ADVANCED CONCRETE LAB MANUAL

Subject Code:

M. Tech. (Structural Engineering) I Year I Semester

(AY_____________)

Department of Civil Engineering

GOKARAJU RANGARAJU
Institute of Engineering and Technology

(Autonomous)

Bachupally, Kukatpally, Hyderabad – 500 090.

GOKARAJU RANGARAJU
INSTITUTE OF ENGINEERING AND TECHNOLOGY

Bachupally, Kukatpally, Hyderabad-500090

Department Of Civil Engineering

ADVANCED CONCRETE LAB

Student Name :

Roll No :

Semester : I

Year : I

Class : M. Tech. (Structural Engineering)

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Lab Manual (Edition 2022) prepared by Dr V Srinivasa Reddy

GOKARAJU RANGARAJU

INSTITUTE OF ENGINEERING AND TECHNOLOGY

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Certificate

This is to certify that Mr. /Ms. ……………………………………………. bearing Roll No………………………………of **Master of Technology (Structural Engineering) I-Year I-Semester** has completed the laboratory work in course **Advanced Concrete Laboratory** (Code…………………..) for the **academic year** ………………as prescribed in the curriculum.

Faculty-in-charge   Head of the Department

External Examiner

Vision

To become a pioneering centre in Civil Engineering and technology with attitudes skills and knowledge.

Mission

1. To produce well qualified and talented engineers by imparting quality education.
2. To enhance the skills of entrepreneurship, innovativeness, management and lifelong learning in young engineers
3. To inculcate professional ethics and make socially responsible engineers.

Programme Educational Objectives (PEOs)

PEO 1:Graduates of the program will equip with professional expertise on the theories, process, methods and techniques for building high-quality structures in a cost-effective manner.

PEO 2:Graduates of the program will be able to design structural components using contempory softwares and professional tools with quality practices of international standards.

PEO 3:Graduates of the program will be effective as both an individual contributor and a member of a development team with professional, ethical and social responsibilities.

PEO 4:Graduates of the program will grow professionally through continuing education, training, research, and adapting to the rapidly changing technological trends globally in structural engineering.

Programme Outcomes (POs)

Graduates of the Civil Engineering programme will be able to-

PO 1: An ability to independently carry out research and develop solutions for a practical problem in structural engineering.

PO 2: An ability to present technical information in form of structural drawings and documents conforming to desired specifications.

PO 3: The student should develop in-depth proficiency in the analysis and design of advanced structures, HSC/HPC mixes, Shells and folded plates, earth quake resistant buildings, ability to model, discriminate elastic/plastic behaviour of materials and synthesize new designs using contemporary softwares.

PO 4: Ability to assess the impact of professional engineering solutions in environmental context along with societal, health, safety, legal, ethical and cultural issues and the need for sustainable development.

PO 5: Ability to possess critical thinking skills and solve core, complex and multidisciplinary structural engineering problems.

PO 6: Ability to recognize the need for life-long learning to improve knowledge and competence.

Course Objectives

1. Familiarize the students with physical, chemical and mechanical properties of cement concrete constituents and understand the mix design of high grade concrete.

2. Analyze the stress-strain curve of high strength concrete and develop correlation between cube and cylinder of high strength concrete.

3. Determine the mechanical properties of high strength concrete and knowledge on cyclic loading on steel.

4. To conduct Non-Destructive testing methods on existing concrete members and behaviour of beams under flexure.

5. To study the behaviour of self-compacting concrete and existing RC structures reinforcement details and corrosion levels.

Course Outcomes

At the end of the course, students will be able to

1. Design high grade concrete and identify, carry out laboratory tests related to the use of concrete on site.

2. Develop correlation between cube and cylinder of high strength concrete and analyze the stress-strain curve.

3. Interpret the mechanical properties of high strength concrete and examine the effect of cyclic loading on steel

4. Assess the quality of existing concrete members by Non-Destructive testing methods and study the behaviour of beams under flexure.

