prepared as well as evaluated for strength characteristics viz. split tensile, compressive and flexural. Ordinary Portland cement is replaced with metakaolin at 0,10,20,30,40 and 50%, while the fine aggregate is replaced with Quartz sand at 40% constant by weight. The specimens are casted and tested for split tensile, compressive and flexural strengths after curing for 7,14,28 days.***

Keywords- ***Quartz sand, Metakaolin, Conventional concrete, Partial replacement, Physical properties.***

I. INTRODUCTION

Concrete, the most far-flung man-made material on planet. The cement industry is one of the primary producers of CO2. In 2018 the cement produced in India is 290 million metric tons and 4250 million metric tons worldwide. The excessive sand mining causes the degradation of rivers which leads to increased flooding and threat to biodiversity. This both leads to global warming and environmental pollution to overcome these issues the usage of Metakaolin to decrease the consumption of cement and Quartz sand to decrease the consumption of sand must be adopted without compromising in strength of concrete. Metakaolin is the white powder of A.2Si by dehydrating kaolin (Al2O3 2SiO3.2H2O) at an acceptable temperature (700-900oC). kaolin is in a very stratified silicate structure, with the layers binding with one another via the Vander Weal's bond, among that "O" is bound determinedly. When Kaolin is heated in air it might undergo many structural changes and heated to around 600^{o}C its superimposed structure will be broken because of dehydration and makes a transient phase with poor crystallinity. The resultant material is called metakaolin. It has irregular arrangement in molecular structure having thermodynamic meta-stable condition and cementitious beneath a satisfactory excitation. With this exalted activity, it is used to production of cementitious materials and elevated strength superior concrete mix. The most prominent sand making material is quartz as it is resistant to different weathering conditions. Sand which has enriched quartz is probably going conventional and has moved off from the source region to several kilometres. It takes longer duration for breakdown of weaker minerals of rocks by phenomena of weather. Sand having this sort of mineral grains from source rocks have formed many years ago and have seen many lithification and weathering cycles. The preceding researches observed better results when the cement and quartz with Metakaolin and subtle aggregate respectively in concrete. In the present work an attempt was made to study mechanical properties of M30 grade concrete with the above replacements. In preceding research, quality of sand made concrete degraded as replacement level increases [1]. The effect of adding metakaolin overshoot the strength of OPC mixes [2]. In some journals they concluded that the optimum usage of metakaolin gives the great result compared to conventional concrete [3]. It was observed that the split tensile strength and flexural strength development in the concrete had similar tendency with compressive strength i.e. the strengths are directly proportional to each other [4]. The better strengthen results were observed by replacement of sand with robo-sand [5]. The various strength characteristics of concrete were improved by the adding 2% of nano silica & 5% of metakaolin [6].

II. MATERIAL CHARACTERISTICS

The different materials and their characteristics were observed such that better concrete mix results can be obtained with combinations

A. Cement

53 grade OPC was used for all the concrete mixes conforming to IS12269:1987.

Table- I: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Fineness modulus	0.16
2	Specific gravity	3.15
3	Initial setting time	30 min
4	Final setting time	450 min

B. Fine Aggregate

For fine aggregate, sand of river was used conforming to IS383:1970

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Table- II: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Bulk density	4.13
2	Specific gravity	2.63
3	Fineness modulus	2.76

C. Coarse Aggregate

For coarse aggregates,20mm Crushed angular aggregates were used conforming to IS383:1970

Table- III: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Fineness modulus	6.42
2	Specific gravity	2.6
3	Water absorption	1.10

D. Quartz Sand

The crushed powder of Quartz rock is taken from the local manufacturer. The micro filling effect of quartz sand improves the particle packing of concrete.

Table- IV: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Fineness modulus	2.7
2	Specific gravity	2.65

Table- V: Chemical Properties

S.NO.	PROPERTY	PERCENTAGE
1	SiO_2+Ai_2O_3+Fe_2O_3	99.53
2	CaO	0.11
3	So_3	0.17
4	Ko	0.07
5	Cl	0.02
6	Na_2O	0.1
7	Loss of Ignition	1

E. Metakaolin

It is the calcined form of kaolinite which is also known as china clay. The Metakaolin was obtained from the supplier ASTRRA Chemicals, Chennai.

Table- VI: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Bulk density	0.45
2	Specific gravity	2.5

Table- VII: Chemical Properties

S.NO.	PROPERTY	RESULT
1	Sio_2	58.3
2	Al_2O_3	34.3
3	Fe_2O_3	4.29
4	CaO	0.38
5	MgO	0.08
6	Na_2O	0.12
7	K_2O	0.05

F. Super Plasticizer

To increase the workability of concrete super plasticizer was used. The super plasticizer used in the experiment was RHEOBUILD 920SH. As per IS9103-1999. The super plasticizer was used 1% of binder and the specific gravity is 1.20.

G. Mix Proportion

The mix proportion for the present study designed as per 10262-2009 is 1:2.17:3. Water/cement ratio is 0.43 The concrete mixes used in the study are

MQ0 – conventional mix

MQ1 – [90% cement + 10% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ2 – [80% cement + 20% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ3 – [70% cement + 30% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ4 – [60% cement + 40% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ5 – [50% cement + 50% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

III. EXPERIMENTAL RESULTS

A. Compressive Strength

The ability of the material to withstand loads which tends to reduce size. Table 9 shows the effects of metakaolin and quartz sand on 7,14 &28 days strengths.

Table- VIII: compressive strength test results

Mix design	Proportion	Compressive strength N/mm^2		
		7days	14days	28days
MQ0	0% M 0% Q	26	36	39
MQ1	10% M 40% Q	28.2	39	41.1
MQ2	20% M 40% Q	30.5	42.2	43.8
MQ3	30% M 40% Q	23.3	32.3	36.1
MQ4	40% M 40% Q	19.1	26.5	32.3
MQ5	50% M 40% Q	16.9	23.4	30.4

M-metakaolin Q-quartz sand

The results of compressive strengths show that the compressive strength increased when the metakaolin increased up to 20% and quartz sand 40%. After that the compressive strength is decreased when the

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metakaolin is increased above 30%. It was clear that the metakaolin and quartz sand influence the strength significantly.

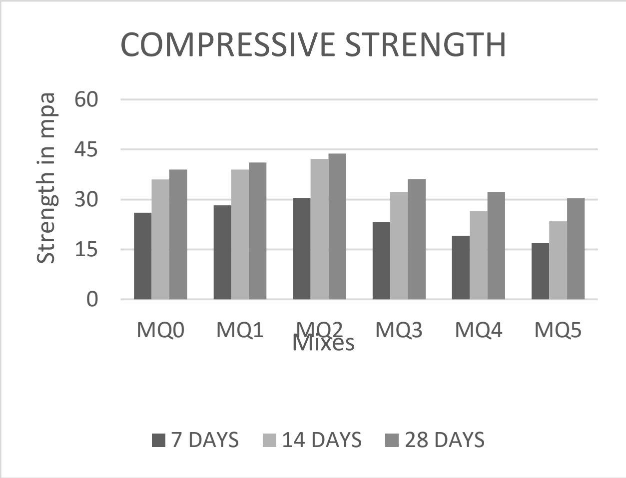

Fig.1 Compressive Strength Results

B. Split Tensile Strength

Ability of the concrete to withstand loads which tend to elongate without breaking. Table 10 shows the effects of metakaolin and quartz sand on 7,14 & 28 days split tensile strength of concrete.

Table- IX: split tensile strength test results

Mix design	Proportion	Split Tensile strength		
		7days	14days	28days
MQ0	0% M 0% Q	2	2.8	3.2
MQ1	10% M 40% Q	2.2	3.1	3.4
MQ2	20% M 40% Q	2.5	3.5	3.7
MQ3	30% M 40% Q	2.1	2.8	3.3
MQ4	40% M 40% Q	1.9	2.6	3
MQ5	50% M 40% Q	1.7	2.45	2.7

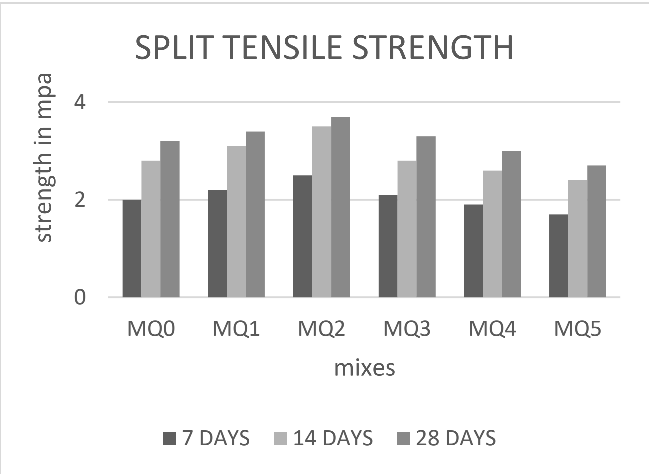

Fig.2 Split Tensile Strength Results

The results of Split tensile strengths show that the tensile strength increased when the metakaolin increased up to 20% and quartz sand 40%. After that the tensile strength is decreased when the metakaolin is increased above 30%. It was clear that the metakaolin and quartz sand influence the strength significantly

C. Flexural Strength

The ability of beam to resist failure in bending. Table 11 shows the effect of metakaolin and quartz sand on 7,14 &28 days flexural strength of concrete.

Table- X: flexural strength test results

Mix design	Proportion	Flexural strength		
		7days	14days	28days
K0	0% M 0% Q	2.9	4.1	4.5
K1	10% M 40% Q	3.1	4.3	4.7
K2	20% M 40% Q	3.2	4.5	5
K3	30% M 40% Q	2.9	4	4.4
K4	40% M 40% Q	2.8	3.9	4.3
K5	50% M 40% Q	2.5	3.5	3.9

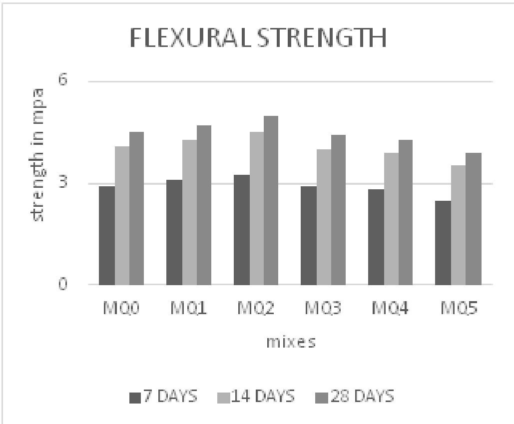

Fig.3 Flexural Strength Results

The results of flexural strengths show that the tensile strength increased when the metakaolin increased up to 20% and quartz sand 40%. After that the flexural strength is decreased when the metakaolin is increased above 30%. It was clear that the metakaolin and quartz sand influence the strength significantly

IV. CONCLUSION

The incorporation of 20% metakaolin and 40% quartz sand is found advantageous (43.8 MPa) for 28 days. Compared to conventional concrete the strength increased 12% for K2 mix. The combination of 20% metakaolin and 40% quartz sand is found peerless for split tensile for 28 days. The K2 split tensile mix was increased 14% compared to conventional concrete. The mix K2 with 20% metakaolin and 40% quartz sand is found beneficial for flexural for 28 days. An improvement of 15% was observed in flexural than conventional concrete. As per the test results it was noticed that split tensile as well as flexural strengths of concrete had similar liabilities with compressive strength. The strengths are directly proportional to each other.

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EVALUATION OF CEMENTING EFFICIENCY IN QUATERNARY BLENDED SELF-COMPACTING CONCRETE

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ABSTRACT

The contribution of metakaolin (MK) to any property of hardened concrete may be expressed in terms of efficiency factor, k. For this new material to be generally accepted by the building industry, a good durability must be proven also in quantitative terms. Therefore a big challenge for researchers within this field is to determine the strength efficiency of metakaolin (MK) in binary, ternary and quaternary blended SCC mixes. For calculating the efficiency of Metakaolin, microsilica and fly ash combination in binary and ternary blended SCC, an equation has been proposed by author based on the principle of Bolomey's equation for predicting the strength of concrete containing mineral admixtures. The strength efficiency factor 'k' is evaluated for three cases in quaternary blended SCC mixes: (1) micro silica (MS) is singly blended in SCC, (2) micro silica (MS) is blended with fly ash (FA) in SCC and (3) Metakaolin (MK) is blended with micro silica (MS) and fly ash (FA) SCC mix. The computed efficiency factors may be incorporated in the design of a blended concrete mixture, a method known as rational proportioning. The k value can be used to transform a certain amount of pozzolan to an equivalent amount of cement in terms of strength contribution; hence, it can be used as a basis for a more efficient proportioning of blended SCC mixes.

Key words: metakaolin, strength efficiency factor, cementing efficiency factor, quaternary blended SCC, Self-compacting concrete.

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1. INTRODUCTION

The cementing efficiency factor, '*k'* of a pozzolanic material is defined as the number of parts of cement in a concrete mixture that could be replaced by one part of pozzolanic material without changing the property being investigated, which is usually the compressive strength. The efficiency factor for strength performance of a pozzolanic material is calculated on the basis of comparison between concrete strength and the w/c ratio for a non-blended mixture and a blended mixture. The efficiency factor is used for proportioning of blended concrete. A rational method of proportioning fly ash concrete was first proposed by Smith, in which the fly ash cementing efficiency factor, '*k'* was defined in such a way that the strength to water cement ratio relation for normal concrete is also valid for ternary and quaternary blended SCC mixes considering the effective water cement ratio, as given by [$W/(C + kP)$], where W is the weight of water in kg/m^3, C is the weight of cement in kg/m^3, P is the weight of blended pozzolanic material. For the optimally blended binary, ternary and quaternary Self Compacting Concrete (SCC) mixes, cementing efficiencies (k) are evaluated to highlight the synergic action of blended pozzolans in SCC mixes of all grades.

2. LITERATURE REVIEW

Bharat Kumar et al. (2001) proposed a method of mix proportioning for concrete containing mineral admixture (MA) by using Bolomey's equation for predicting strength. In their studies, a relative strength-based method to obtain efficiency values for strength performance is used. Malathy and Subramaniam (2007) used the above method to find the efficiency factor of silica fume and metakaolin in their binary mix by using following equation:

$$k = (1/P)\ \{-C + W\ (fc - A2) / A1\}$$

where fc is compressive strength of concrete in MPa, C is the cement content in kg/m^3,W is the water content in kg/m^3 and $A1$, $A2$ are constants influenced by ingredients, curing conditions and age of concrete. Efficiency factor increases with age which shows the activation of pozzolanic activity of mineral admixtures with time. K Ganesh Babu and V Sree Rama Kumar (2000) evaluated efficiency of various Supplementary Cementitious Materials (SCM) such as GGBS, silica fume, fly ash in concretes. As per their studies the overall strength efficiency was found to be a combination of general efficiency factor (depending on the age) and a percentage efficiency factor (depending upon the percentage of replacement), as was the case with a few other cementitious materials like fly ash and silica fume reported earlier. H S Wong, H Abdul Razak (2004), proposes an alternative approach for the evaluation of efficiency factor k of a pozzolanic material. The method, developed following Abram's strength–W/C ratio rule, calculates efficiency in terms of relative strength and cementitious materials content. Juma Sultan Al Rezaiqi (2011) reports the evaluation of the cementitious efficiency of Cement Kiln Dust (CKD), Sarooj clay (SA) and Copper Slag (CS) in concrete at different replacement percentages. Diego Aponte, Marilda Barra, Enric Vázquez (2012) presents the cementing efficiency of high lime fly ash with regards to mechanical and durability properties. The investigated variables were the rate of the incorporation of fly ash, the cement type, the water/cement ratio, and the curing age of the mix. Two cementing efficiency factors were determined; (i) in terms of the compressive strength, (ii) in terms of the chlorides diffusion coefficient. Both of them have been determined in relation to the water/cement ratio. The result shows that the cementing efficiency is strongly influenced by the water/cement ratio. Kanchan Mala, A K Mullick et al. (2013) proposed new method to find the efficiency factor of SF and FA individually in ternary blend cement system, based on principle of modified Bolomey's equation for predicting compressive strength of concrete using binary blend cement system. Efficiency factor for SF and FA were always higher in ternary blend cement system than their respective binary blend cement system.

3. MIX PROPORTION

Quantities required for 1 cu.m are evaluated for ordinary grade (M20) , standard grade (M40) and high strength grade (M80 and M100) of binary, ternary and quaternary blended Self-Compacting Concrete (SCC) made with optimum proportions of Fly Ash (FA), Microsilica (MS) and Metakaolin (MK) combination based on calculations from Nan Su mix design method. Final quantities, for all SCC mixes considered, are assumed after several trial mixes on quantities computed using Nan Su mix design method subjected to satisfaction of EFNARC flow properties and are tabulated in Table 1

Table 1 Final optimized mix proportions of blended SCC mixes for various grades

Grade of SCC Mix	Mix No	Mix Designation (Values indicate percentage by weight of 'P'	% of FA Added bwp*	Quantities in kg / cu.m									
				OPC (i)	FA (ii)	MS (iii)	MK (iv)	Total Powder Content 'P' kg (i)+(ii)+(iii)+(iv)	Fine Aggregate	Coarse Aggregate	Water	S.P.	W/P ratio
M20	C1	C100	-	486	-	-	-	486	904	812	221	9.5	0.45
	B2	C50+FA50	-	243	243	-	-	486	904	812	221	9.5	0.45
	B7	C80+MS20	-	389	-	97	-	486	904	812	221	9.5	0.45
	B13	C75+MK25	-	365	-	-	121	486	904	812	221	9.5	0.45
	T3	C35+FA50+MS15	-	170	243	73	-	486	904	812	221	9.5	0.45
	T15	C25+FA60+MK15	-	123	290	-	73	486	904	812	221	9.5	0.45
M40	C1	C100	-	531	-	-	-	531	891	786	185	9.5	0.35
	B1	C60+FA40	-	319	212	-	-	531	891	786	185	9.5	0.35
	B5	C85+MS15	-	452	-	79	-	531	891	786	185	9.5	0.35
	B10	C80+MK20	-	425	-	-	106	531	891	786	185	9.5	0.35
	T5	C50+FA40+MS10	-	265	212	54	-	531	891	786	185	9.5	0.35
	T9	C35+FA50+MK15	-	186	265	-	80	531	891	786	185	9.5	0.35
M80	B2	C95+MS5	-	665	-	35	-	700	714	658	167	12.5	0.25
	T3	C65+FA20+MS15	-	455	140	105	-	700	714	658	167	12.5	0.25
	Q11	C50+FA28+MS11+MK11	30	455	259	98	98	910	714	658	167	12.5	0.25
M100	B2	C90+MS10	-	630	-	70	-	700	689	636	154	16.0	0.22
	T2	C71+FA19+MS10	-	500	130	70	-	700	689	636	154	16.0	0.22
	Q11	C55+FA23+MS11+MK11	30	500	214	98	98	910	689	636	154	16.0	0.22

4. COMPRESSIVE STRENGTH

The compressive strength of binary, ternary and quaternary blended SCC mixes of ordinary grade (M20), standard grade (M40) and high strength grade (M80 and M100) made with Fly Ash (FA), Microsilica (MS) and Metakaolin (MK) at 3,7,14,28, 60 and 90 days is recorded and presented in Table 2.

Table 2 Compressive Strengths of various grades of optimally blended SCC mixes

Grade of SCC Mix	Mix No	Mix Designation (Values indicate percentage by weight of Total Powder)	Compressive Strength (MPa)					
			3 days	7 days	14 days	28 days	60 days	90 days
M20	C1	C100	10.07	16.36	20.15	25.18	25.34	27.68
	B2	C50+FA50	5.78	11.60	17.39	20.29	28.98	32.24
	B7	C80+MS20	11.61	18.87	26.13	29.03	32.13	33.24
	B13	C75+MK25	18.54	20.16	27.70	33.77	34.35	35.12
	T3	C35+FA50+MS15	9.10	16.22	20.19	22.13	29.37	32.81
	T15	C25+FA60+MK15	15.67	19.88	23.12	27.11	33.29	36.87
M40	C1	C100	20.36	33.32	39.73	48.18	50.19	53.10
	B1	C60+FA40	12.83	21.75	28.61	43.35	53.60	56.78
	B5	C85+MS15	25.77	31.89	42.01	51.99	54.23	57.96
	B10	C80+MK20	41.16	44.76	51.49	53.73	55.41	58.19
	T5	C50+FA40+MS10	20.20	26.01	34.82	44.56	52.13	59.87
	T9	C35+FA50+MK15	34.79	40.13	47.33	49.22	52.37	59.92
M80	B2	C95+MS5	35.43	57.56	78.71	88.56	91.22	93.19
	T3	C65+FA20+MS15	26.18	50.12	65.98	83.17	90.54	94.51
	Q11	C50+FA28+MS11+MK11	50.02	64.19	81.10	85.26	90.71	97.16
M100	B2	C90+MS10	42.11	65.80	92.13	106.04	107.81	109.11
	T2	C71+FA19+MS10	40.51	65.32	81.04	95.31	104.20	111.83
	Q11	C55+FA23+MS11+MK11	66.12	78.32	87.18	93.14	110.71	113.28

bwp* – By weight of Total Powder Content ; W/P ratio – Water/Powder Ratio

5. CEMENTING EFFICIENCY FACTORS

The effect of synergic action of metakaolin (MK), microsilica (MS) and fly ash (FA) combination on the strengths of binary, ternary and quaternary blended SCC may be modelled by using a Cementing Efficiency Factor (k). The Cementing Efficiency Factor is defined as the ratio of the cementing efficiency of blended SCC to the cementing efficiency of the reference SCC. It was observed that this overall strength efficiency of blended SCC was found to be a combination of efficiency factor 'k_a' depending on the age and efficiency factor 'k_p' depending upon the percentage of SCM replacement .This evaluation makes it possible to design blended SCC for a desired strength at any given percentage of replacement.

$k=k_a+k_p$

k= overall strength efficiency factor

k_a= efficiency factor depending on age

$k_{p=}$ efficiency factor depending on percentage of replacement

So it is felt that cementing efficiency concept can be used to understand the behavior of blended SCC to reference SCC.

A number of empirical expressions are frequently used to describe or predict the strength of normal hardened cement paste. The more well-known expression of Bolomey's relates strength and water/cement ratio. This Bolomey's empirical expression frequently used to predict the strength of concrete is theoretically well justifies when applied to hardened SCC. Strength data from experiments on normal hardened cement paste are frequently reported in the literature to be well fitted by Bolomey's empirical expression. The concept of efficiency can be used for comparing the relative performance of SCMs when incorporated into SCC. Efficiency factors found from Bolomey's strength equation are used to describe the effect of the SCMs combination replacement in SCC in the enhancement of strength and durability characteristics. This factor will give only an indication of the added materials' effect on concrete strength, since it does no distinguish between filler effect and chemical reactions. The well-known Bolomey's equation often used to relate strength and water/cement ratio is:

$$S = A [(C/W)] + B \quad (1)$$

S is the compressive strength in MPa,

C is the cement content in kg /m^3,

W is the water content in kg/m^3

A and B are Bolomey's coefficients /or constants

Equation (1) has been shown to practically reduce to following two equations

$$S = A [(C/W) – 0.5]...... \quad (2)$$

$$S = A [(C/W) + 0.5]...... \quad (3)$$

From these above two normalized equations which represent two ranges of concrete strengths based on the change in slope when P/W (powder-water ratio) is plotted against strength. However, it is found that the equation (2) is useful for most of the present day concretes when an analysis was done on test results available and also the extensive data published by Larrard also mentions this equation in his famous book, on 'Concrete Mix Proportioning – A scientific approach'. Therefore, equation (2) can be generally used for re-proportioning MK+MS+FA SCC. The value of constant 'A' can be found out for the given concrete ingredients, by considering a concrete mix of any w/c ratio.

For structural concrete, Equation (1) can be simplified as

$$S = A [(C/W) – 0.5] \quad (4)$$

A strength efficiency factor, k, can then be computed using modified Bolomey's equation

$$S = A [(C+ kP)/W) – 0.5] \quad (5)$$

Where S is the compressive strength in MPa,

C is the OPC content in kg / m^3,

P is the amount of SCMs replaced bwc.

W is the water content in kg/m^3 and k denotes efficiency factor of SCMs combination

By knowing the amounts of 'C', 'P', 'W' and the strength 'S' achieved for each SCMs dosage replacement , efficiency factor "k" has been computed for each of the replacement dosages. Thus, W/(C+ kP) is the water/effective powder ratio and kP is the equivalent cement content of SCMs combination. 'SCMs /OPC ratio' is an important factor for determining the efficiency of SCMs in SCC. So SCMs proportioning is arrived at based on the strength data experiments on SCMs blended SCC Mixes. Efficiency factors found from this strength equation are used to describe the effect of the SCMs replacement. This factor describes the mineral admixture's ability to act as cementing material recognizing that mineral admixture's contribution to concrete strength which comes mainly from its ability to react with free calcium hydroxide produced during cement hydration (Pozzolanic Reaction (PR)).

6. EVALUATION OF CEMENTING EFFICIENCY FACTORS

The present work is an effort to quantify the cementitious efficiency of optimum proportions of Fly Ash (FA), Microsilica (MS) and Metakaolin (MK) combination in binary, ternary and quaternary blended Self-Compacting Concrete (SCC) systems of ordinary grade (M20) , standard grade (M40) and high strength grade (M80 and M100) in terms of efficiency factor 'k'. Table 3 shows bolomey's coefficients (A) for various grades of SCC mixes calculated using bolomey's equation. Then Efficiency factors for optimally blended binary, ternary and quaternary SCC mixes of ordinary grade (M20), standard grade (M40) and high strength grade (M80 and M100) were then determined using same bolomey's equation. Bolomey's coefficients are calculated from the reference mixes.

Table 3 Bolomey's Coefficients (A) for various grades of SCC mixes

Grade of SCC Mix	Bolomey's Coefficients (A)					
	3 days	7 days	14 days	28 days	60 days	90 days
M20	5.93	9.63	11.86	14.82	14.91	16.29
M40	8.59	14.06	16.76	20.33	21.17	22.40
M80	9.60	15.59	21.32	23.99	24.71	25.24
M100	10.41	16.27	22.77	26.21	26.65	26.97

Table 4 Efficiency factors for various grades of blended SCC mixes at different ages of curing

Grade of SCC Mix	Mix No	Mix Designation (Values indicate percentage by weight of Total Powder)	Efficiency Factors					
			3 days	7 days	14 days	28 days	60 days	90 days
M20	C1	C100	-	-	-	-	-	-
	B2	C50+FA50	0.34	0.55	0.79	0.70	1.22	1.25
	B7	C80+MS20	1.59	1.59	2.15	1.59	1.64	1.68
	B13	C75+MK25	3.61	1.72	2.16	1.69	1.70	1.73
	T3	C35+FA50+MS15	0.88	0.99	1.00	0.86	1.19	1.22
	T15	C25+FA60+MK15	1.57	1.22	1.15	1.08	1.32	1.34
M40	C1	C100	-	-	-	-	-	-
	B1	C60+FA40	0.23	0.28	0.42	0.79	1.14	1.17
	B5	C85+MS15	2.47	0.76	1.32	1.44	1.45	1.51
	B10	C80+MK20	5.23	2.42	2.23	1.48	1.49	1.51
	T5	C50+FA40+MS10	0.99	0.64	0.80	0.88	1.06	1.21
	T9	C35+FA50+MK15	1.94	1.29	1.27	1.05	1.08	1.19
M80	B2	C95+MS5	1.00	1.00	1.00	1.00	1.00	1.00
	T3	C65+FA20+MS15	0.34	0.68	0.59	0.85	0.98	1.04
	Q11	C50+FA28+MS11+MK11	1.74	1.21	1.06	0.94	1.00	1.08
M100	B2	C90+MS10	1.00	1.00	1.00	1.00	1.00	1.00
	T2	C71+FA19+MS10	0.88	0.98	1.00	0.69	0.99	1.08
	Q11	C55+FA23+MS11+MK11	2.12	1.37	0.76	0.76	1.05	1.12

7. DISCUSSIONS

Table 4 presents efficiency factors for various grades of optimally blended binary, ternary and quaternary SCC mixes of ordinary grade (M20), standard grade (M40) and high strength grade (M80 and M100) at different ages of curing. The efficiency factor (or k-factor) is defined as the part of the SCM in a pozzolanic concrete which can be considered as equivalent to Portland cement, having the same properties as the concrete without SCM (k= 1 for Portland cement) which means that 1 kg of cement can be replaced with k-factor of SCM or SCMs combination (optimal). Compressive strengths are achieved early in metakaolin based binary and ternary blended SCC of all grades than in microsilica based binary and ternary blended SCC. Due to synergy effect, the interaction of two or more admixtures is so that their combined effect is greater than the sum of their individual effects. In the other words, for reflecting synergic effect, the efficiency factor of Metakaolin, microsilica and fly ash combination should be higher in ternary blended SCC than in binary blended SCC system. For calculating the efficiency of Metakaolin, microsilica and fly ash combination in binary and ternary blended SCC, an equation has been proposed by author based on the principle of Bolomey's equation for predicting the strength of concrete containing mineral admixtures. The efficiency factors evaluated can be used for proportioning of blended SCC. For compressive strength of metakaolin (MK based SCC mixes , k is in the range of 1.08 to 1.69, which means that in a given SCC mix, 1 kg of MK based pozzolanic material may replace 1.08 to 1.69 kg of cement without impairing the compressive strength. This may be valid, provided that the water content is kept constant. Bolomey's coefficients 'A' are calculated from the control mixes. Using computed 'A' value, calculate strength efficiency factors k at all ages for all percentage replacement levels of metakaolin (MK) and fly ash (FA) combination in SCC.