5. Analyze the behaviour of Self Compacting Concrete and understanding reinforcement details and corrosion levels in existing RC structures.

LABORATORY RULES OF SAFETY AND PROCEDURES

The following safety regulations apply to all individuals engaged in testing as well as to those who even casually enter the concrete laboratory area:

RULE-1

SMOKING— Strictly forbidden within any of the laboratory areas.

RULE-2

CLOTHING— Students must come to the laboratory wearing shoes. Half pants, loosely hanging garments and slippers are not allowed. Eye protection will be worn whenever materials are handled that could possibly shoot outward. Ordinary eyeglasses are defined as satisfactory, normal eye protection, and all students are encouraged to wear them when working in the laboratory.

RULE-3

JOKES AND HORSEPLAY—Tricks, practical jokes, and horseplay in any laboratory will result in severe disciplinary actions against the perpetrators. Every person has a responsibility to perform laboratory work with consideration for the safety of him- or herself as well as that of the safety of every other member of the group.

RULE-4

IN CASE OF FIRE—Leave the vicinity and immediately inform the individual in charge and/or a laboratory technician.

RULE-5

VALVES AND CONTROLS—Do not attempt to operate any valve or control on any piece of laboratory equipment before being instructed in its use by the instructor or the laboratory technician and prior to permission from the instructor.

RULE-6

USE OF TOOLS—Use only the proper tool as directed by the instructor or laboratory technician and be certain that it is in good condition.

RULE-7

LIFTING—Never attempt to lift a heavier weight than you can comfortably handle. Get help when needed. In lifting, keep your back straight and as nearly upright as possible. Lift with the leg muscles and not with the more vulnerable muscles of the back and abdomen.

RULE-8

IN CASE OF ACCIDENT—Report every injury, no matter how slight it may appear, immediately to the responsible individual. If possible, the injured person should immediately seek professional medical attention.

RULE-9

CLEANUP AT THE END OF THE LABORATORY EXERCISE—Every squad and each individual is responsible for cleaning all equipment used in that period. All equipment must be cleaned before it is returned to its proper place. Bench tops shall be clean and all equipment or samples cleaned and neatly arranged. All sample containers shall be wiped clean before storing.

RULE-10

GENERAL PROVISION—It is incumbent upon every individual to be thoroughly familiar with these safety rules. Strict attention to instructions by the instructor and/or the laboratory technician is an implied responsibility of every individual. One of the most important responsibilities of the instructor and the laboratory technician is that of safety. Do not hesitate to ask questions when in doubt about any procedure or proper use of apparatus.

ADVANCED CONCRETE TECHNOLOGY LAB

List of experiments performed

S.No.	Name of the Experiment	Pg. No.	Date	Faculty Signature

1. TESTS ON CEMENT AND AGGREGATES

A. FINENESS TEST OF CEMENT BY SIEVE ANALYSIS

(IS:4031(Part 1):1996-Method of physical test for cement
(Determination of fineness by dry sieving)

Aim: to determine the fineness of the cement of the given sample by sieve analysis.

Apparatus

1. IS: 90µ test sieve
2. Bottom pan
3. weighing balance,
4. brush

Theory

The degree of fineness of cement is a measure of the mean size of the grains. The finer cement has quicker action with water and gains early strength without change in the ultimate strength. Finer cement is susceptible to shrinkage and cracking.

Procedure

1. Accurately weigh 100 gm of cement sample and place it over the test sieve. Gently breakdown the air set lumps if any with fingers.
2. Hold the sieve with pan in both hands and sieve with gentle wrist motion, in circular and vertical motion for a period of 10 to 15 minutes without any spilling of cement.
3. Place the cover on the sieve and remove the pan. Now tap the other side of the sieve with the handle of brush and clean the outer side of the sieve.
4. Empty the pan and fix it below the sieve and continue sieving as mentioned in the steps 2 and 3. Totally sieve for 15 minutes and weigh the residue (Left over the sieve).