It is observed from efficiency factor is 1.69 for C75+MK25 and1.32 for C25+FA60+MK15 ordinary grade M20 SCC mixes. For Standard grade M40 SCC mixes, k is 1.48 for C80+MK20 and 1.08 for C35+FA50+MK15 combinations. Metakaolin (MK) and fly ash (FA) blended SCC mix is found to be more efficient because of high usage of waste by-product FA and high reduction of cement content. This study is carried out to understand the cementing efficiency of Metakaolin (MK) in binary, ternary and quaternary blended SCC mixes at 3,7, 14,28, 60 and 90 days. This evaluation makes it possible to design binary, ternary and quaternary blended SCC for a desired strength at any given percentage of replacement. The strength efficiency factor 'k' is evaluated for three cases in quaternary blended SCC mixes: (1) micro silica (MS) is singly blended in SCC, (2) micro silica (MS) is blended with fly ash (FA) in SCC and (3) Metakaolin (MK) is blended with micro silica (MS) and fly ash (FA) SCC mix.

It can be observed that efficiency factors for binary (Mix B2), ternary (Mix T3) and quaternary (Mix Q11) blended high strength (M80) SCC mixes are 1.00, 1.04 and 1.08 respectively. All the three M80 grade SCC mixes give similar strength and satisfy EFNARC specifications. The efficiency factor for quaternary (C50+FA28+MS11+MK11) blended high strength SCC mixes is 1.08 which means that 1 kg of cement can be replaced with 1.08 kg of FA+MS+MK pozzolanic mixture. Efficiency factor for quaternary blended SCC mix reveals that for similar strength, 50% of cement can be replaced with FA28%+MS11%+MK11% combination of pozzolanic mixture. Similar observations are made in blended high strength (M100) SCC mixes.

The computed efficiency factors may be incorporated in the design of a blended concrete mixture, a method known as rational proportioning. The k value can be used to transform a certain amount of pozzolan to an equivalent amount of cement in terms of strength contribution; hence, it can be used as a basis for a more efficient proportioning of blended SCC mixes.

8. CONCLUSIONS

Based on the above discussions the following conclusions are drawn:

The contribution of metakaolin (MK) to any property of hardened concrete may be expressed in terms of efficiency factor, k. For compressive strength of metakaolin blended SCC mixes , k is in the range of 1.08 to 1.69, which means that in a given SCC mix, 1 kg of metakaolin (MK) based pozzolanic material may replace 1.08 to 1.69 kg of cement without impairing the compressive strength. This evaluation makes it possible to design metakaolin blended binary, ternary and quaternary SCC mixes for a desired strength at any given percentage of replacement.

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Strength Conversion Factors for Concrete Based On Specimen Geometry, Aggregate Size and Direction of Loading

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Abstract: The main goal of this study is to find out the effect of effect of specimen shape and size, aggregate size and directions of loading and placement on the compressive strength of M20, M40, M60 and M80 grades of concrete. During the experimental study, different shaped and sized concrete specimens of different concrete mix designs were tested for compressive strength at 28 days. For casting the concrete samples, totally four different moulds were utilized, which were two different sizes of cubes and two different sizes of cylinders. The cubic moulds were 100 and 150 mm. The cylindrical moulds were 150×300 and 100×200 mm. So the relationship between size and shape effect on compressive strength of concrete samples is evaluated. Casted cubes and cylinders are tested for the compressive strength under axial compression on completion of 28 days as per IS: 516-1999.In this study, the effect of specimen sizes, specimen shapes, and placement directions on concrete compressive strengths for various grades widely used is evaluated. In addition, correlations between compressive strengths with size, shape, and placement direction of the specimen are investigated. It was found that with the increase of the size of the concrete specimen, compressive strength tends to decrease. The effect of grade of concrete on the shape effectof the compressive strength decreases as the specimen size increases regardless of strength level. Conversion factors of 0.80 to 0.90 were suggested for converting compressive strength of cylinders to compressive strength of cubes. For cubes, when the placement direction is parallel to the loading direction, the compressive strength is higher than the normal case. As aggregate size increases, compressive strength is found to be increasing.

Index Terms- specimen shape and size,Conversion factors, strength correction factors, aggregate size, loading direction.

I. INTRODUCTION

Determining the compressive strength of concrete is one of the most crucial stages of construction works as the mechanical and durability properties of the concrete depends on the compressive strength of the concrete. To maintain a control on the quality of concrete, concrete samples are casted in various moulds according to various standards adopted in various countries. On the other hand, it is known that different shapes and sizes of concrete samples can cause variations in results of compressive strength. This paper is focused to study the effect of specimen sizes and shapes on compressive strength of concrete. Many previous studies and experimental investigations have been conducted in order to find out how changing specimen shape and size could influence the results. In this study conversion factors are proposed to convert the compressive strength results of different specimens based on size, shape, aggregate size and placement direction. For most countries, sizes and shapes of test specimens to determine the compressive strength of the concrete are different. However, commonly used specimens are cylinders and cubes. Due to the differences in the shape, height/diameter ratio, and end restraint due to the machine platens, cylinder and cube strengths obtained from the same batch of concrete could differ.

II. OBJECTIVES OF THE PRESENT WORK

1. To evaluate the effect of specimen shape and size on the compressive strength of M20, M40, M60 and M80 grade concretes.
2. To suggest strength conversion factors for M20, M40, M60 and M80 grade concrete specimens of different shapes and sizes.
3. To compare the compressive strengths of concrete cubes of M20, M40, M60 and M80 grades when subjected to loading parallel and perpendicular to the placement of concrete.
4. To evaluate the effect of aggregate size on the compressive strength of M20, M40, M60 and M80 grade concrete specimens of different shapes and sizes.

III. MIX PROPORTIONS

The mix proportions of M20 and M40 grade concrete are designed using IS: 10262-2009 and mix proportions for M60 and M80 grade concrete are designed using Entroy and Shacklock's empirical graphs. The mix proportions and materials required for one cubic meter are given in table 1 below.

TABLE 1: MIX PROPORTIONS AND QUANTITIES PER 1 CU. M. OF M20, M40, M60 AND M80 GRADE CONCRETES

Grade of the Concrete	Mix proportions	Cement kg/m^3	Micro-silica kg/m^3	Fly ash	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water L
M20	1: 2.90: 3.14: 0.54	320.4	-		927.3	1005.4	173 L
M40	1: 2.25: 2.56: 0.42	390.7	-		876	999.7	164.1 L

M60	1:1.60:1.84:0.26 (Micro Silica - 6% bwc*) (Superplasticizer(SP) – 1% bwc*)	436	27.8	50.34	819.9	948	130.6 L
M80	1:1.12:1.40:0.23 (Micro Silica - 10% bwc*) (Superplasticizer(SP) – 1.2% bwc*)	451.8	50.2	155.2	732.3	914.1	115.5 L

*bwc-by weight of cement

IV. LATERAL SURFACE AREA/VOLUME RATIO

The table 2 presents the lateral surface/volume ratio and load application area for different concrete specimen shapes and sizes.

TABLE 2: LATERAL SURFACE/VOLUME RATIO AND LOAD APPLICATION AREA FOR DIFFERENT SPECIMENS

Sample type and size in mm	Lateral surface area/volume ratio (mm^{-1})	Area on which load applied mm^2
Cyl.100×200	0.050	7850
Cyl.150×300	0.033	17662.5
Cube 100	0.060	10000
Cube 150	0.040	22500

V. EFFECT OF SPECIMEN SHAPE AND SIZE ON COMPRESSIVE STRENGTH OF CONCRETE

The figure 1 presents variation of compressive strength of various grades of cylindrical and cube concrete specimens.

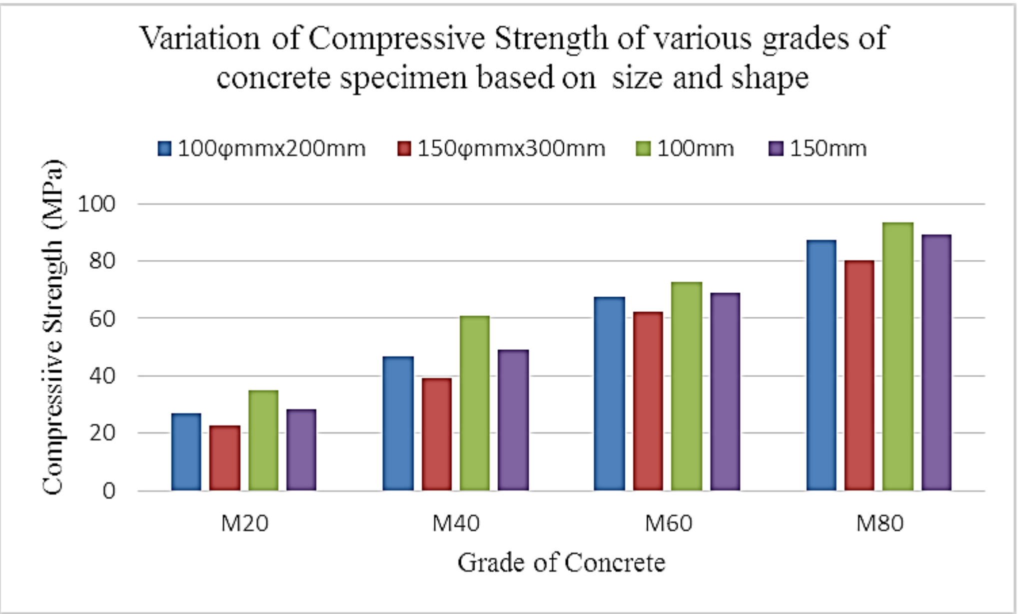

FIGURE 1: VARIATION OF COMPRESSIVE STRENGTH OF VARIOUS GRADES OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS.

VI. COMPRESSIVE STRENGTH CONVERSION FACTORS

The table 3 presents the compressive strength conversion factors based on various shapes and sizes of specimens of M20 and M40 grade.

TABLE 3: COMPRESSIVE STRENGTH CONVERSION FACTORS OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS OF M20 AND M40 GRADE

	Cylinder	Cube

		100ϕmmx200mm	150ϕmmx300mm	100mm	150mm
Cylinder	100ϕmmx 200mm	1.00	1.16	0.84	0.95
	150ϕmmx 300mm	0.86	1.00	0.70	0.80
Cube	100mm	1.19	1.43	1.00	1.24
	150mm	1.05	1.25	0.80	1.00

The table 4 presents the compressive strength conversion factors of cylindrical and cube concrete specimens of M60 and M80 grade.

TABLE 4: COMPRESSIVE STRENGTH CONVERSION FACTORS OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS OF M60 AND M80 GRADE

		Cylinder		Cube	
		100ϕmmx 200mm	150ϕmmx 300mm	100mm	150mm
Cylinder	100ϕmmx 200mm	1.00	1.05	0.90	0.98
	150ϕmmx 300mm	0.95	1.00	0.89	0.90
Cube	100mm	1.11	1.12	1.00	1.05
	150mm	1.02	1.11	0.95	1.00

To convert compressive strength of the specimen to the strength of other specimens (with different cross sectional area), the specimen's compressive strength should be multiplied by the values which were obtained from the table 5.

TABLE 5: COMPRESSIVE STRENGTH MULTIPLICATION FACTORS OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS OF DIFFERENT GRADE CONCRETES

		Cylinder		Cube	
		100ϕmmx200mm	150ϕmmx300mm	100mm	150mm
Compressive Strength	M20	0.95	0.80	1.24	1
	M40	0.95	0.80	1.24	1
	M60	0.98	0.90	1.05	1
	M80	0.98	0.90	1.05	1

VII. EFFECT OF LOADING AND PLACEMENT DIRECTIONS ON COMPRESSIVE STRENGTHS

The table 6 presents the compressive strengths based on loading and placement directions.

TABLE 6: COMPRESSIVE STRENGTHS BASED ON LOADING AND PLACEMENT DIRECTIONS FOR DIFFERENT GRADE CONCRETES OF VARIOUS SPECIMEN SIZES

Specimen shape	Specimen size (mm)	Grade of the concrete	Compressive Strength (MPa)	
			Placement direction parallel to loading direction	Placement direction perpendicular to loading direction
Cube	100	M20	36.90	35.14
		M40	64.17	61.11
		M60	83.35	72.48
		M80	107.61	93.57
	150	M20	29.76	28.34
		M40	51.74	49.28
		M60	79.38	69.03
		M80	102.48	89.11

VIII. EFFECT OF COARSE AGGREGATE SIZE ON COMPRESSIVE STRENGTHS OF CONCRETE

The table 7 presents the compressive strengths of various grades of concrete specimens of different size and shape made with 20mm and 10mm coarse aggregate.

TABLE 7: Compressive Of Various Grades Of Concrete Specimens Of Different Size And Shape Made With 20mm And 10mm Coarse Aggregate

Specimen shape	Specimen size (mm)	Grade of the concrete	(20mm CA) Compressive Strength (MPa)	(10mm CA) Compressive Strength (MPa)
Cylinder	100×200 (diameter ×length)	M20	26.92	24.23
		M40	46.82	42.14
		M60	67.65	60.89
		M80	87.33	78.60
	150×300 (diameter ×length)	M20	22.67	20.40
		M40	39.42	35.48
		M60	62.13	55.92
		M80	80.20	72.18
Cube	100	M20	35.14	31.63
		M40	61.11	55.00
		M60	72.48	65.23
		M80	93.57	84.21
	150	M20	28.34	25.51
		M40	49.28	44.35
		M60	69.03	62.13
		M80	89.11	80.20

IX. DISCUSSIONS

The cube with a 100mm size had the highest compressive strength of all. For this reason, that size of test cube should be more representative, and any cube size below 100 mm cube seems to be unsuitable for testing the compressive strength of concrete.The ratio of the cube strength to cylinder strength with increasing compressive strength of concrete decreases progressively from 1.24 to 1.05. Above-mentioned 1.24 and 1.05 are the ratios corresponding to the cylinder compressive strengths of 20-40 MPa and 60-80MPa, respectively

The compressive strength was insignificantly affected by changing l/d ratio as the strength of concrete increases. For high-strength concrete (HSC), the influence of specimen shape is not so significant.

For cubes, size effect difference with placement direction is insignificant. This is because the failure of cubes occurs not due to lateral expansion but due to crushing and the lateral expansion is restrained due to the end restraint occurred by the machine platens.

For cubes, when the placement direction is parallel to the loading direction, the compressive strength is higher than the normal case. HSC shows more brittle behavior than NSC. This means that the size of fracture process zone and the size effect of HSC, respectively, are smaller and more apparent than NSC. For cubes, because the face of casting is rough compared to the other faces. When load acted on it, it doesn't share the load uniformly and hence the face other than the face of casting is tested. Casting face with the load uneven may cause the cracks prior giving the low compressive strength. In the uniaxial compression test, smaller contact area between the specimen surface and steel platen of test machine resulting in lower friction-based shear forces in small specimens.It has been observed that the restraining effect due to friction between the specimen and the platens extends over the entire height of the cube. But in the case of the cylinder, it remains unaffected. Hence, it is clear that the total stress that will be created in the cube will be higher compared with the cylinder specimen. This will result in a higher value of the compressive strength in cubes than the cylinder even by employing the same concrete mix.

X.CONCLUSIONS

The current work investigated a narrative approach of finding the effect of specimen shape and size, aggregate size and directions of loading and placement on the compressive strength. Based on the results reported in this work and key findings during the experimental investigations, the following conclusions are drawn:

1. With increase of the size of the concrete specimen, compressive strength tends to decrease. The cube with a 100mm size had the highest compressive strength of all.
2. The effect of grade of concrete on the shape effect of the compressive strength decreases as the specimen size increases regardless of strength level. More specifically, for M60 and M80, the difference of compressive strengths between cylinders and cubes is more rapidly disappeared than that of M20 and M40 grades of concrete.
3. Conversion factors of 0.80 to 0.90 were suggested for converting compressive strength of cube to compressive strength of cylinder. The ratio of the cube strength to cylinder strength with increasing compressive strength of concrete decreases progressively from 1.24 to 1.05. Above-mentioned 1.24 and

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1.05 are the ratios corresponding to the cylinder compressive strengths of 20-40 MPa and 60- 80MPa, respectively

4. For cubes, when the placement direction is parallel to the loading direction, the compressive strength is higher than the normal case. For normal strength concrete (NSC) (M20 and M40 grades), the size effect difference with displacement direction is not distinct compared to high strength concrete (HSC) (M60 and M80 grades).
5. To study the wall effect, compressive strength results of different specimens have been plotted against surface/volume ratio of samples. By increasing the ratio of lateral surface to volume, compressive strength has a steady decreasing trend. Increasing the ratio of surface/volume, in fact means that for each cubic meter of the specimens, there is an increasing amount of surface area. As a result, specimens with higher ratio of surface area/volume are willing to have less compressive strength.
6. Compressive strength results were strongly influenced by their specimen sizes and wall effect. When the concrete bonds are weaker, the results of compressive strengths seem to be more uniform, since the compressive strength of the samples are controlled by their bonds' strength.
7. By decreasing the ratio of lateral surface/volume of specimens, the compressive strength increases.
8. The cylinder specimen indicated a small change in compressive strength when the l/d ratio changed from 1.0 to 2.0; compared to cubes. In fact, compressive strength for cylinder increased as l/d increased; whereas for cube, there was a reduction in compressive strength.
9. As aggregate size increases, compressive strength is found to be increasing.

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Appraisal of Processing Techniques for Recycled Aggregates in Concrete

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***Abstract:** Due to depletion of natural aggregates the need for the usage of recycled aggregate in concrete has gained significance. In this regard, the present study is an attempt to evaluate the performance of M20 grade of concrete made with 100% recycled aggregate processed using various techniques. Handpicked aggregate from concrete rubble is used to prepare recycled aggregate concrete. The use of chemical admixture is mandatory to compensate the extra water (3 to 6%) required by the RCA (Recycled Aggregates). RCA treated with calcite mineral precipitating bacterial suspension enhances its surface permeability. RCA exposed to different acid concentrations improved the surface of the aggregate with the removal of the loosely adhered mortar. In thermal – mechanical method the recycled aggregates from rubble are heated in microwave to 300°C to remove adhered mortar from the aggregate and placed in a rotating drum containing iron balls. In chemical–mechanical method the recycled aggregate is exposed to Na_2So_4 and is subjected to freeze-thaw cycles to create mechanical to separate adhered mortar from RCA. In acid soaking beneficiation method the mortar around RCA is removed by immersing them in 5% HCl and H_2SO_4 for 24 hours. All the above mentioned recycled aggregate processing techniques are however to be tested in full scale to study the efficiency of these treatment techniques. Compressive strength and water absorption capacities of various concrete samples made with recycled aggregate prepared using above discussed processing techniques are evaluated.*

***Index Terms-** Recycled aggregate concrete, processing techniques, recycled aggregate, CWD.*

I. INTRODUCTION

Construction and demolition (C&D) rubble management is a matter of great concern in construction industry due to dumping problem, its availability in huge quantities and the transportation cost involved for disposal. Central Pollution Control Board of India (CPCB) reports nearly 60 million tons of solid waste produced every year of which 40 % is from construction rubble. At present the construction debris is used as landfill or infill material but still it remains environmental hazard so a proper solid waste management is required for appropriate disposal. It is suggested that a combined and universal approach of design and construction strategy is required to reduce this construction and demolition waste production. Recycling is one such option to address this concern of disposal of C&D waste.

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Using demolished waste in concrete after proper processing has been an innovative way of developing concrete using recycled aggregate than natural aggregates. Developing the high strength recycled aggregate concrete is always a challenge due to disparities in the quality of recycled aggregate collected from various sources. Past studies suggested that recycled aggregate usage is concrete is limited to 20-30% based on the grade of concrete. But research on recycled aggregate concrete has demonstrated that 50% pre- processed recycled aggregate replacing natural aggregate has improved the performance of the concrete. Many researchers proposed various processing techniques such as soaking RCA in acids and cleaning with water, heating RCA to certain temperature so that temperature stresses are developed which loosens the adhered mortar on the aggregate, and some researchers suggested even ultra-sonic cleaning and PVC coating methods for RCA. In the present work authors demonstrated various pre-processing techniques for recycled aggregates in concrete. But these techniques are yet to be tested for full-scale experimentation of Recycled aggregate concrete.

II. AIMS

The main aim of the present project study is to realise the compressive strength and water absorption properties of 100% recycled aggregate concrete of M20 grade. To achieve the above mentioned objectives, the experimental investigations are planned as shown below–

(1) Determine the mix proportions for M20 grade 100% recycled aggregate concrete (RAC)

(2) Evaluation of workability in terms of slump for M20 100% recycled aggregate concrete (RAC)

(3) Assessment of compressive strength and water absorption capacities of natural and 100% recycled aggregate M20 grade concrete at 28 days age of curing.

III. MATERIALS

A. Cement

Ordinary Portland cement (OPC)

B. Fine Aggregate

Manufactures sand conforming to IS: 383.

C. Coarse Aggregate

Crushed stone coarse aggregate of angular in shape.

D. Recycled aggregates

Recycled aggregates are extracted from demolished and construction waste. The C&D waste collected from locally available, poured water on C&D to remove silt and clay then removed other foreign materials such as broken brick bats, reinforcement, mortar etc. About 100mm size concrete samples separated and fed in the feeding unit of the laboratory jaw crusher of capacity 250 kg/hr. Fig 1 shows the jaw crusher. The jaw of the crusher is adjusted to obtain aggregates of desired size.

The material passing through the feeder unit of the laboratory jaw crusher is broken to appropriate sizes of 20 mm (Fig 2 (b)). The crushed aggregates received from the feeder unit are then sieved through a series of IS sieves as per IS: 2386 (Part I)-1997 to segregate them in various sizes by discarding the material smaller than 20 mm size. The material in size larger is subjected to re-crushing so as to obtain the aggregates of appropriate size. The sieving process also help for the removal of adhered mortar traces loosened during the crushing process. It was observed that the jaw crushers provide the best grain-size distribution of recycled aggregate to be used in making concrete.

E. Super Plasticizer

Conplast SP 430, a Sulphonated Naphthalene based Formaldehyde (SNF) super plasticizer manufactured by Fosroc is used. Dosage range of 0.5 to 1.5% by weight of cement is normally recommended.

Fig 1: Jaw Crusher

Fig 2: a) Construction Demolition Waste **b) Recycled Aggregate after crushing**

IV. RECYCLED AGGREGATE PROCESSING TECHNIQUES

The table 1 below gives various recycled aggregate processing techniques used in the present study to treat construction demolition waste.

V. CONCRETE MIX DESIGN

The grade of the concrete used in the present investigation is M20 made with 100% recycled aggregate (RCA). The quantity of materials per one cubic meter of concrete are designed using IS: 10262-2009 (Table -2).

Table 1 – Various recycled aggregate processing techniques adopted in the present study

Type of specimen	Designation	Recycled aggregate processing technique	Description
M20 grade (Natural coarse aggregate)	Method 1	-	Naturally available crushed angular coarse aggregate
M20 grade (100% Recycled coarse aggregate)	Method 2	Hand-picked	Hand-picked coarse aggregate from concrete rubble
	Method 3	Microbial carbonate precipitation (MCP)	Hand-picked coarse aggregate from concrete rubble are pre-soaked in S. pasteurii bacterial suspension of 10^5 cells/ ml concentration
	Method 4	Acid soaking beneficiation method	Hand-picked coarse aggregate from concrete rubble are pre-soaked in 0.1 M HCl for 24 hours
	Method 5	Acid soaking beneficiation method	Hand-picked coarse aggregate from Construction and demolition waste are pre-soaked in 0.1 M H_2SO_4 for 24 hours
	Method 6	Thermal – mechanical method	Hand-picked coarse aggregate from concrete rubble are heated to 300°C in microwave which loosens the adhered mortar by placing the heated aggregate in the los angles abrasion testing machine
	Method 7	Chemical–mechanical method	Hand-picked coarse aggregate from concrete rubble are exposed to 1% sodium sulfate solution and subjected to repeated freeze-and-thaw action (7 cycles)
	Method 8	Jaw crusher	Construction and Demolition waste is crushed in Jaw crusher into recycled coarse aggregate

Table 2 – Dry Quantities of concrete ingredients per one m^3

Grade	Cement kg	Fine aggregate kg	Coarse aggregate kg		Water L	W/C ratio
			20 mm	10mm		
M20	333	739.11	464.34	703.28	160.02	0.50

VI. WORKABILITY

Slump test on recycled aggregate concrete is carried out in fresh state to evaluate the workability of the concrete made with treated concrete rubble.

VII. COMPRESSIVE STRENGTH

This investigation is carried out to study the compressive strength of M20 grade concrete mix made with 100% recycled coarse aggregate (RCA) at 28 days. For this concrete cubes of 150mm are cast and tested to study the compressive strength of M20 grade rubble concrete and conventional concrete at 28 days as per IS: 516-1999.

VIII. WATER ABSORPTION CAPACITY STUDIES

This study is to evaluate the total water absorption capacity of M20 grade rubble concrete (RCA) and conventional concrete as per ASTM C642-13.

IX. TEST RESULTS AND DISCUSSIONS

A. Workability

In this study, workability of concrete is assessed using slump cone test. Slump values for M20 grade concrete made with treated and recycled concrete rubble and natural crushed aggregate are presented in table 3.

To enhance workability, mineral admixtures such as GGBS can be added in suitable quantity so that the desired strength and workability can be achieved.

For concrete made with rubble, workability in terms of slump values decreases due to the highly porous mortar attached on the surface of the concrete rubble. So some quantity of mixing water, calculated during mix design trials intended for desired workability and strength, may get absorbed by the recycled aggregate reducing the workability of the concrete mix and prolongs the mixing time. This limitation can be overcome by admixing the recycled aggregate concrete with pozzolans.

A. Compressive Strength and Water absorption Studies

Compressive strengths of M20 grade rubble concrete mixes are tabulated in table 4. For this concrete cubes of 150x150x150 mm are cast and tested as per IS: 516-1999 to study the compressive strength under axial compression on completion of 28 days. Similarly the water absorption capacity of M20 grade rubble concrete mixes as per ASTM C642-13 are presented in table 4.

Table 3 – Slump values of recycled aggregate concrete

Grade of concrete	Type of Concrete	Slump mm
M20	Natural Aggregate	90
	Recycled aggregate	45

Table 4 - Compressive strength and water absorption capacity of M20 grade concrete made with 100% recycled aggregate prepared using various processing techniques

Designation	Recycled aggregate processing technique	Compressive Strength (MPa) @ 28 days Age of Curing	% increase / decrease of Compressive strength	Water absorption capacity %
Method 1	-	27.86	-	5.62
Method 2	Hand-picked	17.86	-35.89	11.79
Method 3	Microbial carbonate precipitation (MCP)	35.91	28.89	2.79
Method 4	Acid soaking beneficiation method	26.13	-6.21	6.43
Method 5	Acid soaking beneficiation method	27.19	-2.40	6.55
Method 6	Thermal – mechanical method	22.17	-20.42	8.56
Method 7	Chemical–mechanical method	24.89	-10.66	7.75
Method 8	Jaw crusher	22.19	-20.35	7.87

The following observations were made-

1. When compared to conventional concrete, in 100% handpicked recycled aggregate concrete strength under compression decreases by about 36%. If the handpicked recycled aggregate is treated with bacterial solution then the compressive strength increases by 29% and water absorbtion is reduced by 11.8%.
2. The decrease in compressive strength in rubble concrete is due to high absorbent mortar adhered to the surface of the rubble aggregate. Interfacial Transition Zone (ITZ) in rubble concrete is weak than in conventional concrete. Strength of ITZ depends on the bond between aggregate and cement paste which is not poor in rubble based concrete.
3. In rubble concrete, bond between recycled aggregate and cement paste surrounding is weak so development of CSH crystals in this zone are structured weakly which leads to failure in compression. This phenomenon reduces the compressive strength of rubble concrete drastically. It is understood that porous nature of rubble makes the concrete permeable. Inclusion of mineral admixtures will address this problem suitably.
4. In concrete made with treated rubble, cement content is increased for strength requirement. This may not be a sustainable justified solution so the use of optimally admixed rubble concrete is encouraged to achieve equivalent compressive strength corresponding to natural aggregate concrete.
5. Of all the recycled aggregate processing techniques, recycled treated with mineral precipitating bacterial solution yields maximum compressive strength and has less water absorption capacity.

X. CONCLUSIONS

On the basis of the key findings during the experimental investigations, the following conclusions are drawn:

1. Recycled aggregates are angular in shape with rough surface texture.
2. In rubble concrete, workability decreases due to loss of water in the form of absorbtion by recycled aggregates.
3. Recycled aggregates absorb more water due to its porous nature. So while mixing concrete appropriate correction to water mixed to concrete is to be made to prevent drying shrinkage and increase the volume of void space. This may affect the workability and may lead to higher creep strains on loading.
4. There is a significant increase in the compressive strength of concrete made with bacteria treated recycled aggregate due to formation of calcite mineral precipitation changing the concrete pore structure within the cement-sand environment.
5. Untreated handpicked recycled aggregate yield very less compressive strength and has more water absorption capacity.

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Microstructural Characterization of Calcite Mineral Precipitation in Bacteria Incorporated Concrete

K Satya Sai Trimurty Naidu, M V Seshagiri Rao, V Srinivasa Reddy

Abstract— ***Metabolic activity of alkali-philic calcite (CaCO3) mineral precipitating bacteria when introduced into concrete heals the cracks and improves the microstructure of the concrete. This process of bio-mineralization by mineral producing bacteria can be characterized and quantified by using microstructure characterization techniques. The present paper is focused on characterizing the mineral precipitation in concrete by Sporosarcina pasteurii as calcite using SEM, XRD and TGA nano-characterization procedures to validate that cracks and pores in bacteria incorporated concrete were closed with the mineral precipitates produced due to urealotic activity of bacteria by hydrolyzing the urea based nutrients.***

Keywords — bacterial concrete, Bacillus subtilis, SEM, XRD, TGA

1. INTRODUCTION

The objective of this research was to observe the microstructure of bacteria induced cementitious specimens and to confirm the presence of calcite crystals using TGA, quantified by X-Ray Powder Diffraction (XRD) analysis and visualized by SEM. The above characterization studies establish the fact that the $CaCO_3$ is precipitated in the concrete by *Sporosarcina pasteurii*. Bacterial mineral precipitates were visualized by SEM, quantified by XRD investigations and was also confirmed by TG/DTG Analysis. The samples for the tests were collected, from the bacteria treated cement mortar samples and from control specimens i.e., samples without bacteria, in the form of powders and/or broken pieces.

Aerobic alkaliphilic calcite mineral precipitating microorganism Sporosarcina pasteurii strain was isolated and Sporosarcina pasteurii is known for its high ureolytic activity and calcium carbonate mineral precipitation. Different cell counts of bacteria were derived from the bacterial growth culture by serial dilution method. The nutrients used to cultivate bacterial culture are – Urea, Peptone: 5 g/lit., NaCl: 5 g/lit., Yeast extract: 3 g/lit.

2. RESEARCH FINDINGS & RESULTS

1. Influence of cell count on the strength

Influence of bacterial strain count of Sporosarcina pasteurii on the strength of concrete is studied by preparing mortar samples with various counts of cells and tested for their compressive strengths. At cell count of 10^5 cells per 1 ml of mixing water the strength of concrete was found to be more so for further investigations on bacteria induced concrete this count is considered for optimal production of calcite mineral precipitation in the cracks and pores in the concrete. This process will enhance the pore structure of the bacteria induced concrete. Results are presented in Table 1 shows the bacteria cell count effect on the amount of calcite mineral precipitation in the concrete. More than the optimum bacteria cell count may affect the physical and chemical properties of the concrete matrix. Mortar cube samples were prepared with various cell counts of Sporosarcina pasteurii bacterial strain. The optimal bacterial cell count is chosen based on the sample which yields highest compressive strength. Different cell counts were derived from the bacterial growth culture by serial dilution method.

Table 1 - Compressive Strength of mortar specimens made with various *B. subtilis* cell counts

Cells/ml of mixing water	Avg. Compressive Strength (MPa) ± Standard Deviation	
	28 days	% Increase relative to control
Nil (Without Bacteria)	55.81±0.10	-
10^3	57.23±0.11	2.54
10^4	59.52±0.72	6.65
10^5	65.79±0.68	17.88
10^6	62.21±0.49	11.47
10^7	54.66±0.89	-2.06

2. Scanning Electron Microscopic (SEM) Investigations

SEM investigations on the broken pieces of mortar samples confirmed the presence of calcite mineral precipitates, Figure 1 shows SEM images of mortar sample induced with and without bacterial strain. It can viewed that the concrete sample made with optimal count of bacterial strain has dense distribution of calcite mineral thought out its matrix.

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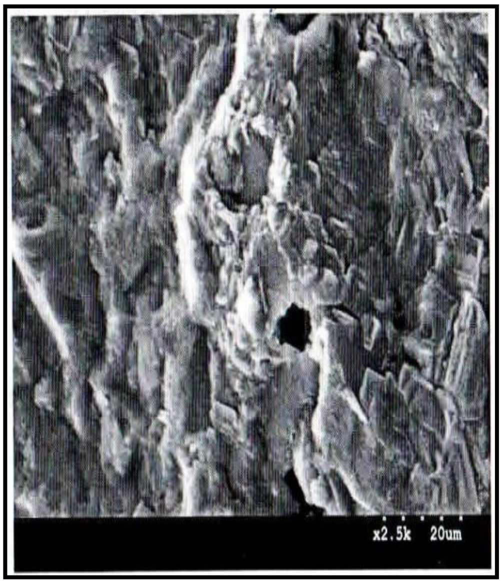
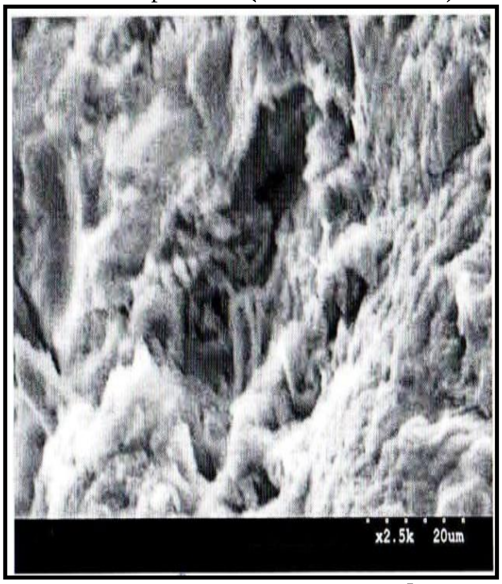


Control Specimen (Without Bacteria)



Bacterial Specimen with optimum 10^5 cell/ml

Fig 1: SEM investigations on specimens without and with bacteria induced in different counts

3. X-Ray Powder Diffraction (XRD) Analysis

Figure 2 shows the sketches of XRD plots of bacteria incorporated and normal mortar specimens. The peaks in the XRD plots shows the presence of each and every mineral present in the samples. In bacteria induced specimens, it can be seen that Ca mineral peak is higher than the sample without bacteria. This confirms the precipitation of calcite mineral due to microbiological activity in concrete.

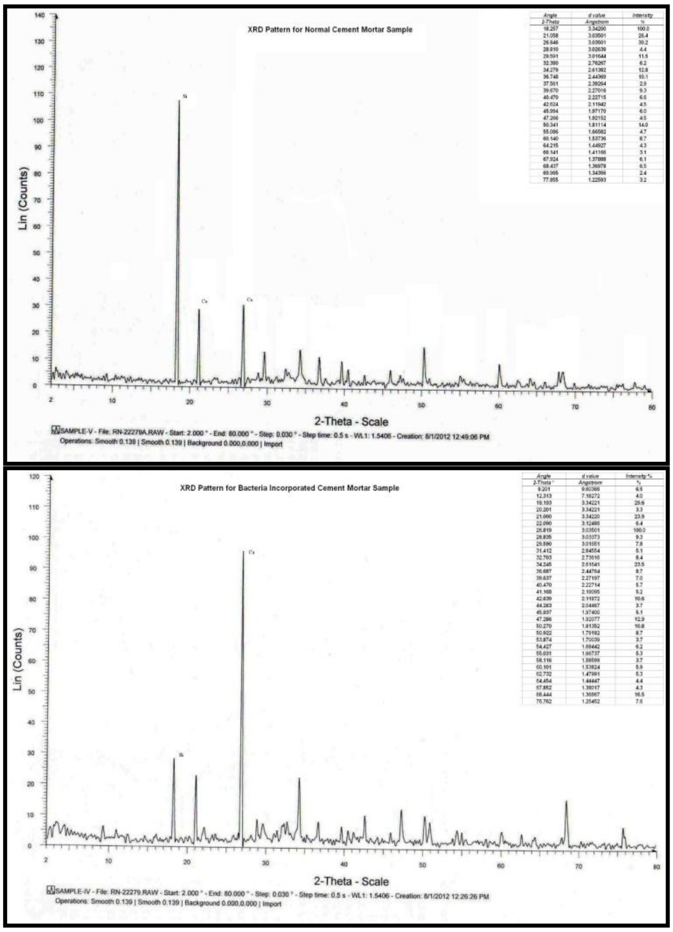


Fig 2: XRD of bacteria induced mortar and concrete specimens

4. Thermo-gravimetric (TG) Analysis

Thermo-gravimetric Analysis (TGA) is a technique which measures a sample's weight as it is heated or cooled in a furnace. TGA thermal curve is drawn between temperature on x-axis and weight (mg) or weight percent (%) on y-axis. The descending TGA thermal curve indicates the loss of weight. In this investigation, the bacteria induced sample is subjected to 50 to 900°C temperature. The calcite mineral precipitates in bacterial concrete when exposed to 500 to 700°C temperature will decompose and releases carbon dioxide due to which there will sudden loss of weight upto 20% in the bacterial concrete sample. This can be observed in Fig 3.

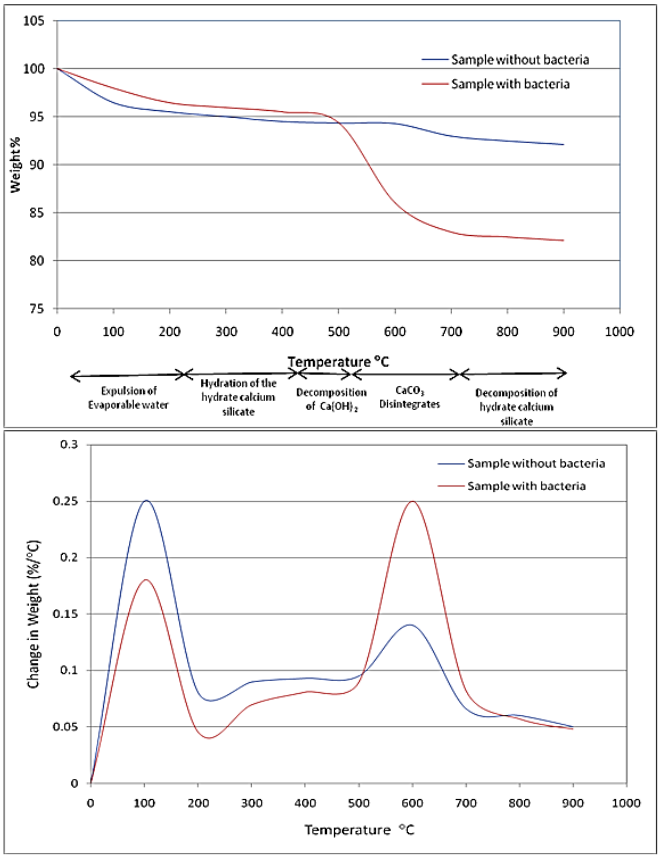


Fig 3: Thermo-gravimetric Analysis on specimens with and without bacteria

CONCLUSIONS

Based on the above investigations, the following conclusions are drawn:

(1) The improvement in compressive strength is due to deposition on the microorganism cell surfaces and within the pores of cement–sand matrix, which plug the pores within the mortar. TG, SEM and XRD analyses reveal the growth of fibrous filler material within the pores due to the presence of such microorganisms. This growth is beneficial in the modification of the porosity and pore size distribution of cement mortar. Plugging of pores and cracks with calcite mineral precipitate reduces the permeability of concrete and eventually enhances the strength and durability of concrete.

(2) The SEM analysis revealed the dense growth of calcite crystals embedded with bacterial cells in bacteria incorporated specimen.

(3) The XRD scanning image of powdered bacteria incorporated sample endorses the existence of high amount of calcium carbonate precipitate.

(4) In the XRD pattern Figure 5.4 (a), of controlled specimen shows the presence of the relatively high amount of quartz mineral when compared to other minerals present in the sample. It can also be noted that the presence of calcite in control mortar sample is due to formation of hydrated C-S-H gel. In case of bacteria incorporated sample XRD spectra Fig 5.4 (b), confirms the presence of relatively high amount of calcite crystals when compared to other minerals present in the sample. This can be attributed to the copious deposition of $CaCO_3$ in bacteria induced samples by Sporosarcina pasteurii during its microbial activity. So the presence of $CaCO_3$ was substantiated using X-Ray Diffraction (XRD) analysis. More number of calcite peaks suggests maximum calcite precipitation which would thereby reduce the pores in concrete.

(5) TGA analysis performed on powdered bacteria incorporated cement mortar sample showed an extreme loss of weight at 500 to 700°C confirming the presence of high amount of CaCO3. It authorizes the presence of $CaCO_3$ in bacteria incorporated specimens.

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Optimization and Development of High-Strength High-Volume Fly Ash Concrete Mixes

Ch Mounika, V Srinivasa Reddy, M V Seshagiri Rao, S Shrihari

Abstract-Cement is the most abundantly used ingredient in the production of concrete due to which its production and use has increased manifold. To reduce the carbon footprint left by the cement production, fly ash is used as cement replacement in concrete. Past research studies suggest that the fly ash replacement can be upto 40% beyond which there will be drastic reduction of strength. In the present study, high strength concrete mix of 70 grade is developed with high volume fly ash of 70% as cement replacement. Silica fume of 10% and hydraulic lime of 30% are used as additives in the development of M70 grade high-strength high-volume fly ash concrete. In the present paper, three types of fly ashes are considered for the study of which one which is ultrafine is chosen based on the pozzolanic index and strength activity index. Excess lime needed for various percentage of fly ashes is evaluated based on the empirical equationsgiven by the Dunstan Jr andZayed.

Index Terms- high volume fly ash concrete, high strength concrete, high performance concrete, lime concrete, quaternary blended concrete.

I. INTRODUCTION

Usage of concrete has increased as construction activities all over the world has increased considerably due to which production and cement has increased extensively leading to emission of high amount of carbon dioxide which is a cause of concern. So in order to reduce the carbon footprint, cement production and use are to be controlled in such a way that cement should be replaced by alternative cementitious materials. Pozzolans can be used as cement replacement to some extent deriving the advantages of both hydration and pozzolonic reactions during hardening stage of concrete. Studies reveal that pozzolan such as fly ash can replace cement upto 40% but the rate of strength gain is slow during initial age but gains strength during later age with superior durability properties. Some studies show that addition of silica fume can enhance the mechanical properties of the concrete especially at the initial age. Due to presence of high amount of pozzolan which has reactive silica as major component, the requirement of calcium hydroxide is more to reactive silica available from fly ash. Since the cement content available is less so the production of calcium hydroxide is also very less,demanding for more calcium hydroxide for CSH gel. So appropriate amount of lime can be supplied as additive to cater to the need of calcium hydroxide required to reactive with reactive silica in fly ash.

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II. OBJECTIVES

1) Mix quantities for the high strength concrete (M70) are obtained using Entroy Shacklock Method
2) Choice of type of fly ash based on pozzolanic index and strength activity index
3) Determination of optimum percentage of fly ash for high volume fly ash concrete
4) Determination of optimum percentage of silica fume
5) Determination of optimum amount of lime to be used for high strength high volume concrete

III. EXPERIMENTAL INVESTIGATIONS AND THEIR TEST RESULTS

A) MIX DESIGN

Mix design procedure for high strength concrete (M70) is based on Entroy Shacklock empirical method. Quantities arrived at are presented in the table 1 below for which the achieved compressive strength at 28 days is 52.6 MPa.

Assuming W/C =0.30 and cement= 450 kg/m^3 to develop high strength concrete, several trails are conducted on the calculated quantities and new quantities are arrived at. Fine and Coarse aggregates are adjusted in such a way that the maximum compressive strength that can be obtained is 55.3 MPa and quantities are tabulated in table 2as follows.

B) LIME REQUIREMENT FOR HIGH VOLUME FLY ASH CONCRETE

For the present study, three types of fly ashes from various sources are procured and tested for their reactivity for pozzolonic action. The one having more pozzolonic index will be chosen to develop high strength high volume concrete.The lime required at 28 days can be calculated from table3. Full hydration is assumed at 28 days and the lime produced by hydration is assumed to be 25%. Calculations for lime needed for 100% pozzolanic reaction as per Dunstan Jr&Zayed 2006 are given in table 3.

Table 4 presents the cement mortar mix quantities for calculating pozzolanic index (PI). According to ASTM C 618, fly ash to be used in concrete has to satisfy the “SAI-StrengthActivity Index”, which is used to measure the reactivity of the fly ash. Strength Activity Index is the measure of percentage of strength of mortar made with 20% mass replacement of cement with pozzolana to that of a strength of cement mortar designed at the age of 7 or 28 days for water/powder ratio of 0.484. To evaluate the reactivity of fly ash, Pozzolonic Index is estimated from the equations mentioned in table 5and its corresponding values are tabulated in table 6. Table 7 presentsthe pozzolonic indices and strength activity indices of various fly ashes used for the study.

Table 1: Quantities for high strength concrete (M70)

Concrete Mix	Cement (kg/m^3)	Water (Litres)	Aggregate		SP ($litre/m^3$)
			Fine (kg/m^3)	Coarse (kg/m^3)	
M70 grade	501.4	115.8	832.2	1008	11

Table 2: Quantities for concrete made with W/C =0.30

Mix	Cement (kg/m^3)	Water (Litres) (w/c=0.30)	Aggregate		SP ($litre/m^3$)
			Fine (kg/m^3)	Coarse (kg/m^3)	
Reference	450	132	940	996	14

Table 3-Calculations for lime required for 100% pozzolanic reaction

Powder content	Q
Weight of Fly ash	Pp
Weight of Cement	Pc
Pozzolanic Index (reactivity of pozzolana with $Ca(OH)_2$)	PI
Free Lime available during hydration	0.25 *Pc*Hx
Reactive pozzolan	PI*Pp
Lime required for 100% pozzolana action	1.85*PI*Pp
Excess lime/ Lime needed= Free Lime available during hydration - Lime required to react with pozzolana	0.25*Pc*Hx - 1.85*PI*Pp

Table 4- Mix quantities and compressive strength of cement mortar specimens

Mix	Cement (%)	Fly ash (%)	Powder Content		Sand gm	w/p ratio	W Water ml	Compressive Strength 28 days (MPa)
			Cement gm	Fly Ash gm				
OPC	100	0	200 (C)	0	600	0.484	96.8	53.1(F_c)
FA Type 1	80	20	160(C_1)	40	600	0.484	96.8	46.8 (F_{cp1})
FA Type 2	80	20	160 (C_2)	40	600	0.484	96.8	49.6(F_{cp2})
FA Type 3	80	20	160 (C_3)	40	600	0.484	96.8	54.3(F_{cp3})

Table 5- Equations to evaluate the reactivity of fly ash in terms of Pozzolonic Index

Pozzolonic Index (PI)= B/A		
$B = [1.598H_yC_c]-[kH_xC_c]-kV_w$	C_c= Volume of cement = (Mass/ Density)of cement = C_1/C_d C_d= Density of Cement	C_d=3.15 g/cm^3 C_c=152ml (480/3.15)
$A = kF_w/F_d-2.85F_w/S_d$	F_w= Weight of fly ash F_d= Density of fly ash S_d= Density of Sand	F_w= 40 g (20%) F_d= 2.15 g/cm^3 S_d=2.65 g/cm^3
Where, $k = [F_{cp}/(2.143*X)]^{1/3}$	F_{cp}= Compressive strength of cement mortar made with pozzolana	46.8 (F_{cp1}) 49.6(F_{cp2}) 54.3(F_{cp3})
$X = F_c/ [(2.145)*(Y/Z)^3]$ MPa	F_c= Compressive strength of cement mortar made with OPC	53.1(F_c)
$Y = 1.598*Cp*Hx$ ml (For pozzolanic cements)	C_p=Volume of pozzolanic cement =(Mass/ Density) of cement = C/C_d	C_p=67.8 ml(200/2.95) 2.95 Sp. gravity of pozzolanic cement
$Z= H_xC_p+V_w$ml	V_w= volume of water	V_w=290 ml W/C=0.484 (ASTM C 618) C=600 gm
Where, $H_x=(0.914W/C/(W/C+0.17)$ and $H_y=(0.914W/C_1)/(W/C_1+0.17)$	H_x= Percentage of hydrated cement H_y=Percentage of hydrated pozzolanic cement	W/C=0.484 (ASTM C 618) W/C_1=0.605 (290/480) H_x=0.676 H_y=0.714

Table 6 –Pozzolonic Indices (PI) of various fly ashes used in the study

F_c	53.1 MPa	Y	Z	$(Y/Z)^3$	X	k	B	A	PI =B /A
F_{cp1}	46.8 MPa	73.2	142.6	0.135	183.4	0.495	-0.02384	-0.10143	0.24
F_{cp2}	39.6 MPa	73.2	142.6	0.135	183.4	0.505	-0.02783	-0.10087	0.28
F_{cp3}	54.3 MPa	73.2	142.6	0.135	183.4	0.520	-0.03381	-0.10003	0.34

Table 7- Pozzolanic & Strength Activity Indexes of different fly ashes

Type of fly ash	PI	SAI
Type 1	0.24	88.1%
Type 2	0.28	93.4%
Type 3	0.34	102.3%

Sample Calculation:

H_x = (0.914*(135/360))/((135/360)+0.17)=0.63

Excess Lime/ Lime needed = (0.25*P_c*H_x)-(1.85*0.24*Pp) =16.64

% Excess Lime/ Lime needed= (Excess Lime/ Lime needed *100)/450=4%

Table 11 presents the mix quantities for various high volume fly ash concrete mixes and table 12 presents the compressive strengths of high volume fly ash concrete mixes made with various percentages of fly ash.

Table 8- Lime calculated for PI=0.24 (Type 1)

Total binder (Q) kg/m^3	% Cement	% FA	Cement (P_c) kg/m^3	Fly ash (P_p) kg/m^3	H_x	Excess Lime/ Lime needed kg/m^3	% Excess Lime/ Lime needed	Remarks
450	0.8	0.2	360	90	0.63	16.64	4	Excess
450	0.75	0.25	337.5	112.5	0.64	4.17	1	Excess
450	0.7	0.3	315	135	0.65	-8.40	-2	needed
450	0.65	0.35	292.5	157.5	0.67	-21.08	-5	needed
450	0.6	0.4	270	180	0.68	-33.88	-8	needed
450	0.55	0.45	247.5	202.5	0.70	-46.79	-10	needed
450	0.5	0.5	225	225	0.71	-59.84	-13	needed
450	0.45	0.55	202.5	247.5	0.73	-73.02	-16	needed
450	0.4	0.6	180	270	0.75	-86.35	-19	needed
450	0.35	0.65	157.5	292.5	0.76	-99.84	-22	needed
450	0.3	0.7	135	315	0.78	-113.49	-25	needed
450	0.25	0.75	112.5	337.5	0.80	-127.33	-28	needed
450	0.2	0.8	90	360	0.82	-141.37	-31	needed

Table 9 - Lime calculated for PI=0.28 (Type 2)

Total binder (Q) kg/m^3	% Cement	% FA	Cement (P_c) kg/m^3	Fly ash (P_p) kg/m^3	H_x	Excess Lime/ Lime needed kg/m^3	% Excess Lime/ Lime needed	Remarks
450	0.8	0.2	360	90	0.63	9.98	2	Excess
450	0.75	0.25	337.5	112.5	0.64	-4.16	-1	needed
450	0.7	0.3	315	135	0.65	-18.39	-4	needed
450	0.65	0.35	292.5	157.5	0.67	-32.74	-7	needed
450	0.6	0.4	270	180	0.68	-47.20	-10	needed
450	0.55	0.45	247.5	202.5	0.70	-61.78	-14	needed
450	0.5	0.5	225	225	0.71	-76.49	-17	needed
450	0.45	0.55	202.5	247.5	0.73	-91.34	-20	needed
450	0.4	0.6	180	270	0.75	-106.33	-24	needed
450	0.35	0.65	157.5	292.5	0.76	-121.48	-27	needed
450	0.3	0.7	135	315	0.78	-136.80	-30	needed
450	0.25	0.75	112.5	337.5	0.80	-152.31	-34	needed
450	0.2	0.8	90	360	0.82	-168.01	-37	needed

Table 10 - Lime calculated for PI=0.34 (Type 3)

Total binder (Q) kg/m^3	% Cement	% FA	Cement (P_c) kg/m^3	Fly ash (P_p) kg/m^3	H_x	Excess Lime/ Lime needed kg/m^3	% Excess Lime/ Lime needed	Remarks
450	0.8	0.2	360	90	0.63	-0.01	0	Not Required
450	0.75	0.25	337.5	112.5	0.64	-16.64	-4	needed
450	0.7	0.3	315	135	0.65	-33.38	-7	needed
450	0.65	0.35	292.5	157.5	0.67	-50.22	-11	needed
450	0.6	0.4	270	180	0.68	-67.18	-15	needed
450	0.55	0.45	247.5	202.5	0.70	-84.26	-19	needed
450	0.5	0.5	225	225	0.71	-101.46	-23	needed
450	0.45	0.55	202.5	247.5	0.73	-118.81	-26	needed
450	0.4	0.6	180	270	0.75	-136.30	-30	needed
450	0.35	0.65	157.5	292.5	0.76	-153.95	-34	needed
450	0.3	0.7	135	315	0.78	-171.77	-38	needed
450	0.25	0.75	112.5	337.5	0.80	-189.77	-42	needed
450	0.2	0.8	90	360	0.82	-207.97	-46	needed

Table 11 - Mix quantities of high volume fly ash concrete

Mix	Cement %	Fly ash %	Cement (kg/m^3)	Flyash (kg/m^3)	Water (kg/m^3)	Aggregate		SP (litre/m^3)
						Fine (kg/m^3)	Coarse (kg/m^3)	
Mix1(FAC0)	100	0	450	0.00	132	940	996	14
Mix2(FAC50)	50	50	225	225	132	940	996	14
Mix3(FAC60)	40	60	180	270	132	940	996	14
Mix4(FAC70)	30	70	135	315	132	940	996	14
Mix5(FAC80)	20	80	90	360	132	940	996	14

Table 12 - Compressive strengths of concrete mixes made with various percentages of fly ash

Type	Cement %	Fly ash %	Compressive Strength (MPa)		
			7 days	28 days	60days
Mix1(FAC0)	100	0	35.9	55.3	60.7
Mix2(FAC50)	50	50	13.4	33.5	39.3
Mix3(FAC60)	40	60	12.9	31.9	35.6
Mix4(FAC70)	30	70	10.7	22.1	32.9
Mix5(FAC80)	20	80	9.9	19.8	26.2

To enhance the early and later strengths, Silica Fume of 5 and 10% by weight of powder (Cement+ Fly ash) is used for the study.

Table 13- Mix quantities of high volume fly ash concrete with silica fume as additive

Mix	Powder		SF %bwp (Additive)	Cement (kg/m^3)	Flyash (kg/m^3)	Silica Fume (kg/m^3)	Water (kg/m^3)	Aggregate		SP ($litre/m^3$)
	Cement % bwp	Fly ash %bwp						Fine (kg/m^3)	Coarse (kg/m^3)	
Mix11(FAC0+SF5)	100	0	5	450	0	22.5	132	940	996	14
Mix12(FAC0+SF10)	100	0	10	450	0	45	132	940	996	14
Mix21(FAC50+SF5)	50	50	5	225	225	22.5	132	940	996	14
Mix21(FAC50+SF10)	50	50	10	225	225	45	132	940	996	14
Mix31(FAC60+SF5)	40	60	5	180	270	22.5	132	940	996	14
Mix32(FAC60+SF10)	40	60	10	180	270	45	132	940	996	14
Mix41(FAC70+SF5)	30	70	5	135	315	22.5	132	940	996	14
Mix42(FAC70+SF10)	30	70	10	135	315	45	132	940	996	14
Mix51(FAC80+SF5)	20	80	5	90	360	22.5	132	940	996	14
Mix52(FAC80+SF10)	20	80	10	90	360	45	132	940	996	14

Table 14- Compressive strengths of various fly ash based concrete mixes

Type	Cement % bwp	Fly ash %bwp	SF %bwp	Compressive Strength (MPa)		
				7 days	28 days	60days
Mix11(FAC0+SF5)	100	0	5	43.08	66.36	72.84
Mix12(FAC0+SF10)	100	0	10	51.70	**79.63**	**87.41**
Mix21(FAC50+SF5)	50	50	5	16.08	20.2	27.16
Mix21(FAC50+SF10)	50	50	10	19.30	28.24	36.59
Mix31(FAC60+SF5)	40	60	5	15.48	28.28	32.72
Mix32(FAC60+SF10)	40	60	10	18.58	35.94	43.26
Mix41(FAC70+SF5)	30	70	5	12.84	26.52	39.48
Mix42(FAC70+SF10)	30	70	10	15.41	31.82	47.38
Mix51(FAC80+SF5)	20	80	5	11.88	23.76	31.44
Mix52(FAC80+SF10)	20	80	10	14.26	28.51	37.73

*%bwp-by weight of powder

Table 15- Compressive strengths of high strength high volume fly ash concrete mixes

Mix Type	Powder		SF %bwp	Hydraulic Lime %bwp	Compressive Strength (MPa)		
	Cement % bwp	Fly ash %bwp			7Days	28 Days	60 Days
Mix12(FAC0+SF10)	**100**	**0**	**10**	**-**	**41.70**	**69.63**	**77.41**
Mix21(FAC50+SF10)	50	50	10	0	19.30	28.24	36.59
Mix21(FAC50+SF10)	50	50	10	10	21.23	33.06	42.25
Mix21(FAC50+SF10)	50	50	10	20	23.35	48.37	58.47
Mix21(FAC50+SF10)	50	50	10	30	25.69	54.21	65.32
Mix21(FAC50+SF10)	50	50	10	40	28.26	50.63	52.85
Mix32(FAC60+SF10)	40	60	10	0	18.58	35.94	43.26
Mix32(FAC60+SF10)	40	60	10	10	20.44	50.53	58.59
Mix32(FAC60+SF10)	40	60	10	20	22.48	55.59	64.44
Mix32(FAC60+SF10)	40	60	10	30	24.73	61.15	70.89
Mix32(FAC60+SF10)	40	60	10	40	27.20	57.26	67.98
Mix42(FAC70+SF10)	30	70	10	0	15.41	31.82	47.38
Mix42(FAC70+SF10)	30	70	10	10	16.95	35.00	52.12
Mix42(FAC70+SF10)	30	70	10	20	18.65	38.50	57.33
Mix42(FAC70+SF10)	**30**	**70**	**10**	**30**	**40.51**	**82.35**	**83.06**
Mix42(FAC70+SF10)	30	70	10	40	22.56	46.59	69.37
Mix52(FAC80+SF10)	20	80	10	0	14.26	28.51	37.73
Mix52(FAC80+SF10)	20	80	10	10	15.69	31.36	41.50
Mix52(FAC80+SF10)	20	80	10	20	17.25	34.50	45.65
Mix52(FAC80+SF10)	20	80	10	30	28.98	57.95	70.22

Mix52(FAC 80+SF10)	20	80	10	40	20.88	41.74	55.24

IV. DISCUSSIONS

Fly ash usage upto 40% in concrete may give high performance but gain of strength is very slow. If high volume of fly ash is intended to be used in concrete for cement replacement then strength is the major cause of concern. In the present study, high strength high volume fly ash concrete is developed with the high volume of fly ash about 70% replacement of cement. This mix achieved strength of 32.9 MPa. It is observed that as fly ash content increases beyond 50%, the compressive strength is reduced gradually. For M70 grade concrete, to achieve the desired strength silica fume is almost mandatory. In this study, silica fume of 5 and 10% by weight of powder (cement and fly ash) are used for study as additive to achieve the desired high strength. From table 14 it can be observed that for silica fume 10% and 100% OPC, the desired 70 MPa strength is achieved. But in high volume fly ash concrete mixes, high strengths could not be obtained due to unavailability of calcium hydroxide for pozzolanic action which is responsible for later strengths. Fly ash used for the study is chosen based on its reactivity of fly ash which can be evaluated in terms of pozzolonic indexes and strength activity indices. Hydraulic lime is added to high volume fly ash concrete made with silica fume to achieve the desired target strength. So based on the various trial and error combinations, it was found that concrete made with 70% fly ash with 10% silica fume and 30% lime as additives imparts high strength to high volume fly ash concrete.