Observations

1. Weight of cement taken =..................................
2. Weight of cement retained after sieving =...............................
3. Type of cement =............................
4. Brand of cement=....................................
5. Room temperature=...........................

$$\text{Percentage weight of Residue} = \frac{\text{Weight of sample left on the sieve}}{\text{Total weight of sample}}$$

Result

Fineness of the given sample is=……………………………………%

Inference

Viva Questions

What is the IS code book to be used to find the fineness of cement?

IS:4031(Part 1):1996-Method of physical test for cement(Determination of fineness by dry sieving)

What is fineness of cement?

The Fineness Test of Cement is done by sieving cement sample through standard IS sieve. The weight of cement particle whose size is greater than 90 microns is determined and the percentage of retained cement particle are calculated. This is known as the Fineness of cement.

Why is fineness of cement test required?

We know that cement hydrates when cement is mixed with the water and a thin layer are formed around the particle.

This thin layer grows bigger and makes cement particles separate. Because of this, the cement hydration process slows down.

On other hand, cement smaller particles react much quicker than the larger particle.

A cement particle with a diameter of 1μm will react entirely in 1 day, whereas the particle with a diameter of 10μm takes about 1 month.

But, there is a side effect of having too much smaller particles in cement results in a quick setting, leaving no time for mixing, handling, and placing.

Therefore to increase the setting time of cement, cement is must be manufactured in a different range of particle sizes. The fineness of the cement test measures this parameter of cement.

Why fineness of cement is important?

Cement smaller particles react much quicker than larger particles. A cement particle with a diameter of 1μm will react entirely in 1 day, whereas the particle with a diameter of 10μm takes about 1 month. If fine cement particle is more in cement then it will be set too quickly and that not feasible on site to place concrete properly.

Which test is used for fineness of cement?

Fineness of cement is tested in two ways: (a) By sieving (b) By determination of specific surface (total surface area of all the particles in one gram of cement) by air-permeability apparatus. Expressed as cm^2/gm or m^2/kg. Generally, Blaine Air permeability apparatus is used. The Blaine Fineness Apparatus is used in measuring the fineness of Portland cement in accordance with ASTM and AASHTO standards. The fineness is measured in terms of the specific area of cement expressed as total surface area in square centimeters per gram.

What is use of fineness of cement?

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength. The fineness of grinding has increased over the years. Fineness, or particle size of portland cement affects hydration rate and thus the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, and thus, the more area available for water-cement interaction per unit volume. Increase in fineness of cement is also found to increase the drying shrinkage of concrete.

In which test 90mm micron sieve is used?
90-micron sieve is having aperture size 90 micron. To determine fineness of cement 100 gram of cement is taken on sieve screen and sieving operation is done carefully without pressing cement particles on screen. After sieving, the coarser particle left on screen is called residue.

What is the sieve size for fineness of cement?
The size of sieve used to test the fineness test of cement is 90 micron IS Sieve.

What is the limit of fineness of cement?
The standard value of fineness of cement should have fineness less than 10 % or fineness of cement should not be more than 10% as per IS Recommendations.

How fineness of cement affects hardening?
The finer the cement particles are, the larger the total surface area is and the bigger the area contacting with water is. Thus, the hydration will be quick, the setting and hardening will be accelerated correspondingly, and the early strength will be high. The fineness of cement affects hydration rate, and in turn, the strength. Increasing fineness causes an increased rate of hydration, high strength, and high heat generation. Bleeding can be reduced by increasing fineness. The workability of concrete increases with an increase in cement fineness. The compressive and split tensile strengths of concrete increases as cement particles increases. Also, the finer the cement, the high the reactiveness of its particle. As the cement gets finer, an early gain in compressive strength is achieved. This gain in compressive strength ceases at higher fineness levels. There is no effect in workability of concrete at intermediate fineness values. However, at high fineness levels, workability increases abruptly.