V. CONCLUSIONS

Based on experiments conducted, the following observations are made-

1. High volume fly ash concrete is developed with 70% replacement of cement with fly ash.
2. Silica fume is used to enhance early strength and to achieve high strength. Silica fume of 10% by weight of powder is used as additive.
3. To achieve M70 grade strength, 30% lime by weight of powder is used as additive.
4. Quaternary blended concrete made with 70% fly ash + 30% cement by weight of powder content and with additives 10% silica fume and 30% lime attains high strength of 83.06 MPa.

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Performance Evaluation of High-Strength High-Volume Fly Ash Concrete

K Veda Samhitha, V Srinivasa Reddy, M V Seshagiri Rao, S Shrihari

Abstract- In the present study, high strength high volume fly ash concrete of M70 grade is developed and its durability properties such as water absorption capacity, porosity, and sorptivityare ascertained. It was found that high volume fly ash does not yield high strength so silica fume is added for early strength gain and for later strength gain lime required for complete pozzolonic action is added to achieve high performance concrete. In this study after testing for various combinations of quaternary blended concrete it was reported that 30% cement +70% fly ash as total powder achieves high strength of nearly 70 MPa, when silica fume of 10% by weight of powder and 30% of lime by weight of powder are added to the total powder content. The high strength high volume concrete developed with this optimum quantities of quaternary blends will be evaluated for the performance.It was found that water absorbtion in high strength high volume fly ash concrete reduced by nearly 85% and porosity is reduced by 34%.

Index Terms – high strength concrete, high performance concrete, high volume fly ash concrete, quaternary blended concrete, lime added concrete.

I. INTRODUCTION

Fly ash is abundantly available industrial by-product which had serious disposal problem. So researchers addressed this environmental concerned fly ash production and disposal problem by recommending to use in construction industry as a concrete ingredient. The use of fly ash in concrete has gained importance due to its high silica content which reacts with calcium hydroxide produced during hydration resulting in pozzolonic action which imparts later strength to the concrete. Fly ash usage in high quantities may affect the early strength gain in concrete but will achieve similar strength at later age. Especially in high volume fly ash concrete, due to presence of high percentage of fly ash and less cement quantity, the strength gain in early stages is very less and also due to less quantity of cement used in concrete the production of hydration product calcium hydroxide is also very less. So to take maximum advantage of pozzolanic action due to presence of high silica content, equal amount lime is required for optimum pozzolanic action. So due to less availability of lime produced during hydration, hydraulic lime is added to the powder content to promotepozzolanic action.

II. OBJECTIVES

1. To develop high strength high volume fly ash concrete of 70 MPa compressive strength.
2. To optimize cement, fly ash, silica fume and lime quantities in high strength high volume fly ash concrete.
3. To determine the split-tensile and flexural strength of high strength high volume fly ash concrete.
4. To evaluate the water absorption ability and porosity of high strength high volume fly ash concrete.

III. EXPERIMENTAL INVESTIGATIONS

A) Mix Design Using Entroy And Shacklock Method

Entroy and Shacklock method is used to arrive at the quantities of M70 grade concrete and after several mix trials the following quantities are arrived at. Water/cement ratio is assumed as 0.3 and cement content is limited to 450 kg/m^3.

B) Materials

Fly ash – F class fly ash is used in the present study. Various fly ashes from different sources are obtained and checked for pozzolonic reactivity and Strength activity Indices. The one with maximum reactivity and very fine is chosen for study.

C) Mix Quantities After Various Trials

Table 2 presents the mix quantities for OPC and high volume fly ash concrete mixes and table 3 presents the compressive strengths of OPC and high volume fly ash concrete mixes.

To improve the early strength in high volume fly ash concrete, Silica fume of 10% by weight of powder (cement+ fly ash) is used. Table 4 gives improved mix quantities of high volume fly ash concrete with silica fume as additive.

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Table 1: Quantities for high strength concrete (M70)made with W/C =0.30

Mix	Cement (kg/m^3)	Water (Litres) (w/c=0.30)	Aggregate		SP (litre/m^3)
			Fine (kg/m^3)	Coarse (kg/m^3)	
Reference	450	132	940	996	14

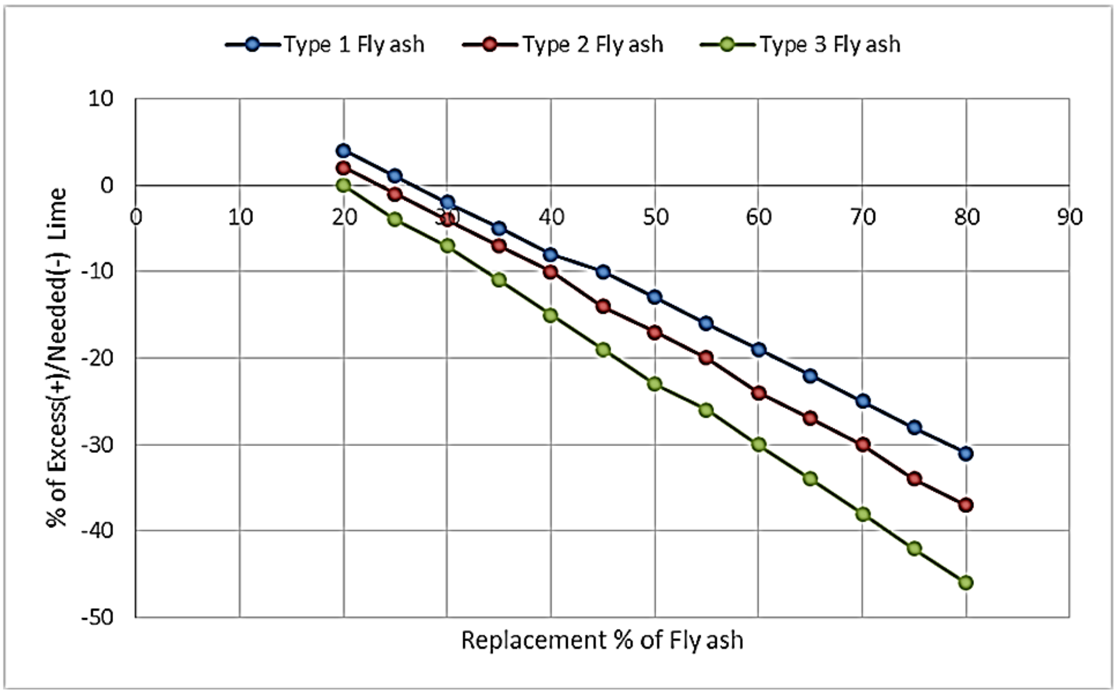

Fig 1 –Excess Lime or Lime needed for various fly ashes

Table 2 - Mix quantities of high volume fly ash concrete

Mix	Cement %	Fly ash %	Cement (kg/m^3)	Flyash (kg/m^3)	Water (kg/m^3)	Aggregate		SP (litre/m^3)
						Fine (kg/m^3)	Coarse (kg/m^3)	
Mix1(FAC0)	100	0	450	0.00	132	940	996	14
Mix2(FAC70)	30	70	135	315	132	940	996	14

Table 3 - Compressive strengths of OPC and high volume fly ash concrete mixes

Type	Cement %	Fly ash %	Compressive Strength (MPa)		
			7 days	28 days	60days
Mix1(FAC0)	100	0	35.9	55.3	60.7
Mix2(FAC70)	30	70	10.7	22.1	32.9

Table 4- Mix quantities of high volume fly ash concrete with 10% silica fume as additive

Mix	Powder		SF %bwp (Additive)	Cement (kg/m^3)	Flyash (kg/m^3)	Silica Fume (kg/m^3)	Water (kg/m^3)	Aggregate		SP (litre/m^3)
	Cement % bwp	Fly ash %bwp						Fine (kg/m^3)	Coarse (kg/m^3)	
Mix11(FAC0+SF5)	100	0	5	450	0	22.5	132	940	996	14
Mix21(FAC70+SF10)	30	70	10	135	315	45	132	940	996	14

D) STRENGTH STUDIES

Table 5 presents compressive strengths of high volume fly ash concrete with silica fume as additive.

Table 5- Compressive strengths of high volume fly ash concrete with silica fume as additive

Type	Cement % bwp	Fly ash %bwp	SF %bwp	Compressive Strength (MPa)		
				7 days	28 days	60days
Mix11(FAC0+SF5)	100	0	5	43.08	66.36	72.84
Mix21(FAC70+SF10)	30	70	10	15.41	31.82	47.38

*%bwp-by weight of powder(Cement + fly ash)

Addition of mere 10% silica fume is not enough to achieve desired compressive strength of 70 MPa. Since fly ash content available is more so is reactive silica which is main component of fly ash. For maximum usage of reactive silica in fly ash for pozzolonic reaction, equal amount of calcium hydroxide should be available. Since the calcium hydroxide available through hydration is not enough for optimal pozzolonic reaction, excess lime is required in the form of additive to cement +fly ash + silica fume mixture. From the studies conducted it was found that 30% lime is required for maximum compressive strength.Table 6 presents compressive strengths of high volume fly ash concrete with silica fume as additive. Table 7 and 8 presents corresponding spit-tensile and flexural strengths of high strength OPC and high strength high volume fly ash concretes.

Table 6- Compressive strengths of high strength OPC and high strength high volume fly ash concrete mixes

Mix Type	Powder		SF %bwp	Hydraulic Lime %bwp	Compressive Strength (MPa)		
	Cement % bwp	Fly ash %bwp			7 Days	28 Days	60 Days
Mix12(FAC0+SF10)	100	0	10	-	41.70	**69.63**	**77.41**
Mix22(FAC70+SF10)	30	70	10	30	40.51	**82.35**	**83.06**

Table 7- Split tensile strengths of high strength high volume fly ash concrete mixes

Mix Type	Powder		SF %bwp	Hydraulic Lime %bwp	Compressive Strength (MPa)	
	Cement % bwp	Fly ash %bwp			28 Days	60 Days
Mix12(FAC0+SF10)	100	0	10	-	4.46	4.51
Mix22(FAC70+SF10)	30	70	10	30	4.54	4.56

Table 8- Flexural strengths of high strength high volume fly ash concrete mixes

Mix Type	Powder		SF %bwp	Hydraulic Lime %bwp	Compressive Strength (MPa)	
	Cement % bwp	Fly ash %bwp			28 Days	60 Days
Mix12(FAC0+SF10)	100	0	10	-	5.01	5.28
Mix22(FAC70+SF10)	30	70	10	30	5.44	5.47

E) EVALUATION OF WATER ABSORPTION ABILITY AND POROSITY

In this test, water absorption and porosity of high strength high volume fly ash concrete as per ASTM C642-13.This test gives an indication of presence of voids and their distribution. 100mm cubes are casted and tested for permeation properties.At specific interval, the amount of water absorbed with respect to that of dry sample is expressed as:

$$WA_i\% = 100 \text{ x } (W_i - W_o)/W_o$$

Where W_i= mass (kg) of the wet specimen at any instant time T; W_o = mass (kg) of the dry specimen. Total duration of test is 24 hrs.and readings are taken at intervals (15 min, 30 min, 1 hour, etc.) for the first 3 hours and then be weighed after 8 hours and again after 24- hours until no more absorption is observed.

Water Absorption (WA) = [(B-A)/ A] x 100

Bulk density = G_1 = [(A)/ C- D]x ρ

Apparant density =G_2 =[(A)/ A-D]xρ

Permeable Voids (PV) = [(G_2 - G_1)/ G_2] x 100

where: A= mass of oven-dried sample in air, kg; B= mass of surface-dry sample in air after immersion, kg ; C= mass of surface-dry sample in air after immersion and boiling, kg and D= apparent mass of sample suspended in water, kg.

G_1= dry bulk density (kg/m^3) and G_2= apparent density (kg/m^3), ρ= density of water (1000 kg/m^3)

Porosity 'P' or interconnected pore space is given as-

Porosity (%) = (V_v/V) = (Weight of Saturated Specimen- Weight of Dry Specimen) / ρV

Where, V_v = Volume of voids in cc= Weight of Saturated Specimen- Weight of Dry Specimen in grams;

V = Volume of specimen in cc = 100 x 100 x100 mm^3;

ρthe unit mass of water (1 g/cc); Eand Fdenote the weight of the dried and fully saturated samples, respectively.

The equation to find the apparent porosity is-

Apparent porosity (%) = [(X-Y)/ (X-Z)] x100

Where X= mass of saturated specimen (immersed in water for 48 hours and weighed dried), Y= Mass of dried specimen and Z= mass of specimen under water suspension.

Porosity of concrete is the ratio of the volume of voids of the specimen to its bulk volume. Porosity contemplates both permeable and impermeable voids whereas apparent porosity deliberates only impermeable voids. The table and fig. shows the amount of water absorption with time. Table 9to 11 and fig 2give the water absorption (WA), Permeable voids and Apparent porosity of high strength concrete made with OPC and high strength concrete made with high volume fly ash.

Table 9 - Water Absorption at different time intervals of high strength concrete made with OPC and high strength concrete made with high volume fly ash

Measuring Intervals t_i (min)	Water Absorption			
	High strength concrete made with OPC		High strength concrete made with high volume fly ash	
	W_o= 2.63 kg		W_o= 2.64 kg	
	W_i(kg)	WA_i(%)	W_i(kg)	WA_i(%)
0	2.651	0.798	2.642	0.076
15	2.662	1.217	2.653	0.492
30	2.671	1.559	2.654	0.530
60	2.672	1.597	2.655	0.568
90	2.673	1.635	2.655	0.568
180	2.674	1.673	2.655	0.568
480	2.674	1.673	2.655	0.568
1440	2.674	1.673	2.655	0.568

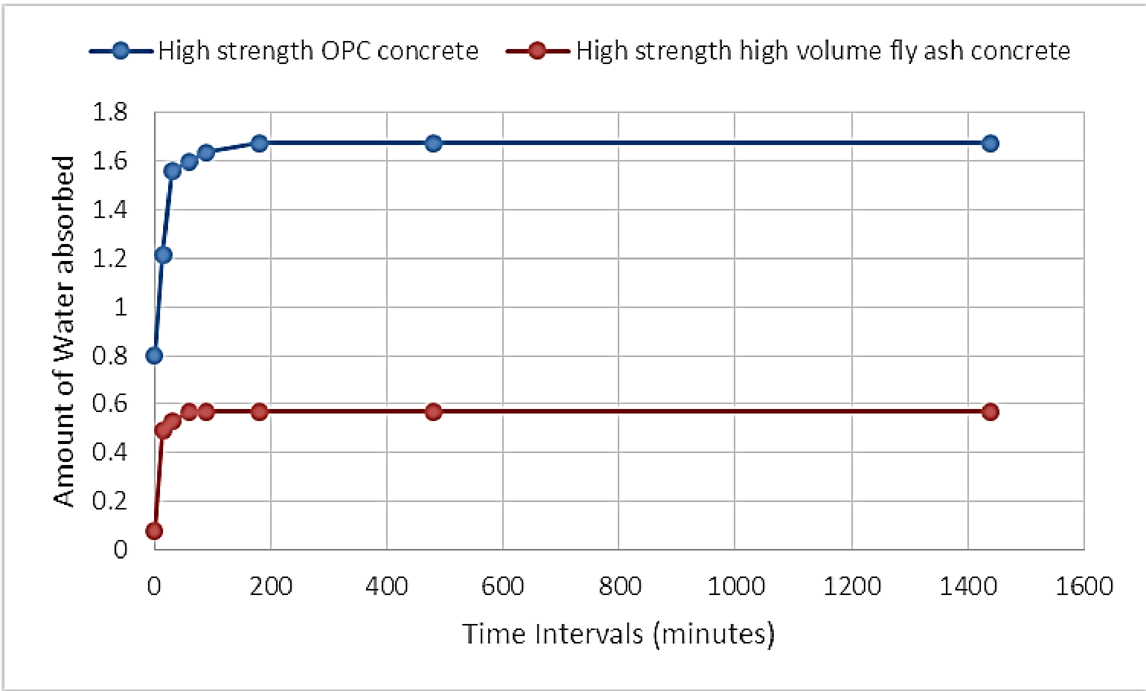

Fig 2- Plot showing amount of water absorption with time

Table 10 - Water Absorption Capacity (WAC), Volume of Permeable Voids and Apparent porosity of high strength concrete made with OPC and high strength concrete made with high volume fly ash

	High strength concrete made with OPC	High strength concrete made with high volume fly ash
A	2.632	2.643
B	2.671	2.652
C	2.692	2.671
D	1.512	1.510
Bulk density (G_1) (kg/m^3)	2230.508	2276.486
apparent density (G_2)(kg/m^3)	2350	2332.745
Water Absorption (WA) (%)	1.482	0.341
Permeable voids (PV) (%)	5	2.4
Apparent porosity (%)	3.365	0.778

Table 11- Porosity of high strength concrete made with OPC and high strength concrete made with high volume fly ash

	High strength concrete made with OPC	High strength concrete made with high volume fly ash
Weight of Saturated Specimen (kg)	2.662	2.661
Weight of Dry Specimen (kg)	2.632	2.651
Porosity, P at 28 days	0.030	0.020
Decrease in Porosity	-	34%

IV. CONCLUSIONS

Based on the experimental studies to evaluate the performance of high strength high volume fly ash concrete, the following conclusions are outlined-

1. High volume fly ash concrete is developed with 70% fly ash as cement replacement. This concrete cannot achieve high strength due to presence of high amount of fly ash presence. Fly ash has high amount of reactive silica which remains unreacted due to unavailability of $CaOH_2$ in the concrete due to which strengths are very less in high volume fly ash concrete.
2. To attain high strength with high volume fly ash, concrete is added with 10% silica fume. Silica fume will enhance the microstructure of the structure significantly but to attain compressive strength of 70 MPa is not possible unless the reactive silica in the fly ash is completely utilized in forming CSH gel as a product of pozzolonic action.
3. To utilize the silica present in fly ash for pozzolonic reaction, lime reactivity of fly ash is evaluated in terms of pozzolonic index and strength activity index.
4. Excess lime required to react with fly ash will be evaluated and is provided in the form of lime as additive. In the present study, 30% lime has yielded better results in terms of high strength gain.
5. Final high strength quaternary blended mix is made up of 30% cement, 70% fly ash, 10% silica fume and 30% lime with water cement ratio of 0.3.
6. Water absorption studies revealed that in high strength high volume fly ash concrete, water absorption ability has reduced by 75%.Permeable voids in high strength high volume fly ash concrete are reduced by 50%.
7. Total porosity of high strength high volume fly ash concrete is reduced by 34% but apparent porosity is reduced by 75%. This indicates that high strength high volume fly ash concrete is a high performance concrete.
8. 8.High strength high volume fly ash concrete has less water absorbtion ability due to its dense microstructure and reduced pore interconnectivity. Pozzolonic products reduce both permeable and impermeable pores thereby enhancing the performance of the high volume fly ash concrete.

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Strength Appraisal of Light Weight Green Concrete Made with Cold Bonded Fly Ash Coarse Aggregate

Y Supriya, V Srinivasa Reddy, M V Seshagiri Rao, S Shrihari

Abstract*- This study focusses on the development of fly ash concrete made with water/cement ratio of 0.5.To develop fly ash concrete in this study, 40% of cement is replaced with fly ash, manufactured sand is used as fine aggregate, light weight fly ash aggregate as used coarse aggregate and for mixing concrete instead of tap water 12% lime concentrated water is used. The fly ash concrete compressive strength obtained is equivalent to that of M30 grade concrete made with OPC. Two sets of samples are prepared one set with 40% fly ash concrete made with river sand and natural crushed stone coarse aggregates and another set of sample with 40% fly ash concrete made with manufactured sand and artificial light weight fly ash coarse aggregates. Experimental studies revealed that use of manufactured sand enhanced compressive, tensile and flexural strengths by 6-8% only. Even permeation properties such as water absorbtion and porosity of fly ash concrete made with manufactured sand and artificial light weight fly ash coarse aggregates is almost similar to that of fly ash concrete made with made with river sand and natural crushed stone coarse aggregates. The results conclude that fly ash coarse aggregates can be used for structural applications instead of natural coarse aggregates but not feasible for use in pavement as per IS 2386. Manufactured sand can be used as 100% replacement to river sand in fly ash based concretes with improved properties of concrete.

***Index terms*- cold bond technique, fly ash aggregate, artificial aggregate, light weight aggregate, polymerization**

I. INTRODUCTION

Fly ash is produced plentifully in India from power plants whose disposal is a major problem and also an environmental concern. So construction industry finds the application of fly ash in concrete development. Fly ash can be used in concrete as cement replacement upto 30% but research is going on to use high volume of fly ash in concrete. Similarly use of river sand as fine aggregate is almost stopped due to depletion of sand resources so an alternative fine aggregate replacement is found in the form of manufactured sand. Similarly for coarse aggregate now-a-days artificial coarse aggregates such as slag, fly ash etc. are being used as coarse aggregate replacement.

II. OBJECTIVES

a) To develop fly ash concrete with fly ash as partial cement replacement
b) Fly ash aggregates are developed using cold bond technique
c) To develop fly ash concrete with fly ash as partial cement replacement, manufactured sand as fine aggregate and artificial light weight fly ash as coarse aggregates
d) Strength studies are made on fly ash concrete made with manufactured sand and artificial light weight fly ash coarse aggregates

III. MIX DESIGN

Mix quantities computed as per IS method are presented below-

Cement = 390 kg/m^3 Water = 191 kg/m^3

Fine aggregates = 887 kg/m^3 Coarse aggregate = 982 kg/m^3

Water-cement ratio = 0.50

IV. DETERMINATION OPTIMUM CONCENTRATION OF LIME WATER AS MIXING WATER

Based on prior study, fly ash mortar cubes are casted with four types of mixing water to determine the optimum concentration of lime water .They are tap water, 30 grams, 60 grams and 120 grams of lime powder into 1L of tap water respectively. Powder lime is dissolved one day before the casting to make saturated lime water so that top water is used for study but not the water containing the sediment lime solids. The pH of lime water is higher than the tap water which activates the fly ash in fresh state. Mortar specimens made with 120 grams lime water found to give optimum strengths so for further study 12% concentration lime water is to be used as mixing water for fly ash concretes.

Since fly ash has high amount of silica and alumina content, to react with it equal amount of $Ca(OH)_2$ should be made available for optimal pozzolonic action. So based on the literature, 12% concentration lime water is used as mixing water in case of fly ash based concretes for better early strengths. Studies revealed that pozzolonic action does not start at least before 7 days. Addition of lime will stimulate pozzolonic reaction during early age. In this study, 23 kg of lime is added to 172 liters of tap water to make 12% concentration lime water to be used as mixing water for fly ash concretes.

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Table 1 – Quantities of concrete mixes made with various percentage replacements of fly ash

Type	Cement %	Fly ash %	Cement (kg/m^3)	Fly ash (kg/m^3)	12% Concentration Lime water as mixing water (kg/m^3)	Fine Aggregate (River sand) (kg/m^3)	Coarse Aggregate (Natural Crushed stone) (kg/m^3)
Mix1(FAC0)	100	0	390	0	195	887	982
Mix2(FAC10)	90	10	351	39	195	887	982
Mix3(FAC20)	80	20	312	78	195	887	982
Mix4(FAC30)	70	30	273	117	195	887	982
Mix5(FAC40)	60	40	234	156	195	887	982

Table 2- Compressive strengths of concrete mixes made with various percentages of fly ash

Type	Cement %	Fly ash %	Compressive Strength (MPa)		
			7 days	28 days	60days
Mix1(FAC0)	100	0	28.12	39.78	41.11
Mix2(FAC10)	90	10	26.78	37.19	43.23
Mix3(FAC20)	80	20	24.12	35.18	44.98
Mix4(FAC30)	70	30	21.11	27.10	45.61
Mix5(FAC40)	60	40	17.55	24.34	33.04

Table 3- Split tensile strengths of concrete mixes made with various percentages of fly ash

Type	Cement %	Fly ash %	Split tensile strength (MPa)		
			7 days	28 days	60days
Mix1(FAC0)	100	0	1.91	2.27	2.31
Mix2(FAC10)	90	10	1.86	2.20	2.37
Mix3(FAC20)	80	20	1.77	2.14	2.41
Mix4(FAC30)	70	30	1.53	1.87	2.43
Mix5(FAC40)	60	40	1.37	1.70	2.07

Table 4- Flexural strengths of concrete mixes made with various percentages of fly ash

Type	Cement %	Fly ash %	Flexural Strength (MPa)		
			7 days	28 days	60days
Mix1(FAC0)	100	0	3.18	3.78	3.85
Mix2(FAC10)	90	10	3.10	3.66	3.94
Mix3(FAC20)	80	20	2.95	3.56	4.02
Mix4(FAC30)	70	30	2.55	3.12	4.05
Mix5(FAC40)	60	40	2.29	2.84	3.45

V. COLD BOND TECHNIQUE

This phase is planned into 2 steps

1) Optimization of alkaline activators for fly ash aggregates
Cubes of size 70.6mm are prepared with cement and fly ash of 10:90 and with the optimal molar quantities of alkaline activator solutions (8M to 16M NaOH and Na_2SiO_3 (SiO_2/Na_2O ratio= 2)) that produces the maximum strength at 60°C temperature cured for 24 hrs. for polymerization process to occur through formation of alumina-silicate oxides. Usually activators are prepared 30 minutes before the casting begins. The ratio of Na_2SiO_3/NaOH is optimally maintained at 2.5. It was found that NaOH of 14 molarity and Na_2SiO_3 with SiO_2/Na_2O ratio 2 yields maximum strength.

2) Dry mix quantities for fly ash aggregates
Quantities required to make one cubic metre of paste, 10 parts of cement and 90 parts of fly ash are mixed with alkaline activators (Na_2SiO_3 +NaOH) in the ratio of 0.35.
Mass of fly ash = 0.90 x 2.13 g/cm^3 x 10^3= 1917 kg/m^3
Mass of cement= 0.10 x 3.15 g/cm^3x 10^3= 315 kg/m^3
Mass of Total Binder= 1917+315=2232 kg/m^3
Mass of Alkaline activators= 0.35 x 2232 = 781.2 kg/m^3

Since Na_2SiO_3/ NaOH ratio is adopted as 2.5 which means that Na_2SiO_3/ NaOH= 5/2

So mass of Na_2SiO_3 solution is 781.2 x 5/7 = 558 kg/m^3 and mass of NaOH solution is 781.2 x 2/7 = 223.2 kg/m^3

3) Preparation of NaOH solution from solid flakes available in the market Since molecular weight of NaOH is 40 gm/mol. So to prepare NaOH solution of 14 molarity, amount of flakes required to be added to one litre water is 14x40=560 gm. Since the solubility of NaOH in water is 1110 gm per 1000ml at 20°C, So to prepare 1000ml of NaOH solution mix 560 gm of NaOH flakes into one litre of water.

NaOH flakes/ Water= 560/1000=0.56

NaOH solution = 0.56 x water + water = 1.56 x Mass of Water. Mass of NaOH solution calculated is 223.2 kg/m^3. So 223.2 =

1.56 x mass of water required to mix NaOH flakes. From which, the mass of water required is obtained as 143 kg/m^3 to mix NaOH flakes of 80.2 kg/m^3 (0.56*143)

So quantity of NaOH required to prepare one m^3 volume of dry mix is 80.2 kg/m^3 and similarly the quantity of Na_2SiO_3 required in one m^3 volume of dry mix is 80.2 x2.5= 200.5 kg/m^3.

Preparation of fly ash coarse aggregate

Fly ash, cement and alkaline activator solutions are mixed to make paste and placed in a tray and flattened to required thickness of aggregate. Cut the flattened paste into square or rhombus shapes of 20mm size and heat treated for 24 hrs. in oven at 60°C. After 24 hrs. heat treatment the hardened aggregates are kept in the abrasion testing drum with abrasion charge and rotate for 15 minutes to attain cubically angular shape to aggregates. These developed light weight fly ash coarse aggregates are tested as per IS: 2386.

VI. PROPERTIES OF FLY ASH AGGREGATES

Fly ash coarse aggregates are angular in shape with a bulk density of 996 kg/m^3 when compared to natural coarse aggregate whose bulk density is 1675 kg/m^3. Specific gravity of fly ash coarse aggregates is found to be 1.84 when compared to natural coarse aggregate whose specific gravity is 2.55. Aggregate crushing value (crushing strength), Aggregate impact value (toughness) and Aggregate abrasion value (wear and tear) are 35.23%, 37.14% and 30% respectively which can be used in structures other than pavements. Water absorption is little higher but within permissible limits of usage for structures other than pavements as per IS 2386.

Table 4- Mix proportions and quantities required to prepare one m^3 volume of dry mix

Ingredients	Quantity	Proportions
Fly ash	1917 kg/m^3	6.08
OPC	315 kg/m^3	1.00
NaOH solid flakes	80.2 kg/m^3	0.25
Na_2SiO_3 Liquid	200.5 kg/m^3	0.64

Fig 1: Artificial fly ash aggregates

Table 5: Quantities of fly ash concrete mixes made with fly ash coarse aggregate

Type	Cement %	Fly ash %	Cement (kg/m^3)	Fly ash (kg/m^3)	12% Concentration Lime water as mixing water (kg/m^3)	Fine Aggregate (Manufactured sand) (kg/m^3)	Coarse Aggregate (Fly ash based) (kg/m^3)
Mix11(FAC0)	100	0	390	0	195	887	982
Mix21(FAC10)	90	10	351	39	195	887	982
Mix31(FAC20)	80	20	312	78	195	887	982
Mix41(FAC30)	70	30	273	117	195	887	982
Mix51(FAC40)	60	40	234	156	195	887	982

Table 6- Compressive strengths of fly ash concrete mixes made with fly ash coarse aggregate

Type	Cement %	Fly ash %	Compressive Strength (MPa)		
			7 days	28 days	60days
Mix11(FAC0)	100	0	30.37	42.96	44.40
Mix21(FAC10)	90	10	28.92	40.17	46.69
Mix31(FAC20)	80	20	26.05	37.99	48.58
Mix41(FAC30)	70	30	22.80	29.27	49.26
Mix51(FAC40)	60	40	18.95	26.29	35.68

Table 7- Split tensile strengths of fly ash concrete mixes made with fly ash coarse aggregate

Type	Cement %	Fly ash %	Split tensile strength (MPa)		
			7 days	28 days	60days
Mix11(FAC0)	100	0	1.99	2.36	2.40
Mix21(FAC10)	90	10	1.93	2.29	2.46
Mix31(FAC20)	80	20	1.84	2.23	2.51
Mix41(FAC30)	70	30	1.59	1.94	2.53
Mix51(FAC40)	60	40	1.42	1.77	2.15

Table 8- Flexural strengths of fly ash concrete mixes made with fly ash coarse aggregate

Type	Cement %	Fly ash %	Flexural Strength (MPa)		
			7 days	28 days	60days
Mix11(FAC0)	100	0	3.31	3.93	4.00
Mix21(FAC10)	90	10	3.22	3.81	4.10
Mix31(FAC20)	80	20	3.07	3.70	4.18
Mix41(FAC30)	70	30	2.65	3.24	4.21
Mix51(FAC40)	60	40	2.38	2.95	3.59

Fig 2 – Concrete made with fly ash aggregate and natural aggregate

VII. CONCLUSIONS

1. Concrete mix is designed for water/cement ratio of 0.5 and for strength of M30 grade
2. Instead of tap water, 12% concentration of lime water is used for mixing concrete for early age pozzolonic activity
3. Cement replacement upto 40% fly ash in concrete is reported here beyond which strengths are rapidly degrading and need other methods to improve the strengths.
4. One set of sample with 40% fly ash concrete made with river sand and natural crushed stone coarse aggregates and another set of sample with 40% fly ash concrete made with manufactured sand and artificial light weight fly ash coarse aggregates are prepared.

5. Upto 30% replacement desired strengths are achieved for made with river sand and natural crushed stone coarse aggregates.
6. Fly ash aggregates are prepared using cold bond technique where high quantities of fly ash is mixed with alkaline activators 14 M NaOH and Na2SiO3 for polymerization process.
7. Fly ash produced through this method has less density and high water absorption is little higher but within permissible limits of usage for structures other than pavements as per IS 2386. But this limitation can be overcome using manufactured sand as fine aggregate.
8. It was established from experimental results that use of manufactured sand enhanced compressive, tensile and flexural strengths by 6-8% only. Even permeation properties such as water absorbtion and porosity of fly ash concrete made with manufactured sand and artificial light weight fly ash coarse aggregates is almost similar to that of fly ash concrete made with made with river sand and natural crushed stone coarse aggregates.

So it can be concluded that fly ash aggregates can be used as coarse aggregate in combination with manufactured sand as fine aggregate for sustainability.

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Statistical Models for Mechanical Properties of Basalt Fibre Reinforced Concrete

V Rama Krishna, V Srinivasa Reddy, M V Seshagiri Rao, S Shrihari

Abstract- In the present study, strength properties of concrete reinforced with basalt fibres are examined and statistical models are developed to establish the relation between the strength parameters. Optimum length and dosage of bundles and filament basalt fibres is decided from lengths 12 mm, 36mm and 50mm and dosage of 0.2%, 0.3% and 0.4% fibre fraction by volume of concrete. This optimum dosage of and length combinations for bundled and filament fibres yield increase in compressive, split-tensile and flexural strength by……%

I. INTRODUCTION

Concrete subjected to tensile stresses develops cracks in the tensile zone which can be controlled by use of steel reinforcement. But micro and macro cracks can be prevented by the use of fibres in concrete. Fibres also enhance mechanical properties other than crack controlling. Fibres like nylon, polypropylene has low modulus of elasticity than that of matrix, high elongation property, don't impart strength but has improved toughness, impact resistance and resistance to explosive loads. Steel, carbon and glass fibre will have high modulus of elasticity, high strength and stiffness. Concrete made with low fibre volume (less than 1%) will be used to reduce shrinkage cracking, concrete made with moderate fibre volume (less than 2%) will improve mechanical properties such as flexural strength, toughness and impact resistance. Basalt fibre has high tensile strength, non-corrosive, bad conductor of electricity, good thermal and chemical resistant. Density of basalt fibre = 2600-2700 kg/m^3. Concrete made with high fibre volume (more than 2%) has improved strain hardening. Long fibres will reduce the workability of the concrete mix. Volume of long fibre required will be less than short fibre. Fibres with l/d ratio less than 50 will scatter easily in the concrete mix. Fibres with l/d ratio more than 100, are likely to interlock. In matrix having large aggregates there is tendency of lumping of fibres around large aggregates.

II. OBJECTIVES

1. To choose the optimum length of fibre and dosage of bundled basalt fibres and basalt filaments for optimum performance
2. To study the effect of basalt fibres on compressive strength, split tensile strength and the flexural strength of basalt fibre reinforced concrete.
3. To establish empirical relation of parameters such as split-tensile strength, flexural strength with compressive strength.

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III. EXPERIMENTAL INVESTIGATIONS

To assess the mechanical properties of basalt fibre reinforced concrete experimentally, the following investigations are done.

1. Dosage of basalt fibre
2. Compressive strength
3. Split-tensile strength
4. Flexural strength
5. Statistical Modelling

In this study an optimum dosage of basalt fibres of type filaments (ϕ=16μ) and bundles with various lengths (12mm/36mm/50mm) is decided upon for a plain concrete mix of M30 grade. During mixing filament fibres with length more than 36 mm forms lumps at higher dosage of 0.3% and 0.4% by volume of concrete. To prevent lumping the fibres are added slowly to the dry mix in the concrete mixer at a constant rate. The bundled fibres usually gets separated and distributed uniformly as individual filaments in the concrete mix.

As the length of basalt fibres increases slump values decreases for both filament and bundle types. Slump of 100 to200mm is desired to achieve. In high dosage and high length chopped basalt fibres slump values are less than 100mm so SP is used.

Table 1- Slump values and Compressive strengths of bundled and filament basalt fibre reinforced concrete mixes

Basalt Type	Designation	Length of fibre (mm)	Dosage percentage by volume of concrete	Slump (mm)	Compressive Strength (MPa)
Plain Concrete	PC	0	0	100	39.12
Basalt Filament	BF1	12	0.2%	195	40.19
	BF2	12	0.3%	152	41.24
	BF3	12	0.4%	173	43.15
	BF4	36	0.2%	210	41.57
	BF5	36	0.3%	220	43.78
	BF6	36	0.4%	200	45.23
	BF7	50	0.2%	220	44.39
	BF8	50	0.3%	225	48.55
	BF9	50	0.4%	140	40.11
Basalt Bundle	BB1	12	0.2%	181	41.40
	BB2	12	0.3%	160	42.48
	BB3	12	0.4%	143	44.44
	BB4	36	0.2%	220	42.82
	BB5	36	0.3%	180	45.09
	BB6	36	0.4%	130	46.59
	BB7	50	0.2%	153	45.72
	BB8	50	0.3%	170	50.01
	BB9	50	0.4%	146	41.31

Table 2- Split-tensile and flexural strengths of bundled and filament basalt fibre reinforced concrete mixes

Basalt Type	Designation	Length of fibre (mm)	Dosage percentage by volume of concrete	Split-tensile Strength MPa	Flexural Strength MPa
Plain Concrete	PC	0	0	2.96	3.62
Basalt Filament	BF1	12	0.2%	3.11	3.89
	BF2	12	0.3%	3.29	4.56
	BF3	12	0.4%	3.78	4.99
	BF4	36	0.2%	3.88	4.13
	BF5	36	0.3%	4.34	5.34
	BF6	36	0.4%	4.52	5.45
	BF7	50	0.2%	3.99	5.22
	BF8	50	0.3%	4.21	5.67
	BF9	50	0.4%	3.98	5.27
Basalt Bundle	BB1	12	0.2%	3.20	4.01
	BB2	12	0.3%	3.39	4.70
	BB3	12	0.4%	3.89	5.14
	BB4	36	0.2%	4.00	4.25
	BB5	36	0.3%	4.47	5.50
	BB6	36	0.4%	4.66	5.64
	BB7	50	0.2%	4.11	5.38
	BB8	50	0.3%	4.34	5.87
	BB9	50	0.4%	4.10	5.46

Fibre addition increases compressive strength of concrete, especially as length of basalt fibre increases the compressive strength increases and workability reduces gradually. Similarly as percentage dosage of fiber increases the compressive strength increases till certain percentage of fibre volume of concrete. The dosages of basalt fibre used are 0.2% (5.2 kg/m^3), 0.3% (7.8 kg/m^3) and 0.4% (10.4 kg/m^3) by volume fraction of the concrete. With increase in length and fibre dosage, workability reduced due to restriction of aggregate movement. At higher dosage mix becomes very stiff and cohesive and compressive strength is low due to ineffective distribution of fibres in concrete in the form of bunching together. The decrease in the slump values at high dosage of basalt fibre reinforced concrete is due to the large fibre surface area and the high content of fibres may require more cement paste to cover them. This consequently increases the water cement ratio.

For fibre length of 50mm and dosage of 0.3% fibre volume of the concrete, the compressive and flexural strengths attained are maximum but the flexural strength is found to be more for fibre length of 36mm and dosage of 0.4% fibre volume of the concrete.

4. EMPIRICAL EQUATIONS

This phase presents relations between split tensile strength, flexural strength in terms of compressive strength.

1) Relation between Split tensile Strength (S) and Compressive Strength (C)

Let the relationship between the split tensile strength (S) and compressive strength (C) be expressed in the form

$S= a (C)^{b}$ 1

a and b are constants

Take log on both sides of equation 1

$\log S = \log a + b \log C$ 2

$\Sigma \log S = N \log a + b \Sigma \log C$ 3

$\Sigma(\log C * \log S) = \log a * \Sigma \log C + b\Sigma(\log C)^2$ 4

N – No of samples considered

Solve the above equations to get

$b = [\Sigma \log C * \Sigma \log S - N \Sigma(\log C * \log S)]/[(\Sigma \log C)^2 -$

$N\ \Sigma(\log C)^2]$ ……..5

and

$\log a= [\Sigma \log S - b\ \Sigma \log C]/ N$

or

$a= \log^{-1}[\ [\Sigma \log S - b\ \Sigma \log C]/ N]$ ………6

From table 3, a = 1.0 and b = 0.35

From Equation1 we get,

$$S = C^{0.35} \qquad \text{…......7}$$

Equation 7 is the proposed empirical expression for S (Theoretical) in terms of C for basalt fibre reinforced concrete.

2) Relation between Flexural strength (F) and Compressive Strength (C)

From table 4, we get

a = 1.0 and b = 0.43

we get, $F = C^{0.42}$

is the proposed empirical expression for F (Theoretical) in terms of C for basalt fibre reinforced concrete.

Table 3- Empirical expression for Split-tensile strength in terms of Compressive Strength

Designation	Split-tensile Strength MPa (T)	Compressive Strength (C)	Y=logT	X=logC	XY	X^2
PC	2.96	39.12	0.471292	1.592399	0.750484	2.535734
BF1	3.11	40.19	0.49276	1.604118	0.790446	2.573195
BF2	3.29	41.24	0.517196	1.615319	0.835436	2.609254
BF3	3.78	43.15	0.577492	1.634981	0.944188	2.673162
BF4	3.88	41.57	0.588832	1.61878	0.953189	2.620449
BF5	4.34	43.78	0.63749	1.641276	1.046296	2.693786
BF6	4.52	45.23	0.655138	1.655427	1.084534	2.740437
BF7	3.99	44.39	0.600973	1.647285	0.989974	2.713548
BF8	4.21	48.55	0.624282	1.686189	1.052658	2.843234
BF9	3.98	40.11	0.599883	1.603253	0.961764	2.570419
BB1	3.20	41.40	0.50515	1.617	0.816828	2.61469
BB2	3.39	42.48	0.5302	1.628185	0.863263	2.650985
BB3	3.89	44.44	0.58995	1.647774	0.972104	2.715159
BB4	4.00	42.82	0.60206	1.631647	0.982349	2.662271
BB5	4.47	45.09	0.650308	1.65408	1.075661	2.735981
BB6	4.66	46.59	0.668386	1.668293	1.115063	2.783201
BB7	4.11	45.72	0.613842	1.660106	1.019043	2.755953
BB8	4.34	50.01	0.63749	1.699057	1.083131	2.886794
BB9	4.10	41.31	0.612784	1.616055	0.990293	2.611634
N=18	Σ		11.17551	31.12122	18.3267	50.98989

Table 4- Empirical expression for Flexural strength in terms of Compressive strength

Designation	Flexural Strength MPa (F)	Compressive Strength (C)	Y=logT	X=logC	XY	X^2
PC	3.62	39.12	0.558709	1.592399	0.889687	2.535734
BF1	3.89	40.19	0.58995	1.604118	0.946349	2.573195
BF2	4.56	41.24	0.658965	1.615319	1.064438	2.609254
BF3	4.99	43.15	0.698101	1.634981	1.141381	2.673162
BF4	4.13	41.57	0.61595	1.61878	0.997088	2.620449
BF5	5.34	43.78	0.727541	1.641276	1.194096	2.693786
BF6	5.45	45.23	0.80956	1.655427	1.340167	2.740437
BF7	5.22	44.39	0.717671	1.647285	1.182208	2.713548
BF8	5.67	48.55	0.824126	1.686189	1.389632	2.843234
BF9	5.27	40.11	0.797268	1.603253	1.278221	2.570419
BB1	4.01	41.40	0.603144	1.617	0.975285	2.61469
BB2	4.70	42.48	0.672098	1.628185	1.094299	2.650985
BB3	5.14	44.44	0.710963	1.647774	1.171507	2.715159
BB4	4.25	42.82	0.628389	1.631647	1.025309	2.662271
BB5	5.50	45.09	0.740363	1.65408	1.224619	2.735981
BB6	5.64	46.59	0.822168	1.668293	1.371617	2.783201
BB7	5.38	45.72	0.730782	1.660106	1.213176	2.755953
BB8	5.87	50.01	0.836957	1.699057	1.422037	2.886794
BB9	5.46	41.31	0.810233	1.616055	1.30938	2.611634
N=18	Σ		13.55294	31.12122	22.2305	50.98989

IV. CONCLUSIONS

1. For fibre length of 50mm and dosage of 0.3% fibre volume of the concrete, the compressive and flexural strengths attained are maximum but the flexural strength is found to be more for fibre length of 36mm and dosage of 0.4% fibre volume of the concrete.

2. The increase in compressive, split-tensile and flexural strength of bundled basalt fibres and filament basalt fibres are almost similar.
3. The optimum length of fibre for basalt filament and bundled fibre concrete is 50 mm and dosage is 0.3% by volume of concrete for which the increase in compressive is 24% and 27% in basalt filament and bundled fibre concrete respectively
4. Flexural strength increase is 56 and 62% for basalt filament and bundle fibre concrete respectively made with optimum length of fibre of 50mm and dosage 0.3% fibre fraction by volume of concrete.
5. It is observed that flexural strength is 52% and 57% more for filament and bundled basalt concrete made with 36mm length fibre and for dosage of 0.4% fibre fraction volume of concrete.
6. Relation between Split tensile Strength (S) and Compressive Strength (C) is $S = C^{0.35}$
7. Relation between Flexural strength (F) and Compressive Strength (C) is $F = C^{0.42}$

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Flexural Capacity of Concrete Beams Reinforced with Basalt Fibre Rebars

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Abstract-An effort to find an alternative for conventional steel in concrete by researchers leads to study the behaviour of basalt fibre reinforced polymer (BFRP) bars in concrete. In the present study the flexural behaviour of basalt fibre reinforced polymerconcrete beams. The tension test on BFRP bars demonstrated that BFRP bars have nearly three times high tensile strength, low modulus of elasticity of nearly one-fourth of conventional steel bars and alsothe stress-strain behaviour is linearwithout any yield point up to failure. In the present study, flexural behaviour of concrete beams reinforced with BFRP rebars comparing with reference beams made with conventional steel reinforcement. Load carrying capacity, deflection at mid-span and mode of cracking is observed. The beam with flexural BFRP reinforcement has load capacity of 46.7 kN whereas for beam with steel rebars has flexural load capacity of 37.6 kN. Deflections of BFRP reinforced concrete beams at midspan during failure is 14mm considerably more than the steel reinforced beam deflection which is 5.6mm, due to much lower modulus of elasticity of BFRP rebars when compared to steel rebars. Average width of cracks at failure in BFRP concrete beams nearly 4 times higher than in the reference steel concrete beams.

Index terms: BFRP, Basalt fibres, FRP, high tensile strength, flexural capacity

I. INTRODUCTION

Fibre reinforced polymer bars are used as alternative to steel rebars in concrete due to their highcorrosion resistance and less conductive to electricity. Density of basalt (2600 kg/m^3) is almost three times less than that of steel (7850 kg/m^3) which means that the BFRP rebars are very light alternative construction material and consumes less energy to produce them than steel rebars which will have an impact on the environment. Basalt rocks are mined and crushes into desired composition and are then melted at 1400 - 1600°C, the molten basalt is then drawn into continuous basalt filaments of12-18µ diameter and are chopped into bundles to be used in concrete.Literature advocates that the rebars to be used in concrete beam shall be made from un-chopped basalt fibres glued into bars and are then pre-stressed up to at least 50% of its tensile strength. It was reported that the tensile strength of BFRP rebars in about 1000 – 1300 MPa and that of steel rebars is 500 MPa. Studies also reported that the modulus of elasticity of basalt fibre is very less than the steel, of about 70 GPa. Basalt fibres rebars are manufactured by bonding continuous basalt fibre filaments (un-chopped) with epoxy resin. Sand is glued onto the surface to enhance bond between BFRP bars and concrete.

II. OBJECTIVES

1) To determine the load capacities at first crack and at failure of concrete beams made with basalt fibre rebars
2) To determine the deflection at mid-span at failure of concrete beams made with basalt fibre rebars
3) To observe the cracking behaviour of concrete beams made with basalt fibre rebars

III. EXPRIMENTAL INVESTIGATIONS

For experimental investigations, two sets of concrete beams are prepared. One with BFRP rebars and another with conventional steel rebars. For concrete beams reinforced with BFRP bars, bottom reinforcement is made up of BFRP bars with steel stirrups. Table 1 presents properties of BFRP bars. It's density is 1/3rd of the steel's density, tensile strength is almost 2.4 times the steel's tensile strength and Modulus of Elasticity is almost 3 times less than steel's E value.

The BFRP reinforcement area with respect to gross concrete area (reinforcement ratio) and the span / depth ratio (l/d) governs the failure mode of the BFRP concrete beam specimen. When l/d increases, the failure mode deviations from shear failure to flexural shear failure. The Ultimate flexural load for beams reinforced with BFRP rebars is greater than the flexural load carrying capacity of beams reinforced with conventional steel rebars. Concrete beams reinforced with BFRP rebars will not fail by sudden failure due to high tensile nature of BFRP rebars. Table 3 presents the results of experimentally obtained carrying capacities of the tested BFRP beams reinforced with 10 mm basalt bars Table 2 presents the BFRP beam details.

Table 1 – Properties of BFRP Bars

Property	Value
Rebar diameter	10mm
Density	2600 kg/m^3
Tensile Strength	1200 MPa
Modulus of Elasticity	70 GPa

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Table 2- Flexure Test beam details

Beam Section	Grade of Concrete	Beam type	Tension Reinforcement	Nominal Compression Reinforcement	Shear Reinforcement	Beam dimensions
Under reinforced	M30	Conventional Concrete Beam	2 Nos - 10mmφ Fe 415 steel bars	2 Nos - 8mm φ Steel bars	2 legged - 8mm φ Steel @100mm c/c	100 mm x 150 mm x 1100 mm
		BFRP Concrete Beam	2 Nos - 10mmφ BFRP bars	2 Nos - 8mm φ Steel bars	2 legged - 8mm φ Steel @100mm c/c	100 mm x 150 mm x 1100 mm

Table 3 – Flexural load capacities and deflections of BFRP and conventional steel beams

Property	Steel reinforced concrete beam	Basalt reinforced concrete beam
Load at First Crack	12.3 kN	26.8kN
Maximum Load Capacity, F	37.6 kN	46.7 kN
Moment Carrying Capacity, M	9.4 kN.m	11.68 kN.m
Deflection at Mid-span, D	5.6mm	14mm
Crack Width at failure	1mm	4mm

Table 4 - Loads (P) and deflections (δ) of concrete beams

Concrete Beam made with Steel Rebar		Concrete beam made with BFRP Rebar	
Load kN	**Deflection at Centre Mm**	**Load kN**	**Deflection at Centre mm**
0	0	0	0
3.95	1	11.2	1
11.35	2	15.8	2
20	2.5	20.7	3
22.4	3	25.85	4
27.15	3.5	30.7	5
33.85	4	35.5	6
34.7	4.5	37.95	7
35.1	5	40.95	8
37.6	5.6	43.05	9
33.25	10	43.7	10
31	11	43.35	11
30	12	44.5	12
29.2	13	45.55	13
27.8	13.78	46.70	14
		44.55	15
		43.1	16
		42.45	17
		37.1	18
		35.25	19
		30.95	20
		28.4	21
		27.05	22
		24.95	23
		23	23.92

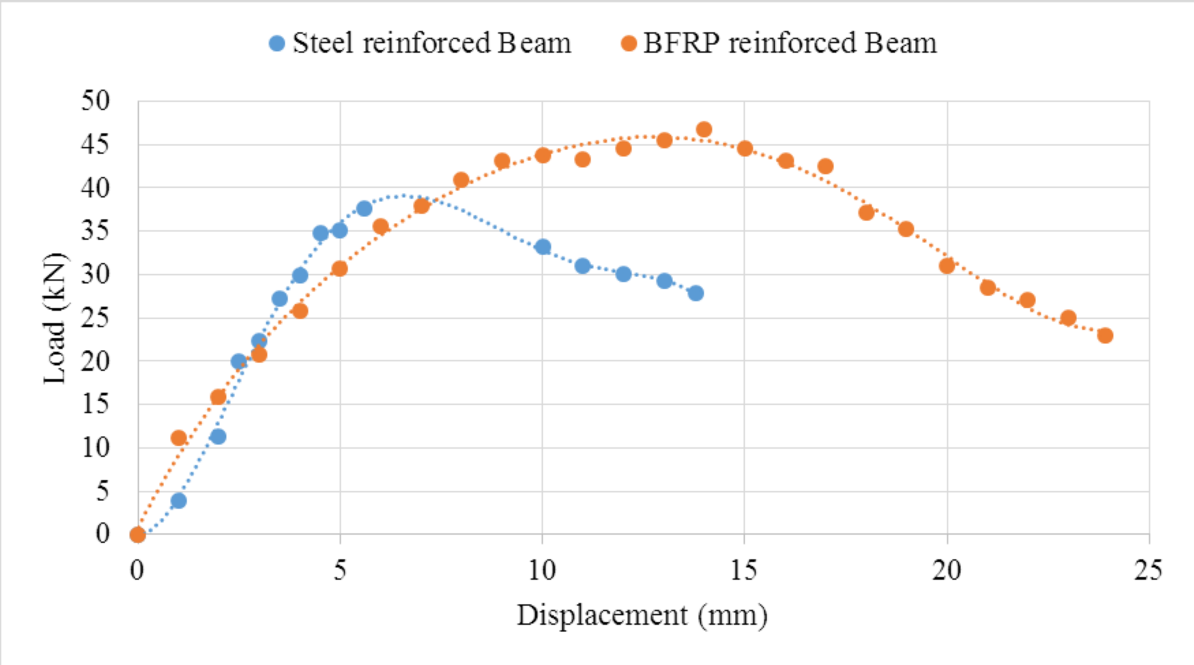

Figure 1- P-δ curve for concrete beams made with conventional steel and BFRP bars

Figure 2- Testing of beam reinforced with steel rebar

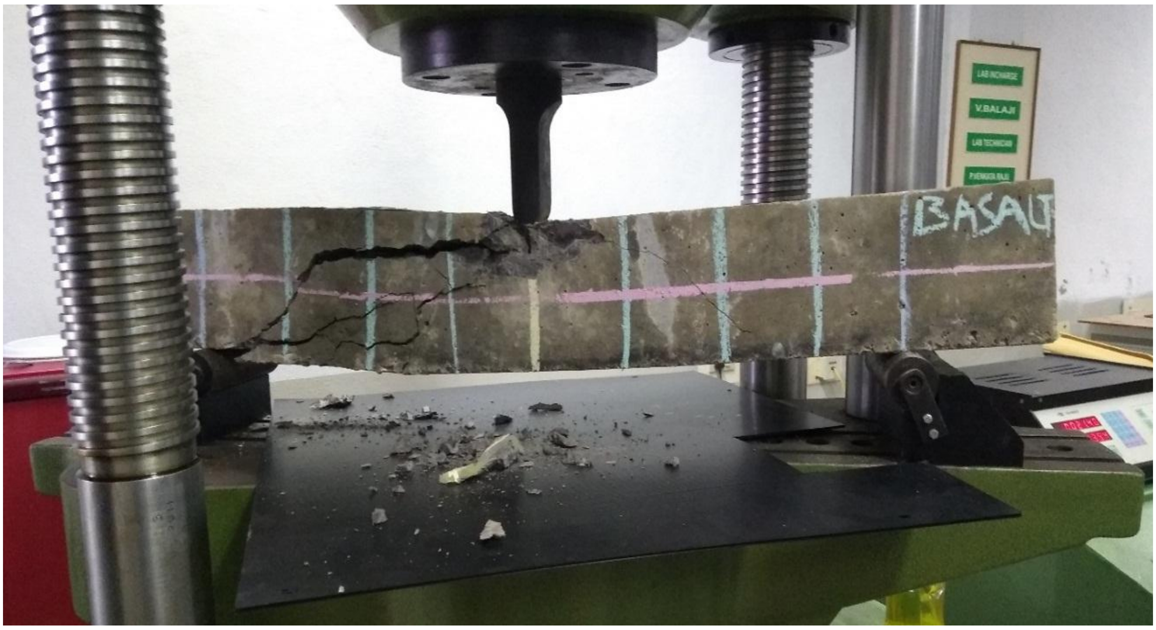

Figure 2- Testing of beam reinforced with basalt rebar

Average width of cracks at failure in BFRP concrete beams nearly 4 times higher than in the reference steel concrete beams. Deflections at mid-span and crack width at failure are more in concrete beam made with BFRP rebar than concrete beam with steel reinforcement which may be major factors in designing the beams. Table 4 presents load – deflections of beams made with BFRP and conventional steel rebarsDeflections of BFRP reinforced concrete beams is considerably more than the steel reinforced beam deflection, due to much lower modulus of elasticity of BFRP rebars when compared to steel rebars.The beam with flexural BFRP reinforcement has load capacity of46.7 kNwhereas for beam with steel rebars has flexural load capacity of 37.6 kN.Modulus of elasticity of BFRP rebars is less than steel rebars because of which there will be excessive deflection at service loads in concrete beams made with BFRP rebars than the concrete beams made with steel bars. Since basalt rebars are purely elastic and don't exhibit yield point unlike steel rebars during tension test its stress-strain curve is linear till failure In the present study the BFRP concrete beams are under-reinforced so the beams fail suddenly due to reinforcement fracture with large deflections. It was observed that steel reinforced concrete beams have failed in flexure whereas BFRP reinforced concrete beams failed in shear so it is suggested that in the design of BFRP concrete beams is little different from that conventional beam design because the BFRP reinforcement area with respect to gross concrete area (reinforcement ratio) and the span / depth ratio (l/d) governs the failure mode of the BFRP concrete beam specimen. When l/d increases, the failure mode deviations from shear failure to flexural shear failure. So specimen length and depth are chosen in such a way so that failure should be flexure failure or shear reinforcement design should be adequate.

IV. CONCLUSIONS

1. The beam with flexural BFRP reinforcement has load capacity of 46.7 kN whereas for beam with steel rebars has flexural load capacity of 37.6 kN.
2. Deflections of BFRP reinforced concrete beams at midspan during failure is 14mm considerably more than the steel reinforced beam deflection which is 5.6mm, due to much lower modulus of elasticity of BFRP rebars when compared to steel rebars.
3. Average width of cracks at failure in BFRP concrete beams nearly 4 times higher than in the reference steel concrete beams

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Cementing Efficiency of Rice Husk Ash and Ground Granulated Blast Furnace Slag in M60 grade Self Compacting Concrete

G Mounika, V Srinivasa Reddy, M V Seshagiri Rao, M Swaroopa Rani

Abstract- This paper enumerates strength gain efficiency of Rice Husk Ash (Rha) and Ground Granulated Blast Furnace Slag (Gbbfs) blend in Self-Compacting Concrete (SCC). From the precious studies carried by the authors it was observed that optimal use of Rha+Ggbfs in low and medium strength concretes imparts initial strengths and also later strengths. In low and medium strength SCC mixes, Ggbfs replaces OPC optimally (30%) and Rha replaces Ggbfs optimally (3%) but in case of high strength SCC mixes, RHA replacing Ggbfs does not offer the required workability or strength so instead of replacing Ggbfs by certain amount, Rha is added to the SCC. It was found that GGBFS does not yield the required workability so RHA is added to GGBFS based SCC. So after various trial mixes it was found that 25% GGBFS by weight of OPC and 5% RHA by weight of GGHFS is added to OPC. It was observed that 5% RHA addition to OPC made with 25% Ggbfs gives desired workability and strength. Due to addition of GGBFS to SCC will enhance the later age compressive strength but early age compressive strength decreases while the desired workability is controlled using SP appropriately. In M60 GGBFS+RHA based SCC, the strength increase at 3 days is nearly 33% and the compressive strength at 28 days decreased by 10%. Similarly tensile strength in a GGBFS and RHA admixed SCC increases by around 27% in M60 grade.