What is meant by specific surface area?
SSA is defined as the surface area of the solid particles divided by the mass of the solid particles. The specific surface of this type of cement should not be less than 2250 cm^2/g. For rapid hardening cement: The residue present in this rapid hardening cement should not exceed 5 % by the dry weight of cement. The specific surface of this type of cement should not be less than 3250 cm^2/g. Portland cement particles are generally in the range of **1–50 micrometre** (µm) while fly ash particles are usually much finer with the average size in bituminous fly ashes being in the range of 7–12 µm.

What is the cement particle size?
On the fine end, less than 10% of the cement is particles smaller than 2 µm. About 10 wt% of the cement is made of particles larger than 50 µm, and only a few wt% is particles larger than 90 µm. Consistency(water demand ratio) increases with increase in fineness of cement, because as the particles are ground finely the total surface area increases and the water needed to wet the surface of these particles will also be more.

Why does fineness of cement is limited up to 10%?
If the cement particles are finer than a particular size than they will have more surface area per unit volume then their water requirement is more to satisfy is heat of hydration and just in case we provide less water as their requirement then cement particles will shrink and causes cracks on structure. Suppose we use huge size of cement particles then their surface area will be less, require less water but inner part of cement particles remain un hydrated so we will no longer get desired strength.

How do you determine the fineness of cement by air permeability method (Blaine Method)?

The fineness of cement is measured as specific surface. Specific surface is expressed as the total surface area in square metres of all the cement particles in one kilogram of cement. The higher the specific surface is, the finer cement will be. Blaine Air Permeability Apparatus is used for determining the fineness of Portland Cement measures the specific surface area of fine materials in square centimeters per gram of test sample. By using this apparatus, a quantity of air is drawn through a bed of definite porosity.

Is the Blaine fineness test a true measure of cement fineness?

It is truth that the Blaine surface area method is not the best to determine fineness of others powders materials than Portland cements. This method was developed to measure cement fineness and the surface specific area is calculated taking into account the regular shapes of cement particles as a spherical shape.

What is cement clinker grinding?

The cement clinker is ground as finished cement, in a vertical roller mill for cement or in ball mills similar to those normally used for grinding hard raw materials in dry and semi-dry processes. However, the cement clinker is more difficult to grind than raw materials and must also be finer ground.

What is setting and hardening of cement?

A. Setting describes the stiffening of the fresh cement paste. Onset of rigidity occurs. Then hardening begins, which indicates that a useful and measurable strength is developing. Setting and hardening result from the continuing reaction between the cementitious material and water.

What is pozzolan cement?

Pozzolanic cements are mixtures of portland cement and a pozzolanic material that may be either natural or artificial. The natural pozzolanas are mainly materials of volcanic origin but include some diatomaceous earths. Artificial materials include fly ash, burned clays, and shales.

Why is it called portland pozzolana cement?

In this reaction insoluble calcium silicate hydrate and calcium aluminate hydrate compounds are formed possessing cementitious properties. The designation pozzolana is derived from one of the primary deposits of volcanic ash used by the Romans in Italy, at Pozzuoli.

What is the difference between Portland and pozzolanic cement?

Portland Pozzolana Cement is a variation of Ordinary Portland Cement. Pozzolana materials namely fly ash, volcanic ash, are added to the OPC so that it becomes PPC. Pozzolana materials are added to the cement in the ratio of 15% to 35% by weight.

Why is cement gray?

In cement manufacturing, Iron Ore is used as one of the main constituents, and Iron Ore is black in color, so when it is combined and melted with the other materials it tints the cement gray.

What are the raw materials of OPC (Ordinary Portland Cement)?

Raw materials used for manufacturing of Portland cement are found naturally in the earth's crust. It is made primarily from calcareous and argillaceous materials and gypsum.

Calcareous materials contain limestone or chalk while argillaceous materials comprise an oxide of silica-alumina and iron. Both are found as clay or shale.