Index words – Cementing efficiency factors, Rice husk ash, Ground granulated blast furnace slag, RHA, GGBFS

I. INTRODUCTION

SCC is a special type of concrete which can flow and compact by itself. To acquire such property the composition of the materials used should be adjusted in such a way that paste content is more for better fluidity and coarse aggregate content should be controlled so that flow is hindered and SP is used to control segregation.

Fines play a major role in SCC contributing for viscosity and workability. The major requirement of SCC is its capability to flow, pass and resist segregation. The Ggbfs is a combination of lime, silica, and alumina. Rha is made up of highly reactive silica due to its high fineness or high surface area and non-crystalline structure.

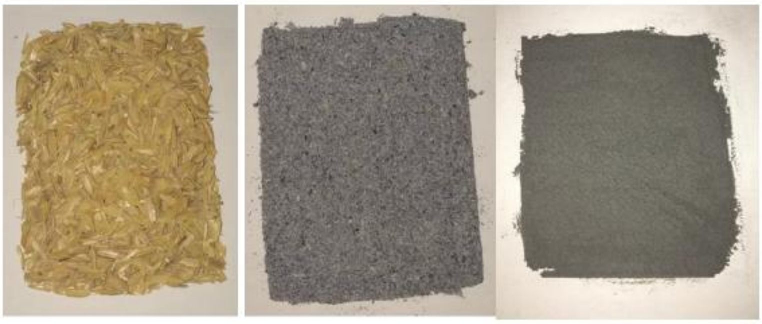

Fig 1: Preparation of Rha

Table 1- Characteristic SCC mix constituents (EFNARC 2005)

Constituent	Typical range by mass (kg/m^3)	Typical range by volume (litres/m^3)
Powder	380 - 600	
Paste		300 - 380
Water	150 - 210	150 - 210
Coarse aggregate	750 - 1000	270 - 360
Fine aggregate (sand)	Content balances the volume of the other constituents, typically 48 – 55% of total aggregate weight.	
Water/Powder ratio by Vol		0.85 – 1.10

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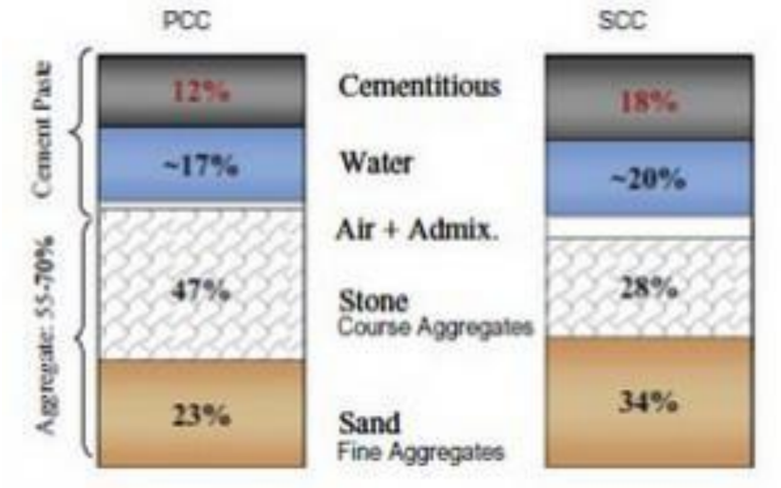

Fig 2 – SCC Components

II. METHODS to check SCC CHARECTERISTICS

The main purpose for tests on SCC is assess its flowabilty or deformable. The requirements for SCC is ability to fill, pass and resist segregation. One single method cannot characterize SCC so the combination of methods are adopted to access the self-compatibility and viscosity of SCC. To access the filling ability Slump flow, T_{50cm} Slump flow, V-funnel, Orimet etc tests are used. J ring, L Box, U Box and Fill Box tests are used to access passing ability of SCC. V-funnel at $T_{5minutes}$ and GTM screen stability tests are used to access the segregation resistance of SCC.

III. DESIGN OF SCC MIX

Local materials can be used in the design with appropriate corrections. Increase the powder content so that the paste content is increased and void content in aggregate is reduced, segregation is resisted by the use of viscosity enhancing agents. So by proper controlling the ingredients mix in SCC the requirements of SCC can be achieved. At present all SCC developers are adopting EFNARC guidelines since no standards are available. Researchers suggested various mix design methods based on several trial mixes. Most important mix designs are Nan-Su mix design method, EFNARC specifications etc.

IV. PROBLEM STATEMENT

In structures where there is dense reinforcement, the flow of concrete may be prohibited due to presence of coarse aggregate due to which concrete may not pass into congested reinforcement areas forming voids and leads to poor compaction. So in SCC, coarse aggregate size and quantity is reduced to facilitate smooth flow into closed reinforcement areas. The purpose of this project work is to evaluate the cementing efficiency in terms of strength of M60 grade ternary blended SCC made using GGBFS and RHA.

V. PROJECT SIGNIFICANCE

SCC can be developed using cement alone but usage of fly ash in SCC with the help of SP imparts similar performance as that of OPC only SCC. But rate of strength gain is effected when fly ash is used in high quantities in SCC. The early age strengths regain is very slow due to usage of fly ash while the later age strength gain is significant. This phenomena can be applicable to low and medium grade fly ash based SCC but it is not possible in high strength grade SCC because target strength in high strength fly ash concrete cannot be achieved with fly ash alone in SCC need some advocator to make fly ash active during early age. Similar is the case of GGBFS admixed in concrete instead of fly ash. GGBFS imparts later age strength to low and medium grade concretes but rate of gain of strength in early days is very low so RHA is added to GGBFS based SCC to boost the strength in early 3 and 7 days. So in the present work the strength efficiency of RHA and GGBS in SCC is evaluated to comprehend the role of pozzolanic behaviour of RHA and GGBS combination on the performance of SCC.

VI. OBJECTIVES

1. Appraise the compressive strength of M60 grade ternary blended SCC mix
2. Evaluate the influence of GGBFS and RHA blend on compressive strength of M60 grade SCC mixes
3. To estimate the strength efficiency factors of GGBFS and RHA based SCC mix at different ages of curing.

VII. LITERATURE REVIEW

The idea of SCC was coined by Okamura of Japan (1986). After which lots of research was reported and discussed below.

K Ozawa et al. (1989) studied the influence of 10-20% FA and 25-45% GGBFS on the properties of SCC as improving.

Badawe B.R and B.R Kumbhar (1997) found that concrete made with RHA has similar behaviour as that of concrete made with silica fume. Chemical resistance of H2SO4 of RHA based concrete is studied.

Rao M V S et al. (1999) studied the effect of 60% FA and 30% RHA replacement on the compressive strengths at 7 and 28 days and found to be improved by 44%. RHA improves early day strength and fly ask later age strength. Flexural strength of RHA based fly ash

Ganesh Babu K et al. (2000) appraised the efficiency of various admixtures or SCMs in concrete based on age and replacement percentage.

Nan - Su et al. (2001) suggested an innovative mix design practice for SCC, to make sure that the concrete attained the flowability, self-compacting capability and other anticipated SCC properties.

M V S Rao et al. (2004) investigated M40 to M80 grade concretes by considering 10% RHA as optimal percentage replaceement. They detected at higher RHA replacement percentages, the workability is significantly decreased so SP is required in high quantities.

Ravindra Krishna et al. (2005) studied the durability aspects of RHA based concrete through acid attack resistance and found that acid resistance increased by 80%.

Tahir Kibriya et al. (2006) accesses the characteristics of high strength grade RHA based SCC. Authors replaced 50% Portland cement with RHA and found to offer high resistance to sulphate and acidic environment with reduced permeability.

A Ahmadi et al. (2007) studied that RHA augment the micro and macro structure of the ITZ in SCC. Author reported that RHA of 20% replacement showed promising improvement in properties.

VIII. CEMENTING EFFICIENCY

In this paper strength efficiency of GGBFS+RHA blend in high grade (M60)SCC is expressed as efficiency factor "k".

The Bolomey suggested an empirical formula to predict the strength of hardened concrete. That equation modified as

f_{ck} = a [(C+k*GR)/W] + 0.5

f_{ck} = estimated compressive strength (MPa.)

C =cement content (kg / m^3)

GR is the GGBFS+RHA mixture (kg/m^3)

W = water content in kg/m^3 and k represents efficiency factor.

IX. TEST RESULTS AND DISCUSSIONS

Table 2 presents the quantities of materials in blended SCC of M60 grade. Table 3 presents compressive strength of GGBFS admixed SCC at various percentage of replacement. Table 4 present compressive strengths of M60 grade blended concrete made with 25% GGBFS by weight of cement and 5% RHA by weight of powder of at all ages of concrete curing.

In M60 grade, the target strength at 28 days could not be achieved even after 25% GGBFS is admixed to concrete. So RHA is added to GGBFS based concrete. It was found that 5% RHA by weight of powder added to 25% GGBFS by weight of cement admixed concrete gives desired workability and compressive strength for M60 grade concrete.In M60 grade SCC replacement of cement or GGBFS by RHA does not give desired performance so after various trials it was decided that 5% RHA addition gives desired workability and strength. Due to addition of GGBFS to SCC will enhance the later age compressive strength but early age compressive strength decreases while the desired workability is controlled using SP appropriately. In M60 GGBFS based SCC, the strength reduction at 3 days is nearly 10% and the compressive strength at 28 days decreased by 11%. RHA is added as replacement of cement to improve the early age strength of SCC. In M60 GGBFS+RHA based SCC, the strength increase at 3 days is nearly 33% and the compressive strength at 28 days decreased by 10%. Similarly tensile strength of GGBFS and RHA admixed SCC increases by around 3 to 27% in M60 grade.

X. CEMENT EFFICIENCY FACTOR

Bolomey's Coefficients (A) are figured from equation suggested by Bolomey. The strength efficiency factor 'f' of GGBFS in SCC for various replacement percentages at different ages can be assessed using strength and water/(cement+k*GGBFS) relation proposed by Bolomey.

Table 2 - Quantities of materials in blended SCC of M60 grade

Grade	Cement 'c' (kg)	Optimum % of replacement	GGBFS 'g' (kg)	RHA 'r' (kg) (%)	Water 'w' (kg)	Powder 'p' (p=c+g+r) (kg)	w/p ratio
M60	600	0% (GGBFS)	0	-	190	600	0.32
	450	25% (GGBFS)	150	-	190	600	
	450	(GGBFS+RHA)	150	30 Additive (5% bwp)	190	630	0.30

Table 3 -Compressive strength of GGBFS admixed SCC at various percentage of replacement.

% of GGBFS Replacement (of cement quantity)	Compressive strength (N/mm^2) M60		
	3 d	7 d	28 d
0	21.90	43.03	65.97
10	18.39	32.23	54.92
15	18.19	41.49	55.79
20	19.44	33.87	58.20
25	19.68	34.43	59.22
30	17.96	31.97	54.69

d- days

Table 4-Compressive strength of M60 grade concrete made with various percentage of GGBFS by weight of cement and 5% RHA by weight of powder

% of GGBFS Replacement (of cement quantity)	RHA 5% added (of powder quantity) kg	Compressive Strength (N/mm^2) M60		
		3 d	7 d	28 d
0	0	21.90	43.03	65.97
10	30	18.95	40.44	66.03
15	30	19.75	41.68	68.16
20	30	20.22	41.93	69.39
25	30	20.78	43.97	72.07
30	30	20.26	42.63	70.39

Table 5 - Tensile strength of M60 blended SCC mixes

Designation	Tensile strength (N/mm^2) @ 28 days	
OPC based SCC mix	100% OPC M60 Grade SCC mix	3.89
GGBFS admixed SCC mix	Replacement percentage of GGBFS (of cement quantity) is 25% in M60 Grade SCC mix	4.02
GGBFS and RHA admixed SCC mix	Optimum replacement percentage of GGBFS and RHA Combination is 25% GGBFS (of cement quantity) and 5% RHA (of GGBFS quantity) in M60 Grade SCC mix	4.93

Table 6 - Calculations of Bolomey's Constants

Age	M60
3d	A=7.49
7d	A=14.74
28d	A=22.58

Table 7 - Evaluation of Strength Efficiency factor 'k' of GGBFS in SCC

Replacement % of GGBFS (bwc)	Cementing Efficiency Factor(k) M60		
	3 d	7 d	28 d
0	-	-	-
10	0.15	0.01	0.04
15	0.38	0.08	0.15
20	0.59	0.12	0.54
25	0.66	0.35	0.69
30	0.53	0.24	0.55
35	0.68	0.12	0.47

Table 8 -Evaluation of GGBFS and RHA combination Cementing or Strength Efficiency in M60 SCC mix

Optimum replacement percentage of GGBFS and RHA (bwc)	Cementing Efficiency Factor 'k' M60		
	3 d	7 d	28 d
30% Powder (25% GGBFS bwc + 5%RHA bwg as additive)	0.72	0.95	1.38

Table 9- Cementing or Strength Efficiency factors of GGBFS and RHA in SCC

Pozzolan	Efficiency Factor 'k' (For optimum % replacement)								
	M20 Grade			M40 Grade			M60 Grade		
	3 d	7 d	28 d	3 d	7 d	28 d	3 d	7 d	28 d
GGBFS	0.81	1.27	1.89	0.72	1.21	1.64	0.53	0.24	0.55
GGBFS and RHA	1.08	1.28	2.30	0.77	1.27	2.00	0.72	0.95	1.38

Cementing or Strength Efficiency factor of admixture (called as supplementary cementing material (SCM)) indicates the amount of powder in kg replaces one kg of cement to achieve similar strength. For matching the performance of SCM with regard to concrete durability, the notion of strength or cementing efficiency factor is used. The strength or cementing efficiency factor (k-value) is expressed as the part of the pozzolan (Powder) in an SCM admixed or in additive concrete which can be considered as equivalent to OPC.

XI. CONCLUSIONS

Based on the result of this research the following conclusions can be drawn:

1. For M 60 grade SCC Mix the mandatory target strength was not attained at 25% GGBFS so 5% RHA was added instead of replacement of GGBFS while in M20 and M40. The calculations have shown that the Strength Efficiency factor 'k' at 3, 7 and 28 days were high at 25% GGBFS and 5% RHA addition (bwc).
2. The Strength Efficiency factor for M60 grade SCC 'k' was 0.72, 0.95 and 1.38 at 3, 7 and 28 days respectively at optimal 25% GGBFS replacement and 5% RHA as .additive.
3. Strength efficiency is more in GGBFS and RHA admixed SCC mixes than in GGBFS alone admixed SCC mixes.
4. Strength efficiency increased by 10% in high grade SCC mixes made with GGBFS and RHA when compared to OPC based SCC mixes.

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Estimation of Ground Granulated Blast Furnace Slag and Rice Husk Ash Cementing Efficiency in Low and Medium Grade Self-Compacting Concretes

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Abstract - Ternary blended Self Compacting Concrete (SCC) made with rice husk ash (RHA) and GGBFS (ground granulated blast furnace slag) has developed as a substitute to normal concrete. It has advantages such as less cement usage, energy usage, cost and for other ecological and socio-economic benefits. The current work quantifies the 3, 7 and 28-days cementitious efficiency for various percentages of RHA and GGBFS combination in SCC. The usage of GGBFS in M20 and M40 SCC reduces workability but increases compressive and tensile strength when compared with OPC based SCC. The optimum GGBFS is found to be 30% for low and medium strength levels of SCC. For M20 and M40, 30% GGBFS reduces workability slightly but still within desired limits. So after various trial mixes it was found that 27% GGBFS by weight of OPC and 3% RHA by weight of GGBFS quantity can be admixed to OPC SCC to achieve similar strength and workability and also better rate of strength regain in early days of hardening. In M20 and M40 grades of SCC, 3% RHA by weight of GGBFS quantity is replaced. Due to addition of GGBFS to SCC will enhance the later age compressive strength but early age compressive strength decreases while the desired workability is controlled using SP appropriately. This is true for all grades of GGBFS based SCC. In M20 GGBFS based SCC, the strength gain at 3 days is nearly 9% but the compressive strength at 28 days increased by 31%. In M40, GGBFS based SCC, the strength gain at 3 days is nearly 14% but the compressive strength at 28 days increased by 21%. RHA is added as replacement of cement to improve the early age strength of SCC. RHA addition to concrete as cement replacement may help to improve strength marginally but impacts the workability drastically so SP should be used controllably to attain the desired workability. In M20 GGBFS+RHA based SCC, the compressive strength enhancement at 3 days is 21% and the compressive strength at 28 days increased by 46%. In M40, GGBFS+RHA based SCC, the compressive strength enhancement at 3 days is 20% and at 28 days increased by 34%. Similarly tensile strength in all grades of GGBFS and RHA admixed SCC increases by around 15 to 34% in M20 grade and 9 to 36% in M40 grade SCC mix. So it can be concluded that RHA and GGBS combination principally yields early strength which is not possible in SCC mixes primary made with fly ash.

Index words – Cementing efficiency factors, Rice husk ash, Ground granulated blast furnace slag, RHA, GGBFS

I. INTRODUCTION

Hajime Okamura is considered to be the first person to present the idea of concrete consolidates by itself.

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This type of special concrete called self-compacting concrete (SCC) has enhanced performance and various This concrete is supposed to have ability to flow and don't require any form of compaction as adopted in conventional concrete. social-economic benefits. The composition of SCC mix majorly consists of powder and fine aggregates and uses mineral and chemical admixtures. This concrete is highly workable, self-consolidating and highly flowable. Self-consolidating concrete mainly consists of high contents of cement paste and has issues with segregation, shrinkage and heat generation. So use of admixtures such as Water Reducers and Viscosity modifiers are used in SCC to control the rheology of concrete. There is no standard code available in India for SCC. In SCC, fines are the major game changer and is resposible for fluidity and SP is responsible for viscosity and workability. SCC should process filling ability, passing ability and segregation resistance. In order to attain the above properties SCC should contain high amount of fillers such as fly ash along with the use of chemical admixtures. The materials used in producing SCC are Cement (10% of total mix volume), Fine aggregate, Coarse aggregate (less than 50% of total aggregate ratio), Water, Mineral and Chemical admixtures. From durability point of view, the cement content should not be more than 500 kg/m^3 and if the cement content is less than 350 kg/m^3 the usage of fillers or pozzolans is advisable. Cement and filler together forms powder material. Powder in SCC prevents segregation of aggregates and improves workability. Usage of powders in SCC alters the microstructure of SCC by improving the density of particle packing and easy viscosity and friction between particles.

II. EFNARC PROVISIONS

1. Water/powder ratio by volume is taken as 0.85 to 1.10. Water content is restricted to 210 litre/m^3.
2. Total powder content – minimum 380 and maximum 600 kg per meter cubic.
3. Coarse aggregate -about 45-50 % of total aggregate weight. Fine aggregate content is used more.
4. VMA is used to control the variations of the sand grading and the moisture content of the aggregates.

III. DESIGN OF SCC MIX

Increase the powder content so that the paste content is increased and void content in aggregate is reduced, segregation is resisted by the use of viscosity enhancing agents.

At present all SCC developers are adopting EFNARC guidelines since no standards are available Researchers suggested various mix design methods based on several trial mixes. Most important mix designs are Nan-Su mix design method, EFNARC specifications etc.

IV. OBJECTIVES OF THE PRESENT STUDY

1. Study the influence of GGBFS on compressive strength of M20, M40 and M60 grade SCC mixes
2. Study the influence of GGBFS and RHA on compressive strength of M20, M40 and M60 grade SCC mixes
3. To evaluate the strength efficiency factors for 3, 7 and 28 days of GGBFS and RHA based SCC mixes.

V. CEMENTING EFFICIENCY

The influence of GGBFS and RHA mixture is based on the age of the concrete and the percentage of replacement. RHA develops the micro-structure of the ITZ. In this paper cementing efficiency of GGBFS+RHA blend in low (M20) and medium (M40) grades of SCC is conveyed as efficiency factor "k". It was found that optimum replacement level of GGBFS in cement concrete is 30% and 25% for low (M20) and medium (M40) grades of SCC. The Bolomey suggested an empirical formula to predict the strength of hardened concrete. That equation modified as

f_{ck} = a [(C+k*GR)/W] + 0.5

f_{ck} = estimated compressive strength (MPa.)

C =cement content (kg / m^3)

GR is the GGBFS+RHA mixture (kg/m^3)

W = water content in kg/m^3 and k represents efficiency factor.

The rate of pozzolanic reaction (PR) and cement hydration (CH) governs the value of k. If the strength attained by the blended concrete is same as that of concrete made with only cement then k is equal to one indicates that the total powder contents are same in both types of concrete otherwise if k less than one, for similar strengths total powder content in blended concrete is less than cement content in conventional concrete signifying that the pozzolanic reaction would be slower than cement hydration so the conventional concrete will attain more strength than blended concrete. The GGBFS based concrete has k is less than one at early age and would reach unity at later age. If k greater than one means pozzolanic reaction occurs along with hydration of cement and strength attained by blended concrete is higher than reference concrete for same water-cement ratio. GGBFS + RHA based SCC has 'k' more than one at 3 and 7 days and therefore the strengths of GGBFS + RHA based SCC is higher. The contribution of GGBFS and RHA may be expressed in terms of efficiency factor, k. For compressive strength of concrete, k is in the range of 0.7 to 1.8, which means that in a conventional concrete, 1 kg of GGBFS may replace 0.7 to 1.8 kg of cement to attain the similar compressive strength for same water cement ratio.

VI. EXPERIMENTAL TEST RESULTS

The following tables present experimental results of various tests conducted. Table 1 presents the quantities of materials in blended concretes of various grades. Table 2 shows Compressive strength of GGBFS admixed SCC at various percentage of replacement,

Table 1- Quantities of materials in blended concretes of various grades

Grade	Cement 'c' (kg)	Optimum % of replacement	GGBFS 'g' (kg)	RHA 'r' (kg) (%)	Water 'w' (kg)	Powder 'p' (p=c+g+r) (kg)	w/p ratio
M20	400	0% (GGBFS)	0	-	180	400	0.45
	280	30% (GGBFS)	120	-	180	400	
	280	30% (GGBFS+RHA)	116.4	3.6 (Admixed) (3% of optimum GGBFS)	180	400	
M40	500	0% (GGBFS)	0	-	190	500	0.38
	350	30% (GGBFS)	150	-	190	500	
	350	30% (GGBFS+RHA)	145.5	4.5 Admixed (3% of optimum GGBFS)	190	500	

Table 2 -Compressive strength of GGBFS admixed SCC at various percentage of replacement.

% of GGBFS Replacement (of cement quantity)	Compressive strength (N/mm^2)					
	M20			M40		
	3 d*	7 d*	28 d*	3 d*	7 d*	28 d*
0	15.58	22.47	30.97	20.04	33.06	47.95
10	10.81	19.71	33.59	15.48	29.77	49.84
15	11.81	20.44	35.18	16.45	30.68	50.49
20	12.00	20.93	36.14	16.92	30.93	50.78
25	12.33	21.93	36.67	17.26	31.17	52.68
30	14.15	24.34	40.58	17.72	34.93	57.94
35	12.91	23.46	39.22	16.86	32.79	54.00

*d- days

Table 3 - Compressive strength of optimally blended GGBFS and RHA based concrete of low and medium grade

Optimum GGBFS and RHA Combination % of replacement	Compressive strength (N/mm^2)					
	M20			M40		
	3 d	7 d	28 d	3 d	7 d	28 d
30% (Total Powder) (3% RHA replaced by weight of GGBFS)	17.73	27.42	45.32	23.88	38.75	64.08

In M20 and M40 grade concretes, cement replaced with 30% GGBFS improves the compressive strength at 28 days. This improvement is observed till 30% replacement after which the compressive strength slows decreases. After various trial mixes, desired target strength is obtained when 3% or RHA by weight of GGBFS (27% GGBFS and 3% RHA) is added to concrete. Blending 27% GGBFS and 3% RHA to concrete not only improves 28 day compressive strength but also increase 3 and 7 days strength and attains required workability. Table provides compressive strengths of GGBFS and RHA blended concrete of M20 and M40 grades at all ages of concrete curing. The usage of GGBFS in M20 and M40 SCC reduces workability but increases compressive and tensile strength when compared with OPC based SCC. The optimum GGBFS is found to be 30% for low and medium strength levels of SCC. For M20 and M40, 30% GGBFS reduces workability slightly but still within desired limits. So after various trial mixes it was found that 27% GGBFS by weight of OPC and 3% RHA by weight of GGBFS quantity is admixed to OPC SCC. This 27% GGBFS+3% RHA combination produces essential workability and Strength in case of M20 and M40 grade SCC mixes. Due to addition of GGBFS to SCC will enhance the later age compressive strength but early age compressive strength decreases while the desired workability is controlled using SP appropriately. This is true for all grades of GGBFS based SCC. In M20 GGBFS based SCC, the strength gain at 3 days is nearly 9% but the compressive strength at 28 days increased by 31%. In M40 GGBFS based SCC, the strength gain at 3 days is nearly 14% but the compressive strength at 28 days increased by 21%. In M60 GGBFS based SCC, the strength reduction at 3 days is nearly 10% and the compressive strength at 28 days decreased by 11%. RHA is added as replacement of cement to improve the early age strength of SCC. RHA addition to concrete as cement replacement may help to improve strength marginally but impacts the workability drastically so SP should be used controllably to attain the desired workability. This is principally true for M20 and M40 grade SCC mixes. So 5% RHA is added to cement instead of replacement along with 25% of GGBFS. In M20 GGBFS+RHA based SCC, the strength enhancement at 3 days is 21% and the compressive strength at 28 days increased by 46%. In M40 GGBFS+RHA based SCC, the strength reduction at 3 days is 20% and the compressive strength at 28 days increased by 34%. Similarly tensile strength in all grades of GGBFS and RHA admixed SCC increases by around 15 to 34% in M20 grade and 9 to 36% in M40 grade. In M20 and M40 grade concretes, cement replaced with 30% GGBFS improves the compressive strength at 28 days. This improvement is observed till 30% replacement after which the compressive strength slows decreases. After various trial mixes, desired target strength is obtained when 3% or RHA by weight of GGBFS (27% GGBFS and 3% RHA) is added to concrete. Blending 27% GGBFS and 3% RHA to concrete not only improves 28 day compressive strength but also increase 3 and 7 days strength and attains required workability. Table 4 provides split tensile strengths of GGBFS and RHA blended concrete of M20 and M40 grades at all ages of concrete curing.

Table 4 – Split-tensile strength of optimally blended GGBFS and RHA based concrete of low and medium grade

Designation		M20	M40
Mix1	-		
	Tensile strength (N/mm^2) @ 28 days	2.33	2.76
Mix2	% of GGBFS Replacement (of cement quantity)	30%	30%
	Tensile strength (N/mm^2) @ 28 days	2.68	2.97
Mix 3	Optimum GGBFS and RHA Combination % of replacement	27% GGBFS (of cement quantity) and 3% RHA (of GGBFS quantity)	27% GGBFS (of cement quantity) and 3% RHA (of GGBFS quantity)
	Tensile strength (N/mm^2) @ 28 days	3.12	3.76

VII. ASSESSMENT OF CEMENT EFFICIENCY FACTOR

The strength efficiency factor 'f' of GGBFS in SCC for various replacement percentages at different ages can be assessed using strength and water/(cement+ k*GGBFS) relation proposed by Bolomey. Bolomey's Constants (A) are calculated from equation suggested by Bolomey. The strength efficiency factor 'f' of GGBFS in SCC for various replacement percentages at different ages can be assessed using strength and water/(cement+ k*GGBFS) relation proposed by Bolomey.

Table 5- Calculations of Bolomey's Constants

Age	M20	M40
3d	A=8.23	A=8.57
7d	A=11.88	A=14.15
28d	A=16.37	A=20.48

Table 6 - Evaluation of Strength Efficiency factor 'k' of GGBFS in SCC

Replacement % of GGBFS (bwc)	Cementing Efficiency Factor(k)					
	M20			M40		
	3 d	7 d	28 d	3 d	7 d	28 d
0	-	-	-	-	-	-
10	0.16	0.26	1.74	0.12	0.19	1.27
15	0.25	0.56	1.79	0.24	0.63	1.29
20	0.33	0.78	1.84	0.39	0.78	1.30
25	0.38	0.98	1.86	0.58	0.85	1.46
30	0.81	1.27	1.89	0.72	1.21	1.64
35	0.66	1.16	1.67	0.66	1.03	1.43

Table 7- Evaluation of GGBFS and RHA combination Strength Efficiency in M20 and M40 SCC mixes

Optimum GGBFS and RHA Combination % of replacement (bwc)	Efficiency Factor 'k'					
	M20 Grade			M40 Grade		
	3 d	7 d	28 d	3 d	7 d	28 d
30% Powder (27% GGBFS and 3% RHA)	1.08	1.28	2.30	0.77	1.27	2.00

Table 8-Cementing or Strength Efficiency factors of GGBFS and RHA in SCC

Pozzolan	Efficiency Factor 'k' (For optimum % replacement)					
	M20 Grade			M40 Grade		
	3 d	7 d	28 d	3 d	7 d	28 d
GGBFS	0.81	1.27	1.89	0.72	1.21	1.64
GGBFS and RHA	1.08	1.28	2.30	0.77	1.27	2.00

Cementing or Strength Efficiency factor of admixture (called as supplementary cementing material (SCM)) indicates the amount of powder in kg replaces one kg of cement to achieve similar strength. For matching the performance of SCM with regard to concrete durability, the notion of strength or cementing efficiency factor is used. The strength or cementing efficiency factor (k-value) is expressed as the part of the pozzolan (Powder) in an SCM admixed or in additive concrete which can be considered as equivalent to OPC.

VIII. DISCUSSIONS

SCC can be developed using cement alone but usage of fly ash in SCC with the help of SP imparts similar performance as that of OPC only SCC. But rate of strength gain is effected when fly ash is used in high quantities in SCC. The early age strengths regain is very slow due to usage of fly ash while the later age strength gain is significant. This phenomena can be applicable to low and medium grade fly ash based SCC but it is not possible in high strength grade SCC because target strength in high strength fly ash concrete cannot be achieved with fly ash alone in SCC need some advocator to make fly ash active during early age. Similar is the case of GGBFS admixed in concrete instead of fly ash. GGBFS imparts later age strength to low and medium grade concretes but rate of gain of strength in early days is very low so RHA is added to GGBFS based SCC to boost the strength in early 3 and 7 days.

So in the present work the strength efficiency of RHA and GGBS in SCC is evaluated to comprehend the role of pozzolanic behaviour of RHA and GGBS combination on the performance of SCC.

IX. CONCLUSIONS

Based on the result of this research the following conclusions can be drawn:

1. Strength efficiency factor of M20 grade SCC mix made with optimum 30% GGBFS are 0.81, 1.27 and 1.89 at 3, 7 and 28 days respectively.
2. Strength efficiency factor for M20 grade SCC 'k' was 1.08, 1.29 and 2.30 at 3, 7 and 28 days respectively at optimal 27% GGBFS bwc and 3% RHA bwg combination. The compressive strength of 28 days increased by 32%.
3. For M 40 grade SCC Mix made with optimum 30% GGBFS the evaluations have shown that the strength efficiency factor are 0.72, 1.21 and 1.64 at 3, 7 and 28 days respectively.
4. Strength efficiency factor for M40 grade SCC 'k' was 0.77, 1.27 and 2.00 at 3, 7 and 28 days respectively at optimal 27 % GGBFS and 3% RHA combined mixture.
5. Strength efficiency is more in GGBFS and RHA admixed SCC mixes than in GGBFS alone admixed SCC mixes.
6. Strength efficiency increased by 30% in lower grade, 20% in medium grade and 10% in high grade SCC mixes made with GGBFS and RHA when compared to OPC based SCC mixes.

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TH13 – Others

Effect of Wetting-Drying Cycles on Strength Behaviour of Lime Stabilized Expansive Soil

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Abstract. The behaviour of stabilized subgrade soil subjected to cyclic Wetting and Drying (W-D) in the region, where temperature and climatic variations are significant like Rajasthan (temperature rises up to 50°C), is essential for understanding its long-term durability. In the present study, effect of cyclic W-D on the strength behaviour of lime treated black cotton soil cured up to 28 days has been investigated. The objectives have been achieved by performing the detailed characterization of materials used and by investigating the Unconfined Compressive Strength (UCS) of soil treated with optimum lime content (6%). The lime treated sample cured up to 28 days has been selected by considering the fact that formation of cementitious compounds of Al-and Si-hydrates, which are mainly responsible for strength improvement, need longer time periods. The UCS has been determined for lime treated soil cured up to 28 days without and with subjected to W-D (up to 50°C) for one and four cycles. The results showed that the improvement in soil plasticity has been observed immediately after addition of lime. The strength of lime treated soil tested in drying state increases over the curing period and number of W-D cycles. The increase in strength can be attributed to the pozzolanic reactions which happen over the time and thereby, formation of compacted matrix with formation of cementitious compound.

Keywords: *Black cotton soil, Lime, Micro-analysis, Strength, Wetting-Drying.*

Study on CBR of Lime and Cement Stabilized Copper Slag Cushion Laid over Expansive Soil

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Abstract. Expansive soils when subjected to change in water content would undergo commonly swelling and shrinkage a cyclic process seasonally. Cohesive non-swelling method is one of the techniques used to control the swelling and shrinkage behavior of these soils. On the other hand, using of waste materials in the pavement construction especially on clayey sub-grade has been in progress all over the world. Copper slag is one of the waste materials, which is being used for various applications in civil engineering. The laboratory test results related to soaked CBR (California Bearing Ratio) test conducted on a stabilized copper slag cushion-soil system for various thickness ratios ranging from 0.25 to 1.00 and stabilized with lime and cement separately are discussed. The increase in soaked CBR with the addition of lime from 2% to 10% to the copper slag for the thickness ratios of 0.25 to 1.00 was from 4 to 35 times when compared with no cushion, whereas, with the addition of cement from 2% to 10% to the copper slag for the same thickness ratios was noticed from 7 to 39 times. The results showed that the soaked CBR increases as the ratio of the thickness of cushion to the thickness of the expansive soil bed is increased and also with the increase in percentage of admixture.

Keywords: *Expansive soil, Copper slag, Cement, Lime.*

A Geotechnical Study on Breached Summer Storage Tank

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Abstract. This paper presents some of the observations made as well as geotechnical testing carried out in search of reasons of breached out summer storage tank, which was about to be commissioned for supply of water especially during summer season to the villagers of Nuzendlamandal in Andhra Pradesh. The tank has about 10 acres of storage area and the levels of water in the tank are not the same throughout the area but varying from 3m to 5.5m. The breaching of tank was occurred, at a location where the water level is 5.5m high, and where two mutually perpendicular bunds are joining. The disturbed and undisturbed soil samples collected from the location where breaching of tank took place were tested in the laboratory to understand the basic characteristics of the soil used for bund construction. The grain size analysis, compaction control, free swell index, liquid and plastic limits, permeability and shear characteristics are determined. It is noticed that the locally available soil is used for bund construction and it is of medium to high plastic in nature. The compaction levels at certain places are found to be inappropriate and the slopes of bund throughout are not as per the specifications. The filling up of water into the tank was done at a time, but not in stage by stage filling process. The reasons of breaching of earth bund are noticed as erosion of soil due to windblown water wave action, not providing the revetment on upstream slope and required slope as per the specifications.

Keywords: *Summer storage tank, Compaction control, Grain size, Liquid limit, Bund slope, Wave erosion.*

Agartala-Bangladesh Railway Embankment Construction over Soft Soils Incorporated with Prefabricated Vertical Drains: A Case Study

RaiBahadur Reang[1], Dr. Sujit Kumar Pal[2] and Dr. Sanjay Paul[3]
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Abstract. Three Embankments of different dimensions for the railway tract at contiguous locations are being constructed over soft soils using prefabricated vertical drains for connecting two cities; Agartala and Dhaka. Prefabricated vertical drains were supplied from Maccaferri and the installation rig machineries were provided by IRCON. PVDs were installed in triangular pattern with three different spacing (0.7, 0.8 and 1.0 m) with according depths (15, 6 and 7.5 m). For conducting physical and engineering properties, soils were collected from different locations as well as from different depths using auguring and wash boring method at suitable intervals along with SPT tests. It has been observed that the natural soil profile was composed of three different layers of different thickness; sandy silty-clay at top, silty-clay in the middle and sandy silty-clay at bottom respectively overlying the hard stratum. A sand layer of thickness 0.2 m is being provided underlain by a strip drains made up of polypropylene, which accelerates and helps sand layer draining off the water from PVDs, over which paralinks were also laid that function as reinforcement to embankment soil deposits. Settlements predictions of the existing soils were made and determined. Different results were obtained at various locations. Without PVD, the settlement of the soil strata at chainage Ch-03+900 to Ch-04+400 km is observed to be 2305 mm and the corresponding settlement time is 189306 days. While the design was made considering PVD the consolidation settlement and time gave as 1660 mm and 122 days respectively.

Keywords: *Prefabricated Vertical Drain, Stratified Soft Soil, Settlemen*

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A Geotechnical Study on Breached Summer Storage Tank

Nandyala Darga Kumar[1] and C Lavanya[2]

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Abstract. This paper presents some of the observations made as well as geotechnical testing carried out in search of reasons of breached out summer storage tank, which was about to be commissioned for supply of water especially during summer season to the villagers of Nuzendla mandal in Andhra Pradesh. The tank has about 10 acres of storage area and the levels of water in the tank are not the same throughout the area but varying from 3m to 5.5m. The breaching of tank was occurred, at a location where the water level is 5.5m high, and where two mutually perpendicular bunds are joining. The disturbed and undisturbed soil samples collected from the location where breaching of tank took place were tested in the laboratory to understand the basic characteristics of the soil used for bund construction. The grain size analysis, compaction control, free swell index, liquid and plastic limits, permeability and shear characteristics are determined. It is noticed that the locally available soil is used for bund construction and it is of medium to high plastic in nature. The compaction levels at certain places are found to be inappropriate and the slopes of bund throughout are not as per the specifications. The filling up of water into the tank was done at a time, but not in stage by stage filling process. The reasons of breaching of earth bund are noticed as erosion of soil due to windblown water wave action, not providing the revetment on upstream slope and required slope as per the specifications.

Keywords: Summer storage tank, Compaction control, Grain size, Liquid limit, Bund slope, Wave erosion.

1.0 Introduction

Water storage tanks are increasingly built commonly for irrigation and drinking water purposes especially in the dry areas. Several types of tanks such as clay bund, coffer dam, PVC lining, sand-bentonite lining, bitumen lining, lining of concrete or bricks, sand-cement sausages lining is in practice. The choice of a type of earth bund depends largely on the availability of the materials and the costs involved. Water storage tanks made of earth bunds are economical and require a people of minimum skills to construct it. Earth materials are usually three types. These are: 1. Granular: silts, sand, gravels and boulders which are not cemented together 2. Cohesive: clays, or materials which have sufficient clay minerals in them for them to act as clays 3. Lithified: rock. Generally cohesive soils are preferred for earth bund construction. Several types of designs for tank bund sections are available. Since free board varies from one tank to the other depending upon wave height, each tank proposal is required to be designed separately. As the variation in wave height for minor irrigation tanks is within a very small range, it is proposed to have the same free-board for all minor irrigation tanks considering the most severe condition. Increase in cost, if any by adopting such a method, would be marginal and thus it is negligible. Any marginal increase in free-board (by 0.1 or 0.2m.) will have additional factor of safety during cyclones and in the event of any breach of tank on the upstream side. Thickness of revetment as 0.30 m may be considered. However actual thickness of revetment can vary from 0.25m to 0.30m depending upon the size of stone available. For bunds more than 16 m height, the sections are to be finalized based on soil test results. The stability of bund sections must be checked up with slip circle method [1].

In general the earth dams/levees fail by means of hydraulic failure, excessive seepage and structural failure. About 40% of earth dam failures have been attributed to hydraulic failure and these may be due to overtopping, wave erosion, toe erosion and gullying. The earth dam may also fail due to excessive seepage. Uncontrolled seepage can erode fine soil material from the downstream slope or foundation and continue moving towards the upstream slope to form a pipe or cavity often leading to a complete failure of the embankment. About 25% of the dam failures have been attributed to structural failures. Structural failure of an earthen embankment may take in the form of a slide or displacement of material in either the downstream or upstream face. Majority of times the earth dams fail due to hydraulic failures such as wave erosion, toe erosion and gullying. Notching of upstream face by wave action reduces the embankment cross section thickness and weakens embankment material. Hydraulic toe erosion occurs when flow is in the direction of a bank at the bend of the river and the highest velocity is at the outer edge and in the center depth of the water. Gullies are formed due to rainfall erosion of embankment slopes and also caused by traffic from people and vehicles [7, 8, 9].

In the recent past there were many preventive and remedial measures came up into the real practice, which includes modifying the geometry of the slope, controlling the groundwater; constructing tie backs, spreading rock nets, providing proper drainage system and provision of retaining walls, etc. The destructive effects of soil liquefaction, sudden drawdown, ground water flow would cause sometimes sudden or excessive settlements, causing breaching of earth bund. Proper design of foundation system requires the following: (i) purpose of engineering structures, probable service life loadings, types of framing, soil profile, construction methods, construction costs, and client/owner's needs, (ii) design without affecting environment and enough margin of safety with respect to unforeseen events and uncertainty in determination of engineering properties of soil and acceptable tolerable risk level to all the parties, i.e., public at large, the owner, and the engineer [2].

The geotechnical or structural failure is an unacceptable difference between expected and observed performance. The failure of a structure may be due to poor design, faulty construction, excessive loads and soil related failure. There are several factors contributing to the failure of foundation, if overlooked or addressed improperly, such as, construction error, improper soil investigation, fluctuation of ground water table, seismic loads, etc [3]. Commonly we find two types of construction errors such as temporary protection measures and actual foundation work [4]. The response of clay to the construction of structures on it is not truly undrained. A significant consolidation develops initially in the over consolidated natural clay, which becomes normally consolidated during construction. An undrained behavior develops only in the normally consolidated clay during the initial stages of the construction. The soil type is important in offering resistance against failure of earth mass and earth slope geometry to avoid slope failure [5, 6].

2.0 Description of Summer Storage Tank

The summer storage tank was built in an area of 10.8 acres in Nuzendla Mandal, Narasaraopet division, Guntur district, Andhra Pradesh state, India. Its storage capacity is 37580 m^3. The highest storage level is 5.65m and this maximum storage level is spotted in the North – East corner of the tank. The plan area of tank is almost rectangular and its line diagram with salient points is shown in Fig.1. Also, the photographs of breached portion are presented in Fig.2.The bed is sloping towards North - East corner. The storage level in the South-West corner is 3m. As the nature of soil in the original bed is pervious and to control the percolation losses, the bed is covered with 0.5m thick clay layer which is of highly compressible in nature and its liquid limit and free swell index are 68% and 110% respectively. The tank is made up of earth bunds in all the four sides with a slope of 2.5(H):1(V) in both the upstream and downstream sides. The soil used for earth bund construction is almost homogeneous and is intermediate to highly compressible clay. The breaching of earth bund took place in the North-East corner of the tank, where the highest water storage level is 5.65m. The breaching of bund is occurred during filling up of water in the tank.

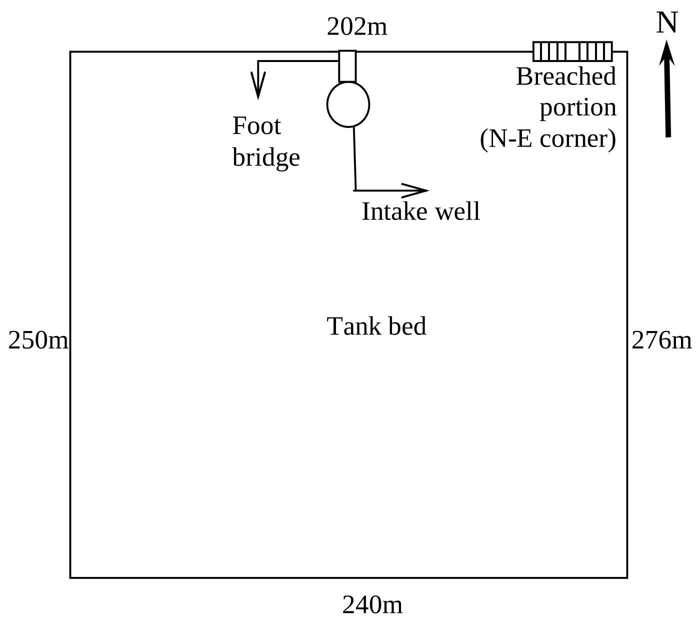

Fig.1. Line diagram of summer storage tank

Fig.2. Photos showing breached sections of summer storage (SS) tank

The summer storage tank consists of homogeneous earth bund made up of CI and CH soils. A 0.6m deep concrete wall is built all around the tank from the bed level to downwards in the upstream side, to avoid seepage beneath the bund section. Rock toe is provided in the downstream side; from North-East corner of the tank, up to about ¼ of the distance either side in the North and East directions of the tank. The width of the breached portion is about 6m to 7m and it took place in the North-East corner. No revetment and gravel cover is provided in the upstream side of the bund in all the four sides.

3.0 Tests Conducted and Discussion of Results

The soil samples were collected from different locations in the vicinity of breached portion of the tank. The location of soil samples collected is presented in Table 1.

Table.1 Location of soil samples collected for investigation

No.	Sample Location
1	71.00m from intake well foot bridge at RL.101.625 towards breached location
2	71.00m from intake well foot bridge at RL.101.255 towards breached location
3	71.00m from intake well foot bridge at RL.101.165 towards breached location
4	60.00m from intake well foot bridge at RL.99.760 towards breached location
5	60.00m from intake well foot bridge at RL.100.695 towards breached location
6	60.00m from intake well foot bridge at RL.101.770 towards breached location
7	51.00m from intake well foot bridge at RL.102.225 towards breached location
8	74.00m from intake well foot bridge at RL.102.300 towards breached location
9	74.00m from intake well foot bridge at RL.102.585 towards breached location
10	Bed portion of SS Tank

The location of soil samples is measured with reference to the foot bridge of intake well in the tank area. The undisturbed soil samples are collected in the form of cores from sample locations 6, 7, 8 and 9 to ascertain their field dry density and field moisture contents. Also the direct shear test is conducted on the undisturbed soil samples. The disturbed soil samples collected from the locations 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 are utilized for determining the index properties of soils such as liquid limit, plastic limit, free swell index, grain size distribution and compaction characteristics. The respective test results are presented and discussed in the following sub-sections. The tests were conducted as per the Bureau of Indian Standard (BIS) test procedures [10, 11, 12, 13, 14, 15].

3.1 Atterberg limits and Free swell index

The liquid limit, plastic limit and free swell index tests are conducted on all the ten samples which were collected from the site. The standard test procedure is followed while testing the soil samples in the laboratory [10, 11]. From the results presented in Table 2, it is observed that the liquid limit of soil samples 1 to 9, is varying from minimum 46% to maximum 66%. The bed clay, i.e., soil sample 10 has a liquid limit of 68%. The free swell index is varying from 65% to 85% and for bed clay, it is 110%. The compressibility of soils is varying from intermediate to highly compressible nature.

3.2 Sieve analysis

The soil samples were tested for grain size distribution by conducting the wet sieve analysis as per the standard test procedure of testing of soils in the laboratory [12]. The results obtained are presented in Table. 3. Also grain size distribution curves for the samples 1 to 5 and 6 to 10 are presented in Figs. 3 and 4 respectively.

Table 2. LL, PL, PI and FSI for soil samples 1 to 10

Sample No	Liquid Limit (LL) in %	Plastic Limit (PL) in %	Plasticity Index (PI)	Free Swell Index (FSI) in %
S1	62	28	34	76
S2	66	29	37	80
S3	48.5	19	29.5	70
S4	64	27	37	75
S5	48	18	30	70
S6	47	19	28	65
S7	46	18	28	65
S8	61	26	35	70
S9	56	22	34	75
S10	68	28	40	110

From the results (Table 3), it is noticed that all the soil samples have percentage silt & clay fraction more than 50%. Fine sand fraction is varying from 8% to 22.5% and remaining soil fractions such as gravel, coarse sand and medium sand are negligible. With the help of test results presented in Tables 2 and 3, the soil samples are classified. The percentage of soil fraction available in each soil sample is further presented in Fig.5 in the form of bar chart. From the classification of soil samples presented in

Table 4, it is noticed that some of the soil samples are in the intermediate compressible clay (CI) category and some of them are in the category of highly compressible clay (CH) soil.

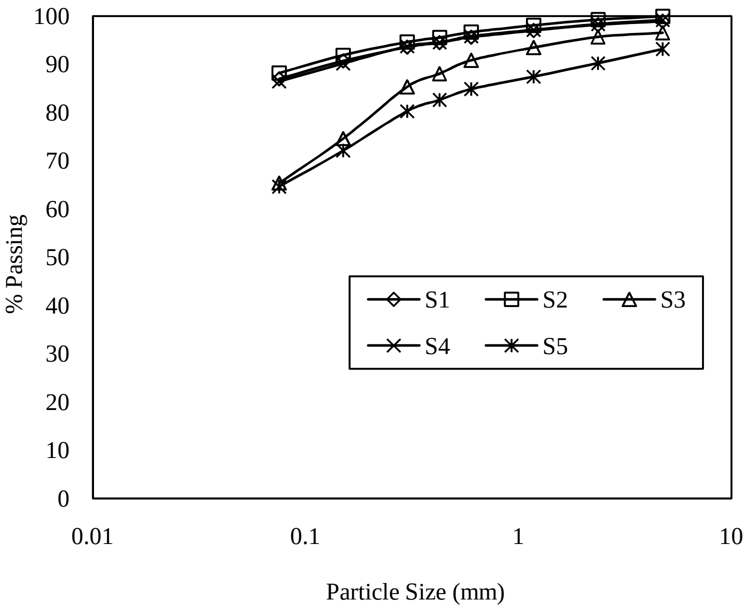

Fig.3. Grain size distribution curves for soil samples 1 to 5

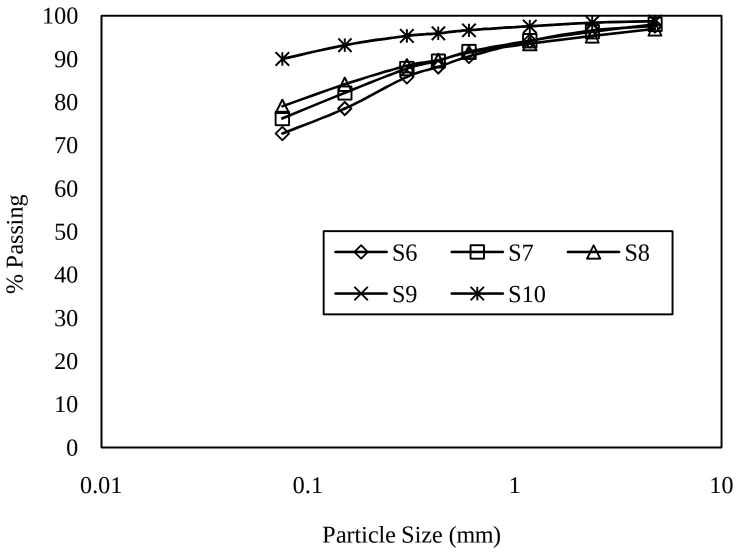

Fig.4. Grain size distribution curves for soil samples 6 to 10

Table. 3 Soil fractions in per cent present in samples 1 to 10

Sample No.	% Soil Fraction				
	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt & Clay
S1	1	1	3	8	87
S2	0	1	3	8	88
S3	3.5	1.5	7.5	22.5	65
S4	1	1	3	8.5	86.5
S5	7	3	7	18.5	64.5
S6	2.5	1.5	8	15	73
S7	2	2	6	14	76
S8	3	2	5	11	79
S9	1.5	2	4.5	15	77
S10	1	1	2.5	5.5	90

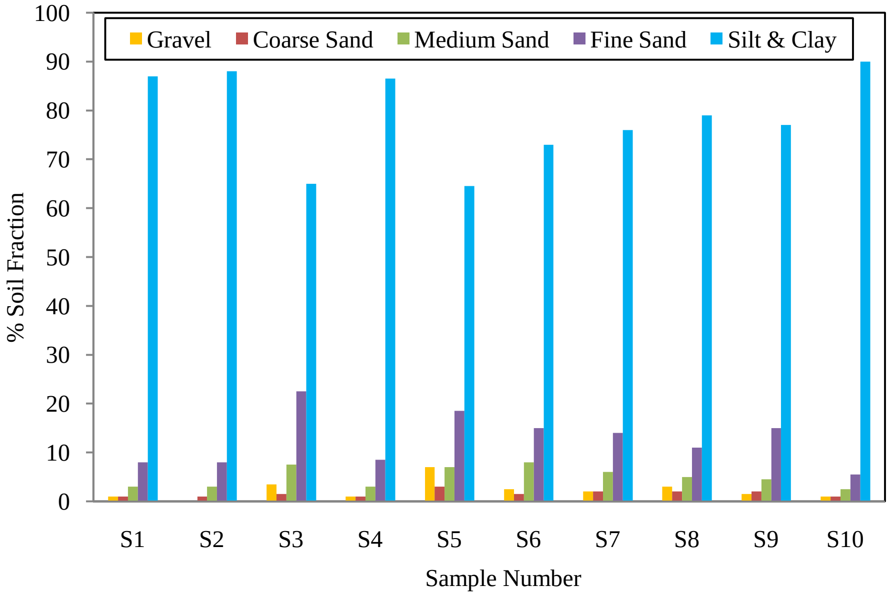

Fig.5. Soil fraction in per cent present in soil samples 1 to 10

Samples 1, 2, 4 and 10 have fine fraction (which is passing through 75 micron sieve) more than 85%. Soil samples 6, 7, 8 and 9 have the % fine fraction above 70 and below 80. Soil samples 3 and 5 have the fine fraction about 65%. Overall all the samples 1 to 10 have the fine fraction above 50%. The sample 10 is the bed sample and it has fine fraction 90%.

Table 4. Classification of soil samples 1 to 10

Sample No.	Soil Classification	
1	CH	Highly Compressible Clay
2	CH	Highly Compressible Clay
3	CI	Intermediate Compressible Clay
4	CH	Highly Compressible Clay
5	CI	Intermediate Compressible Clay
6	CI	Intermediate Compressible Clay
7	CI	Intermediate Compressible Clay
8	CH	Highly Compressible Clay
9	CH	Highly Compressible Clay
10	CH	Highly Compressible Clay

3.3 Compaction Test

The standard Proctor's compaction test was conducted on all the samples in the laboratory as per the standard test procedure of testing of soils [13]. The compaction curves showing water content-dry density relationship are presented in Figs. 6 to 7. The optimum moisture content (OMC) and the maximum dry density (MDD) results obtained from the compaction curves are presented in Table 5. From the OMC, MDD results, it is noticed that the soil samples possess typical clayey soil behaviour. The MDD of earth bund soil samples (1 to 9), is varying from 16.3 kN/m^3 to 17.25 kN/m^3 and OMC is varying from 17% to 22.5%. The tank bed sample has OMC 25% and MDD 15.10 kN/m^3. The bed clay is highly compressible and impervious in nature.

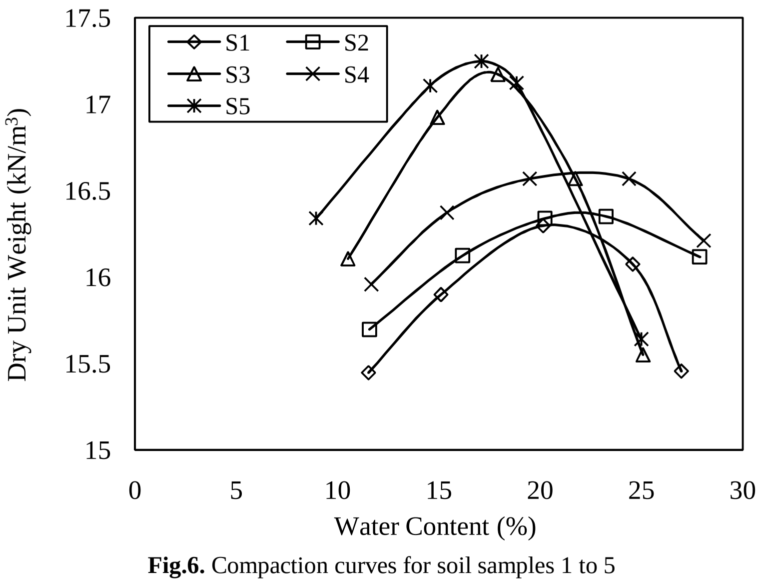

Fig.6. Compaction curves for soil samples 1 to 5

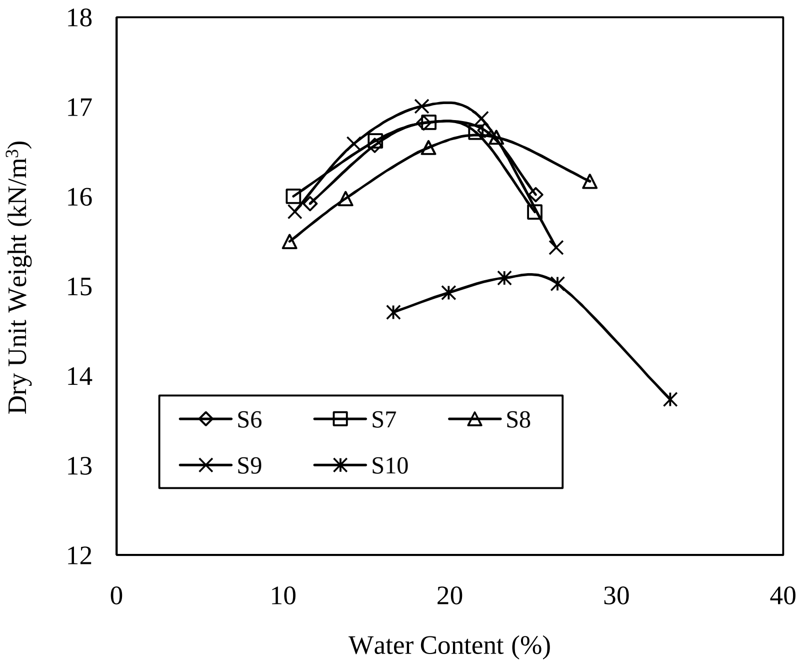

Fig.7. Compaction curves for soil samples 6 to 10

For soil samples 6, 7, 8 and 9, the degree of compaction is estimated and the result is presented in Table.6. For the above four samples the degree of compaction is above 95%.

Table. 5 OMC and MDD of soil samples 1 to 10

Sample No	Compaction Characteristics	
	Optimum Moisture Content, OMC in %	Maximum Dry Density, MDD in kN/m^3
S1	21.00	16.30
S2	22	16.37
S3	17.5	17.2
S4	22.50	16.60
S5	17.00	17.25
S6	20.5	16.85
S7	20.00	16.86
S8	21.50	16.70
S9	20.00	17.05
S10	25.00	15.10

Table 6. Field dry density and Field moisture content of core samples

Sample No.	S6	S7	S8	S9
Field Moisture Content (FMC) in %	18.37	16.81	14.34	20.66
Field dry Density (FDD) in kN/m^3	16.21	16.80	16.01	16.87
Maximum Dry Density (MDD) in kN/m^3	16.85	16.86	16.70	17.05
Relative Compaction (%)	96.20	99.64	95.86	98.94

3.4 Direct Shear Test

A simple direct shear test (quick test) was conducted on the undisturbed soils collected from the locations 6, 7, 8 and 9 of an earth bund near the breached portion. The test was conducted as per the standard test procedure [14]. The strength envelopes obtained from the tests are presented in Fig.8. The shear parameters such as cohesion and angle of shearing resistance obtained from the tests are presented in Table 6. The cohesive strength is varying from 30 kPa to 50 kPa and the angle of shearing resistance is varying from 7.75 degrees to 19.87 degrees.