What is manufacturing process of cement?
All the raw materials are mixed in a certain proportion according to their composition and purity. After that, they are burnt in the kiln at a temperature of 1450 °C to form clinkers which are later grinded to required fineness to obtain this cement. There are two methods of manufacturing of cement:
(a) Wet Process of cement manufacturing,
(b) Dry Process of cement manufacturing.

What are the disadvantages of OPC?
The major disadvantages of OPC is that it emits large amount of CO_2. This is harmful for environment. Ordinary Portland cement cannot be used for mass concreting (dams, roads etc) as it has high heat of hydration as compared to PPC that causes shrinkage cracks in thestructure. Higher grade like grade 53 is also not recommended for plastering as it is known to develop shrinkage cracks due to its high strength and high heat of hydration. Its resistance to aggressive chemicals, alkalis, sulphates, chlorides is lower than PPC; hence it can be said that OPC is less durable than PPC. OPC is costlier than PPC.

What are the things that should be keep in mind before purchasing cement?
Purchase the cement from authorized company outlets only. It is mandatory for any cement manufacturer to have ISI mark. Hence, the bag must carry the ISI mark. Check the stitching of cement bag and ensure that the cement bag has not been re-stitched. Check the week number and year of the manufacturing which is printed on the cement bags. Avoid purchasing cement bags manufactured before 3 months of the purchase date. Strength of cement decreases with over period of time. Condition of the bags should be good and stored at moisture free area in cement store. Avoid damaged bag such as sometimes cement bags turned into hard like a rock. These types of cement bags are useless because the chemical reaction have been taken place inside and it became rock. Check for the manufacturer's name or trademark on the bag.Many other information printed on cement bags should be checked. Check whether you are buying the right grade as specified by in-charge engineer/architect. i.e. 33/43/53 Grade, PPC/OPC. Check the weight, either of the truck or a random bag.

What are the Chemical Compounds of Cement?

1. Tricalcium aluminate
2. Tricalcium silicate
3. Dicalcium silicate
4. Ferrite
5. Magnesia
6. Sulphur trioxide
7. Iron Oxide
8. Alkalis
9. Free Lime
10. Alumina

Note:
Portland cement is not a brand name, but it is a general term for the most common cement type. Joseph Aspdin founded the patent for Portland cement on 21st October 1824. In the ancient era, volcanic ash or tuff and lime was used as a binder in construction. Portland cement is a type of hydraulic cement; hence the hydration process starts after the water is added in it. The hydration process is most important for its strength gain. When cement

comes in contact with water, chemical reaction called hydration takes place which causes the cement to set and harden so that it holds the aggregates and other materials together in a concrete mixture. The cement manufacturing process consists of grinding the raw material and then burning it into a kiln at around 1400 °C. The raw material thus gets converted into clinker form. After that, the clinker is cooled and ground to a fine powder thereby adding 3% to 5% of gypsum into it. This process is either a wet process or a dry process.

B. STANDARD CONSISTENCY OF CEMENT PASTE

(As per IS: 4031-1988 Part- 4)

Objective

To determine the quantity of water required to produce a cement paste of standard consistency. In simple language, we can say that to determine the minimum percentage of water required for the cement paste for its complete hydration.

Apparatus

a) Vicat's apparatus conforming to IS: 5513-1976
b) Weighing Balance
c) Gauging Trowel for mixing the cement
d) Stopwatch, for recording the mixing time
e) Glass plate
f) Thermo -Hygrometer, it will show ambient temperature & humidity

Reference Code

IS:4031(Part 4):1988-Methods of physical tests for hydraulic cement (Determination of consistency of standard cement paste)
IS: 5513-1996 for specification for Vicat's apparatus.

Theory

The standard consistency of a cement paste is defined as that consistency which will permit the vicat plunger to penetrate to a point 5 to 7 mm from the bottom of the vicat mould. For finding out initial setting time, final setting time, soundness of cement and compressive strength of cement, it is necessary to fix the quantity of water to be mixed in cement in each case. This test helps to determine water content for other tests like initial and final setting time, soundness & compressive strength. Consistency refers to the relative mobility of a freshly mixed cement paste or mortar or its ability to flow. For a mortar the standard consistency is measured by flow table test. Generally the normal consistency for OPC ranges from 26 to 33%.

Procedure

1. Firstly set the room temperature between 25°C to 29°C & relative humidity of the room shall be between 60% to 70%.
2. Take about 300 gms cement, weighting with an accuracy of ± 0.3 gms.
3. The normal consistency of ordinary portland cement generally found 25 to 35%. So we should test the sample with 25% of water content. If the VICAT plunger (Dia- 10±.05 mm and height 50±1 mm) do not penetrate to a depth of 5 to 7mm from the bottom of VICAT mould then we will increase the percentage of water by 0.5% until the depth of VICAT plunger found between 5 to 7mm.
4. If we start the consistency test with 25% water content then we will add the water 300*0.25= 75 gms.
5. Put the cement sample over the glass plate. After that water has been added to the cement.
6. Start the stopwatch. The gauging time shall be counted from the adding of distilled water to dry cement until commencing to fill the mould.
7. Mix the cement paste properly with gauging trowel.
8. Remember gauging-time should not be less than 3 minutes nor more than 5 minutes.
9. Fill the cement paste into the VICAT mould (Upper diameter of the mould 70±5mm and bottom diameter 80±5mm and height should be 40±0.2mm).
10. The VICAT mould should be resting upon a glass plate.

11. After completely filling the mould, smoothen the surface of the paste, making it level with the top of the mould.
12. Slightly shaken the mould to expel the air.
13. Immediately place the test block with the non-porous resting plate, under the rod bearing the plunger.
14. Lower the plunger gently to touch the surface of the test block and quickly release, allowing it to sink into the paste.
15. Record the depth of penetration.
16. Prepare trial pastes with varying percentages of water and test as described above until the plunger is 5mm to 7mm from the bottom of the Vicat mould.

Observation and calculation

Trail No.	Weight of Cement taken (gms)	Percentage of water added (by weight of dry Cement) (%)	Amount of water added (ml)	Penetration (mm)
1	300	26		
2	300	28		
3	300	30		
4	300	32		
5	300	34		
6	300	36		
7	300	38		

Calculate percentage of water (P) by weight of dry cement required to prepare cement paste of standard consistency by following formula, and express it to the first place of decimal.

$$\text{Standard consistency (\%) (P)} = \frac{\text{Weight of water added}}{\text{Weight of cement}} \times 100$$