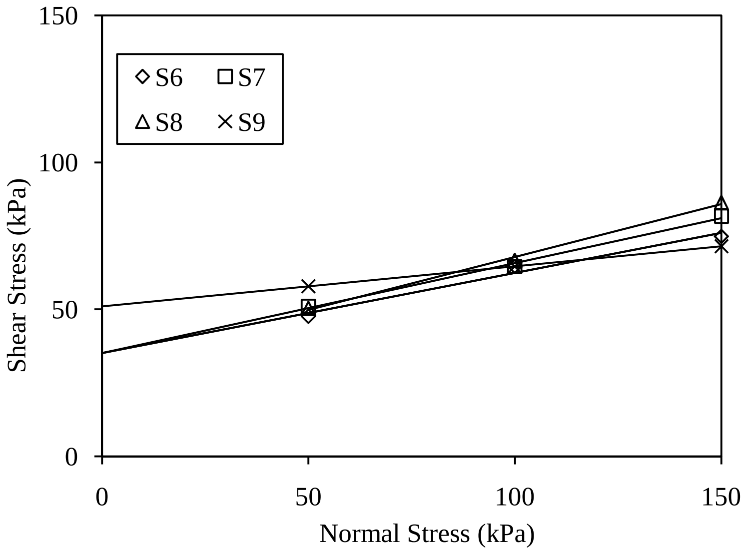

Fig.8. Shear stress verus normal stress curves for samples 6 to 9

Table 7. Direct shear test results of core samples

Sample No.	S6	S7	S8	S9
Undrained cohesion, c in kPa	35	36	30	50
Angle of shearing resistance, ϕ (^{o})	15.22	17	19.83	7.75

3.5 Permeability Test

The sample collected from the locations 6, 7, 8 and 9 are prepared at their respective OMC and kept for saturation in the permeameter mould as per the standard test procedure of testing of soils for permeability [15]. As the per cent fine fraction present in soil samples is more, a falling head permeability test was conducted. The coefficient of permeability of four soil samples 6, 7, 8 and 9 is in the order of 10^{-6} cm/s to 10^{-8} cm/s and on an average 10^{-7}cm/s. From the permeability results, it is observed that the soil samples used for earth bund are impervious to highly impervious in nature.

4.0 Reasons of Breaching of Bund and Recommendations

From the field observations and laboratory test results of soil samples of breached portion, the following points are identified as reasons for earth bund breaching.

- The sloping of bed towards breached portion caused more concentration of water pressure as compared to the other portions of bund.
- Instead filling the tank with water in stages, the tank was filled up at a time to the full storage level.
- As per the specifications the revetment of thickness 0.25m to 0.3m is required to be provided on the upstream slope, but it was not provided.
- The windblown water wave action was prevailed predominantly in the tank area.
- The compaction of soil was inappropriate.

5.0 Conclusions

From the field observations and test results, the following measures for closing the breached portion are suggested.

- No gullies and slope failures in the bund are noticed around the tank. The failure is due to hydraulic action on the upstream slope of bund where water concentration is high.
- The breached portion of the earth bund can be closed by selecting a suitable soil such as GC, GW, SC, SM and required to compact in layers as per the specifications and ensured the required degree of compaction.
- If it is expensive to get the suitable soil to close the breached portion of the earth bund, the same clay soil (CI or CH) which was used previously for earth bund formation can be used towards closing of the breached portion provided; the upstream and downstream slopes respectively are required to be changed from 2.5:1 and 2.5:1 to 3.5:1 and 2.5:1.
- A gravel cover and revetment layer each of minimum 300mm thick as per the specifications is required to be provided so as to avoid the direct attack of wind generated water waves and to keep the upstream slope safe.
- It is required to ensure such that no gaps and uncompacted soil is left while closing the breached portion of the bund and it is also required to ensure the appropriateness of connectivity of bund formations.
- It is important to ensure that the filling up of water in the tank should be done in stages not at a time to the full capacity.

Acknowledgement

The authors are thankful to the officials of Rural Water Supply and Sanitation (RWSS & S) Division Narasaraopet, Guntur District, Andhra Pradesh State, India for having

given us the opportunity to carry out the geotechnical investigation towards identifying the reasons for breaching of summer storage tank, which was built at Nuzendla Mandal, Guntur District, Andhra Pradesh State, India.

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Study on CBR of Lime and Cement Stabilized Copper Slag Cushion Laid over Expansive Soil

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Abstract. Expansive soils when subjected to change in water content would undergo commonly swelling and shrinkage a cyclic process seasonally. Cohesive non-swelling method is one of the techniques used to control the swelling and shrinkage behavior of these soils. On the other hand, using of waste materials in the pavement construction especially on clayey sub-grade has been in progress all over the world. Copper slag is one of the waste materials, which is being used for various applications in civil engineering. The laboratory test results related to soaked CBR (California Bearing Ratio) test conducted on a stabilized copper slag cushion-soil system for various thickness ratios ranging from 0.25 to 1.00 and stabilized with lime and cement separately are discussed. The increase in soaked CBR with the addition of lime from 2% to 10% to the copper slag for the thickness ratios of 0.25 to 1.00 was from 4 to 35 times when compared with no cushion, whereas, with the addition of cement from 2% to 10% to the copper slag for the same thickness ratios was noticed from 7 to 39 times. The results showed that the soaked CBR increases as the ratio of the thickness of cushion to the thickness of the expansive soil bed is increased and also with the increase in percentage of admixture.

Keywords: Expansive soil, Copper slag, Cement, Lime.

1.0 Introduction

Copper slag (CS) is a waste by product which comes out from the smelting process. Metal industry slag, mine stone and mining waste are generally suitable for recycling and reuse as alternative materials in buildings, roads and for other geotechnical applications in civil engineering [1, 2, 3, 4, 5, 6]. Life-cycle analysis for the use of industrial waste slag in road and earth constructions produced the results which are technically viable and economically feasible, thus advocating the reuse of waste by-products in construction applications [7].

Copper slag, upon mixing with soil, would become an effective stabilizing agent for the improvement of expansive soils especially in highway embankments, sub-grades and sub-bases. Also, by mixing it with fly ash, it becomes suitable for embankment fill material. Slag, when mixed with fly ash and lime, develops pozzolanic reactions [8]. Fly ash has been widely accepted as an embankment and structural fill material [9, 10].

Copper slag has particle size equal to that of medium sand. Also, due to the scarcity of sand, Copper slag along with binding material or an admixture could be used as an alternative material to that of sand in road construction. If the copper slag is mixed with calcium based compound like cement or lime in the presence of water, the silica and alumina present in it will react chemically on hydration and the resulting product may be used for the improvement of sub-grades and sub-bases.

Moisture migration from outside the structure to the inside causes uplift of the structure and results in a mound-shaped heave of the floor. Severe cracking might result in the walls of the structure therefore. In pavements, longitudinal cracking may result, due to the migration of moisture from the shoulders to the centre. Techniques like sand cushion [11] and cohesive non-swelling soil (CNS) layer [12] have been tried to arrest heave.

In an expansive soil stratum, development of cohesion in the soil-water system takes place due to its saturation, which helps to arrest heave below a depth of 1.2m [12]. However, the soil in the top 1.2m can undergo heave due to changes in water content. So, if an environment which is free from moisture variations is prevailed within the depth of 1.0 to 1.2 m, then it could be ensured that there wouldn't be any swelling and shrinkage in the soil. Obviously, it is possible to completely arrest the swelling and shrinkage behaviour in soil by altering the soil properties using admixtures. Copper slag cushion admixed with lime or cement, laid on the expansive soil, might be suitable in improving the required strength and other properties as calcium reacts with silica and alumina present in copper slag and develops cementatious products. This helps arrest the heave of the expansive soil beneath it. Similar studies were reported in literature; using copper slag when admixed with lime or cement as a cushion in improving the performance of expansive sub-grades [13].

2.0 Experimental Investigation

2.1 Expansive soil

Expansive soil used in the study was collected from the Nalgonda district in Telangana, India. The basic properties of soil are presented in Table 1. The plasticity index of the soil is high. It has free swell index of 220% which shows a very high degree of expansiveness.

2.2 Copper Slag

Copper slag was collected from the Sterilite Industries, Tuticorin, Tamilnadu. The physical and chemical properties of the slag are presented in Tables 2 and 3 respectively.

Table 1. Basic Properties of Soil

Property	Value
Grain Size Analysis	
Gravel (%)	4
Sand (%)	33
Silt & Clay (%)	63
Consistency Limits	
Liquid Limit (%)	75
Plastic Limit (%)	35
Plasticity Index (%)	40
IS Classification	CH
Free Swell Index (%)	220
MDD (kN/m^3)	14
OMC (%)	21
CBR (%)	1.0

Table 2. Physical Properties of Copper Slag

Property	Value
Grain Size Analysis	
Gravel Size (%)	1.00
Sand Size (%)	98.9
Silt & Clay Sizes (%)	0.05
Hardness, Moh's Scale	6.5 – 7.0
Specific Gravity	3.6
Plasticity Index	Non-Plastic
Swelling Index	Non-Swelling
Granule Shape	Angular with sharp edges
MDD (kN/m^3)	23.5
OMC (%)	6
Direct Shear test	
Cohesion (kPa)	0
Angle of internal friction (deg)	40
Permeability (cm/sec)	1.54×10^{-2}
CBR (%)	3.5

(***Courtesy:***Sterilite Industries Ltd, Tuticorin, Tamilnadu, India)

Table 3. Chemical Composition of Copper Slag

Property	(% wt)
Iron Oxide, Fe_2O_3	55 – 60
Silica, SiO_2	28- 30
Aluminium Oxide, Al_2O_3	1 – 3
Calcium Oxide, CaO	3– 5
Magnesium Oxide, MgO	1.0– 1.5

(***Courtesy:***Sterilite Industries Ltd, Tuticorin, Tamilnadu, India)

2.3 Admixtures

Lime and Cement are used as admixtures separately with the copper slag. Hydrated lime, which consists of 95% of calcium hydroxide and 53-Grade Ordinary Portland Cement are procured from the local market.

2.4 Tests Conducted

California Bearing Ratio (CBR) test is a penetration test planned to measure the sub-grade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to find out the thickness of pavement and its constituent layers. This test is most extensively used for the design of flexible pavements.

Soaked CBR tests were conducted for the copper slag mixed with various percentages of lime and cement separately and laid on the expansive soil bed as a copper slag cushion. The percentages of admixture used were 2%, 6% and 10%. The copper slag and the admixture were mixed in dry condition in various percentages and then, water corresponding to the desired percentage of water was added to it. Samples were prepared for different thickness ratios (t_c/t_s) ratios such as 0.25, 0.50 & 1.00.

Laboratory California Bearing Ratio (CBR) tests were conducted on the samples as per IS code procedure [14]. The cushioned – soil specimen in the CBR mould consists of expansive soil bed at the bottom and copper slag cushion on the top of the soil bed. This specimen was kept for soaking after placing the surcharge weights and the dial gauge to read the swelling for 96 hrs. The overall thickness of the soil bed and the cushion prepared in the CBR mould for testing was 127 mm and its diameter 150 mm.

3.0 Results and Discussion

3.1 Test Results

Figs. 1, 2 and 3 present the soaked CBR results of the cushion-soil system with 2%, 6% and 10% lime in the copper slag respectively. From Fig.1, it is noticed that the soaked CBR is increasing as the ratio of thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) increases. The increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 2% lime to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 is about 4.28, 5.71 and 6.42 times respectively, when compared with no cushion.

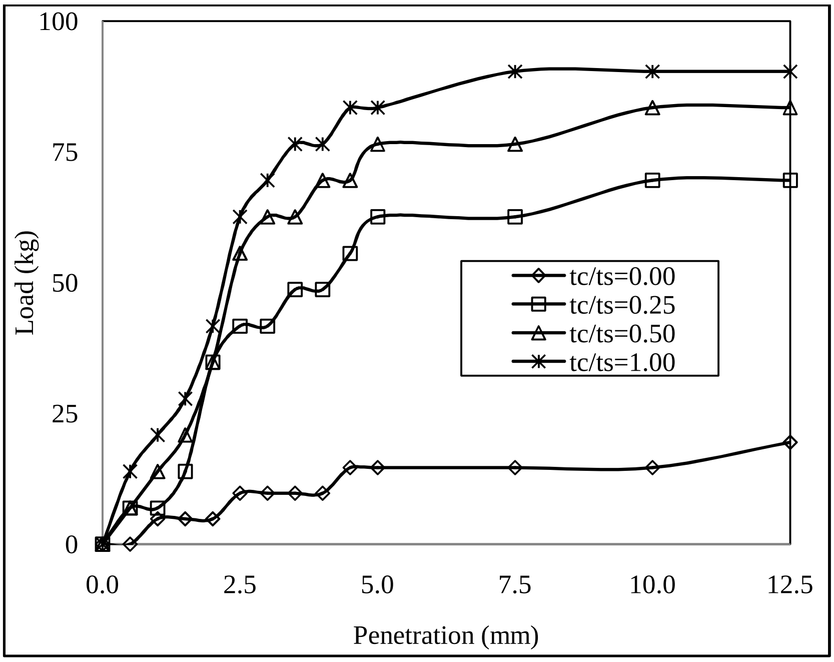

Fig. 1. Load-penetration relation of cushion-soil system with 2% lime in the cushion after soaking

Fig 2 presents the soaked CBR results of the cushion-soil system with 6% lime in the copper slag. From these curves, it can be noticed that the increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 6% lime to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 is about 11.41, 12.84 and 17.12 times respectively, when compared with no cushion.

From Fig 3, it can be noticed that the soaked CBR is increasing as the ratio of thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) increases. The increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 10% lime to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 is about 17.50, 24.0 and 35.50 times respectively, when compared with no cushion.

Figs 4, 5 and 6 presents the soaked CBR test results of the cushion-soil system with 2%, 6% and 10% cement respectively in the copper slag after subjecting them to soaking period of 96 hours. From Fig.4, it can be noticed that the soaked CBR is increasing as the ratio of thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) increases. The increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 2% cement to the copper slag for the thickness ratios of

0.25, 0.50 and 1.00 is about 7.13, 9.27 and 15.69 times respectively, when compared with no cushion.

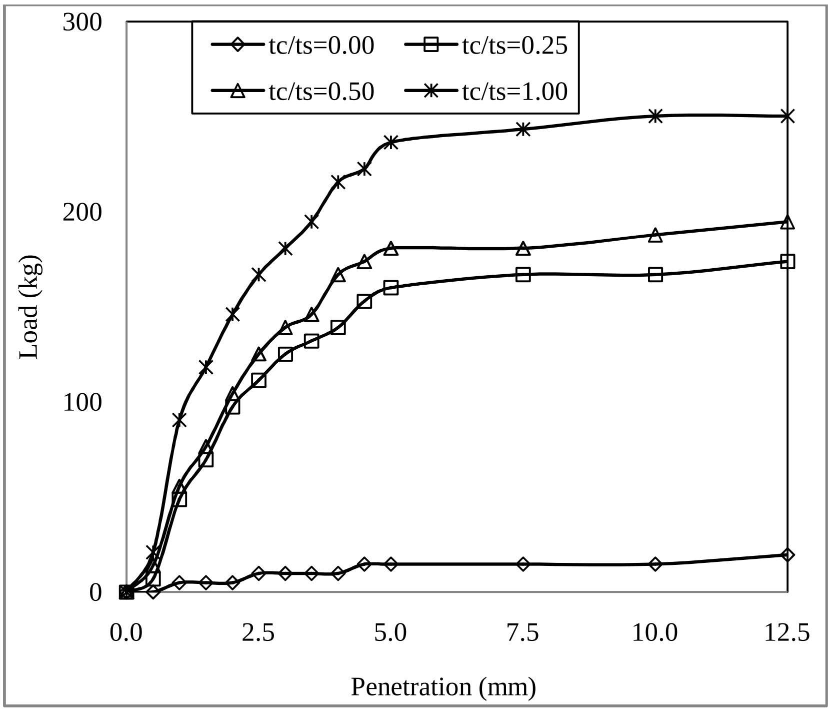

Fig. 2. Load-penetration relation of cushion-soil system with 6% lime in the cushion after soaking

From Fig 5, it can be noticed that there is a increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 6% cement to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 and is about 13.55, 18.54 and 24.25 times respectively, when compared with no cushion.

Fig 6 shows soaked CBR results of the cushion-soil system with 10% cement in the copper slag. From these curves, it may be noticed that the soaked CBR increases as the ratio of thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) is increased. The increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 8% cement to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 was about 23.54, 28.53 and 39.23 times respectively, when compared with no cushion.

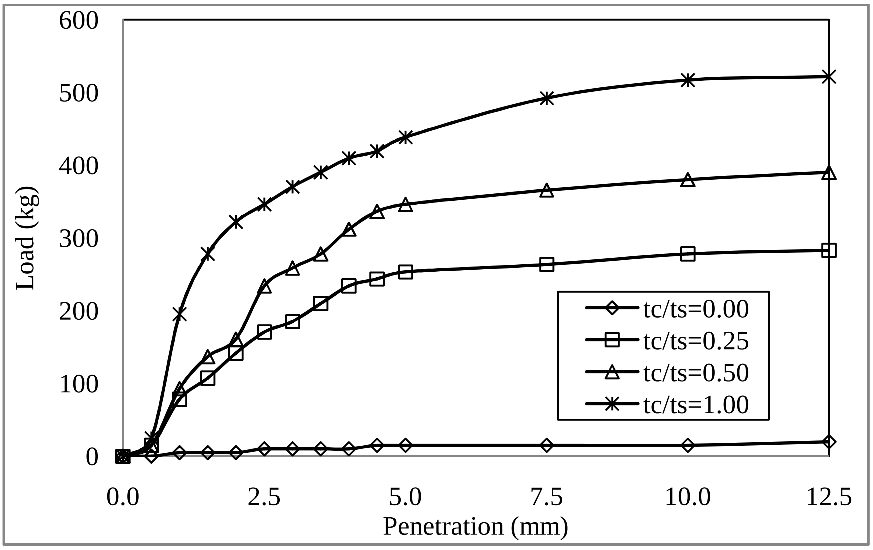

Fig. 3. Load-penetration relation of cushion-soil system with 10% lime in the cushion after soaking

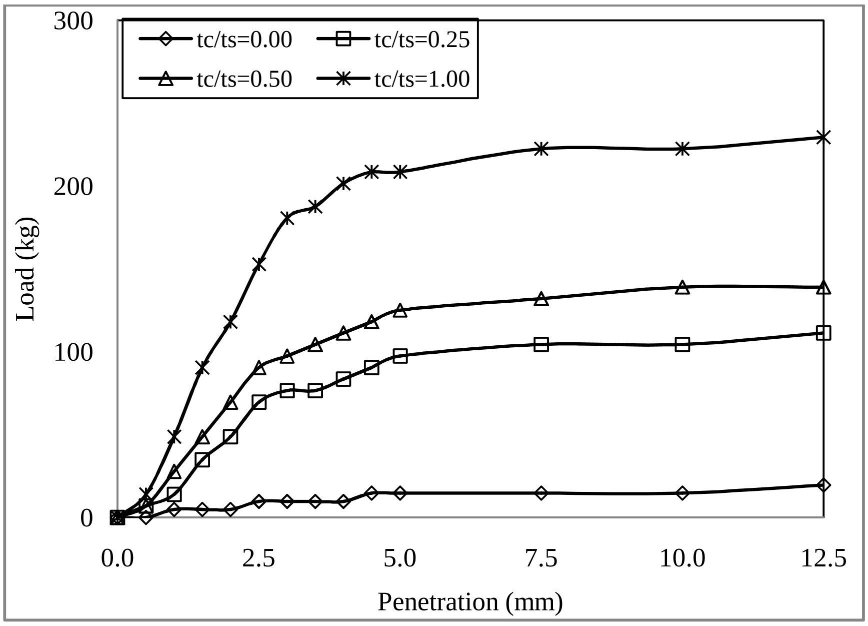

Fig. 4. Load-penetration relation of cushion-soil system with 2% cement in the cushion after soaking

Figs. 7 and 8 show the comparison of soaked CBR values of the lime, cement cushion-soil system respectively. From these figures it can be noticed that the soaked

CBR value increasing as the ratio of the thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) is increased. And, from these two figures (Figs.7 and 8) the increase in CBR is noticed with an increase in percentage of lime and cement.

The results of soaked CBR as given in Table 4 shows that the soaked CBR values of cement stabilized copper slag cushions are more than those of lime stabilized copper slag cushions. At lower values of the additive (lime or cement) and under smaller cushion thicknesses, the CBR values noticed are low for the stabilized copper slag as cushioning material.

Since the minimum value of soaked CBR recommended for any material for use as sub- base, when used for 2Million Standard Axle loads (2msa) is 20%, appropriate value of copper slag cushion thickness and additive content may be chosen accordingly. Since the general practice in pavement construction is to cure the material after laying, upon which the strength would further increase, lower values of copper slag cushion thickness and additive content can also be used for getting the required value of CBR. This may be verified by conducting a field CBR test.

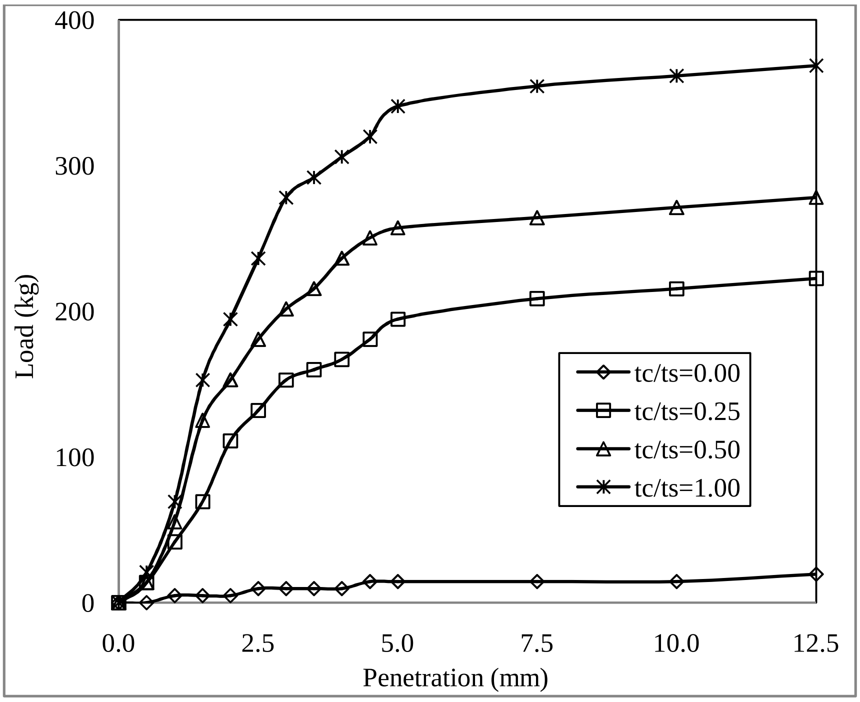

Fig. 5. Load-penetration relation of cushion-soil system with 6% cement in the cushion after soaking

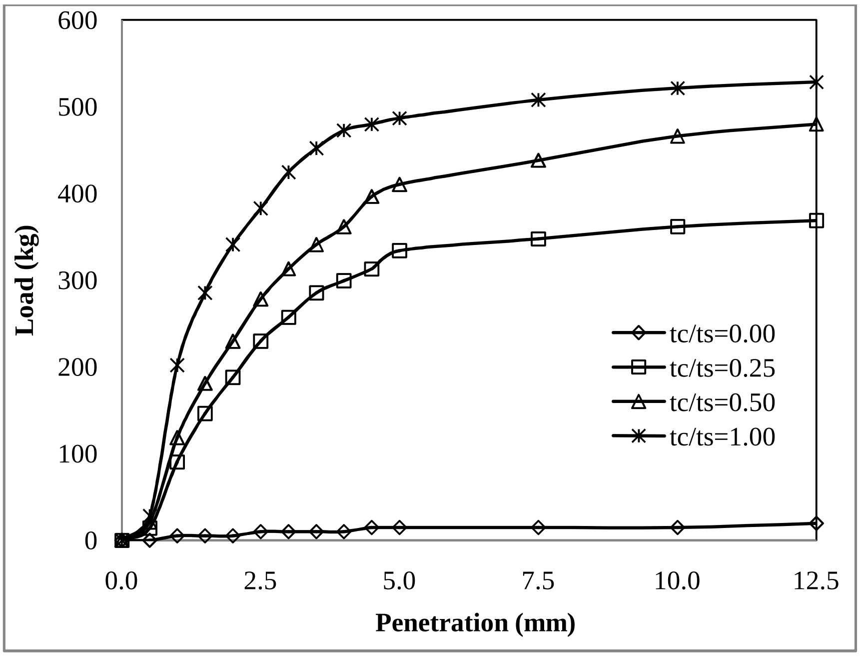

Fig. 6. Load-penetration relation of cushion-soil system with 10% cement in the cushion after soaking

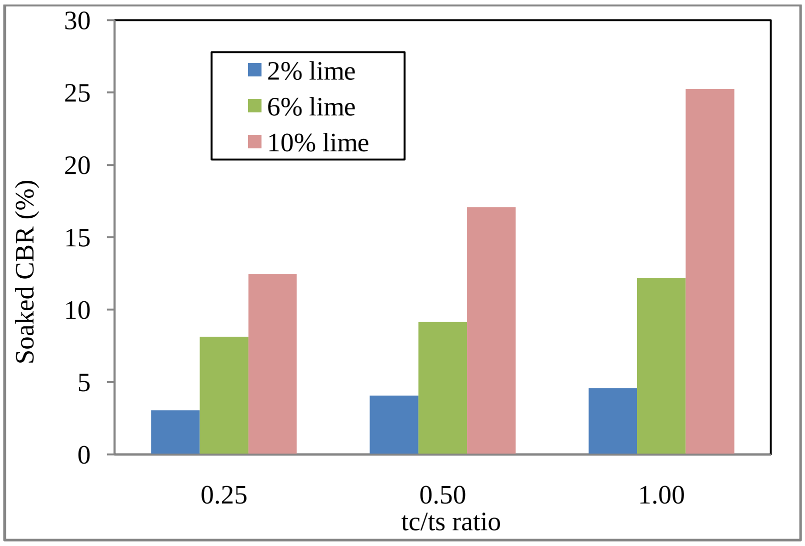

Fig. 7. Comparison of Soaked CBR values of the cushion-soil system with various percentages of lime added to the copper slag cushion

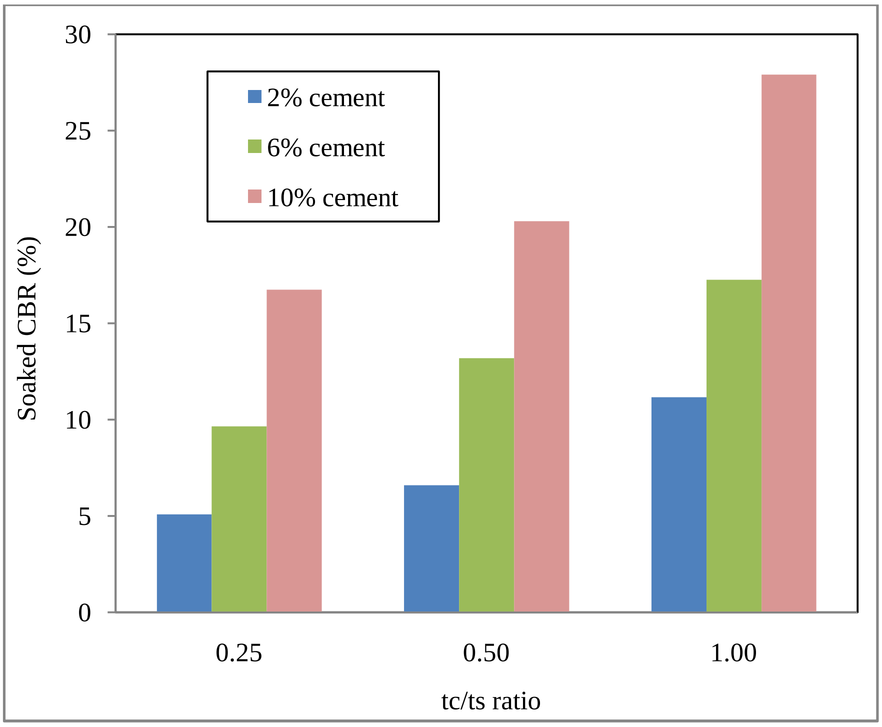

Fig. 8. Comparison of Soaked CBR values of the cushion-soil system with various percentages of cement added to the copper slag cushion

Table 4. Soaked CBR (%) values of cushion-soil system with different percentages of lime/cement in the cushion

Thickness ratio/ Admixture	**tc/ts=0.25**	**tc/ts=0.50**	**tc/ts=1.00**
2% Lime	3.05	4.06	4.57
2% Cement	5.08	6.60	11.17
6% Lime	8.12	9.14	12.18
6% Cement	9.64	13.20	17.26
10% Lime	12.45	17.08	25.26
10% Cement	16.75	20.30	27.91

4.0 CONCLUSIONS

- From the results, it is noticed that there is a clear improvement in the soaked CBR value of the cushion-expansive soil system when the cushioning material was mixed with lime or cement as an additive.
- From the soaked CBR test results, it may be noticed that the increase in the soaked CBR value with the addition of lime from 2% to 10% to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 is from 4 to 35 times, whereas with the addition of cement, this improvement is noticed as 7 to 39 times, when compared with the soil bed with no cushion.
- Studies indicate that cement is more effective than lime for a soaked CBR value of an expansive soil bed when copper slag cushion is laid over it.

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