Result

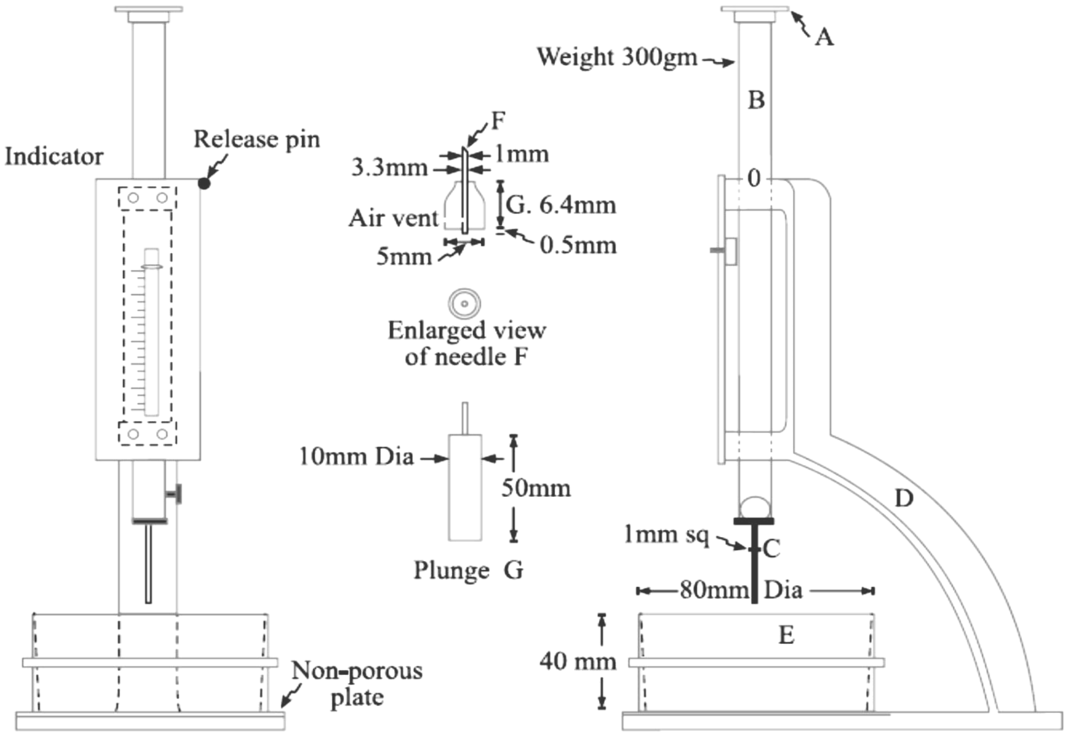
Express the amount of water as a percentage by mass of dry cement to the first place of decimal.

Standard consistency (P) for the given sample of cement is…………………..%

Precautions

- Gauging time should be strictly observed
- Room temperature should be well maintained as per test requirement.
- All apparatus used should be clean.
- The experiment should be performed away from vibrations and other disturbances.

Inference



Vicat's Apparatus

Viva Questions

What is Consistency of cement?

As Per IS Code 4031: The standard Consistency of a cement is defined as " A consistency which allow the Vicat Plunger to penetrate to a point 5 mm to 7 mm from the bottom of the mould". In simple language, we can say that the minimum percentage of water required for the cement paste for its complete hydration. Or Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm dia and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould.

Why do we do cement consistency test?

Finding out standard consistency of cement is essential because the amount of water added in cement affect the setting time of cement, Less water added than this standard consistency would not complete chemical reaction thus resulting in the reduction concrete of strength and more water would increase water-cement ratio and so would reduce its strength.

What is the normal consistency of cement paste?

The normal consistency of cement paste generally varies from 25% to 35%. There is no trial-and-error method by using the Vicat apparatus to find out the correct consistency of cement. To prepare a mix of cement paste 25-35% water by weight of cement added to achieve good consistency of cement.

What is the difference between cement and concrete?

It's simple. Concrete is used for the finished products, such as sidewalks, foundations, and the surface of many roads. Concrete contains sand, gravel and cement. Cement is the special hardening ingredient (the gray powder) that makes concrete harden. Cement is usually made of 60% lime (limestone), 25% silica, 5% alumina, and 10% other materials, such as gypsum and iron oxide.

What are the different grades of cements?

Generally, there are three grades of cement available in the market. Cement is available in 33 grade, 43 grade and 53 grade. The grade of cement is generally differentiated in terms of indicates the strength of cement. The strength of cement is generally measured as compressive strength. Compressive strength is the strength of cement molded in a standard cube, after 28 days of curing. Compressive strength usually measured in Mega-pascal (MPa) or in N/mm2. 33 grade cement means that the compressive strength of the cement after 28 days is 33N/mm^2 when tested as per Indian Standards under standard conditions. It may not be suitable for concrete grade above M20. Due to the availability of higher grades in the cement, use of 33 grade cement has declined. Nowadays 33 grade cement is hardly manufactured. 43 grade cement means that the compressive strength of the cement after 28 days is 43N/mm^2 when tested as per Indian Standards under standard conditions. It is suitable make concrete mix up to M30. 43 grade cement is also used to make precast items, such as tiles, blocks, pipes, etc. It can be used where setting time is not a necessary criterion. 53 grade cement means that the compressive strength of the cement after 28 days is 53 N/mm^2 when tested as per Indian Standards under standard conditions. 53 grade cement has a fast setting time as compared to 43 grade cement. This grade of cement is not used for ordinary works. It is mostly used for the structural purposes as in reinforced cement concrete. 53 grade cement is suitable in making concrete mix above M 25. It can also be used in prestressed concrete.

It is very important to check the grade of cement before using, it because it ultimately affects the strength of your structure. If you do not use suitable grade of cement for the particular job, you never get your desired strength.

Explain the extraction and processing of raw materials used for cement

Raw materials employed in the manufacture of cement are extracted by quarrying in the case of hard rocks such as limestones, slates, and some shales, with the aid of blasting when necessary. Some deposits are mined by underground methods. Softer rocks such as chalk and clay can be dug directly by excavators.

The excavated materials are transported to the crushing plant by trucks, railway freight cars, conveyor belts, or ropeways. They also can be transported in a wet state or slurry by pipeline. In regions where limestones of sufficiently high lime content are not available, some process of beneficiation can be used. Froth flotation will remove excess silica or alumina and so upgrade the limestone, but it is a costly process and is used only when unavoidable.

Explain the manufacturing process of cement

There are four stages in the manufacture of portland cement: (1) crushing and grinding the raw materials, (2) blending the materials in the correct proportions, (3) burning the prepared mix in a kiln, and (4) grinding the burned product, known as "clinker," together with some 5 percent of gypsum (to control the time of set of the cement). The three processes of manufacture are known as the wet, dry, and semidry processes and are so termed when the raw materials are ground wet and fed to the kiln as a slurry, ground dry and fed as a dry powder, or ground dry and then moistened to form nodules that are fed to the kiln.

How cement production impacts environment?

It is estimated that around 4–8 percent of the world's carbon dioxide (CO_2) emissions come from the manufacture of cement, making it a major contributor to global warming. Some of the solutions to these greenhouse gas emissions are common to other sectors, such as increasing the energy efficiency of cement plants, replacing fossil fuels with renewable energy, and capturing and storing the CO_2 that is emitted. In addition, given that a significant portion of the emissions are an intrinsic part of the production of clinker, novel cements and alternate formulations that reduce the need for clinker are an important area of focus. Dust emission from cement kilns can be a serious nuisance.

Explain the Chemical composition of OPC

Portland cement is made up of four main compounds: tricalcium silicate ($3CaO \cdot SiO2$), dicalcium silicate ($2CaO \cdot SiO2$), tricalcium aluminate ($3CaO \cdot Al2O3$), and a tetra-calcium aluminoferrite ($4CaO \cdot Al2O3Fe2O3$). In an abbreviated notation differing from the normal atomic symbols, these compounds are designated as C3S, C2S, C3A, and C4AF, where C stands for calcium oxide (lime), S for silica, A for alumina, and F for iron oxide. Small amounts of uncombined lime and magnesia also are present, along with alkalies and minor amounts of other elements.

Explain the hydration process of cement?

The most important hydraulic constituents are the calcium silicates, C2S and C3S. Upon mixing with water, the calcium silicates react with water molecules to form calcium silicate hydrate ($3CaO \cdot 2SiO2 \cdot 3H2O$) and calcium hydroxide (Ca[OH]2). These compounds are given the shorthand notations C–S–H (represented by the average formula C3S2H3) and CH. During the initial stage of hydration, the parent compounds dissolve, and the dissolution of their chemical bonds generates a significant amount of heat. Then, for reasons that are not fully understood, hydration comes to a stop. This quiescent, or dormant, period is extremely important in the placement of concrete. Without a dormant period there would be no cement trucks; pouring would have to be done immediately upon mixing. Following the dormant period (which can last several hours), the cement begins to harden, as CH and C–S–H are produced. This is the cementitious material that binds cement and concrete together. As hydration proceeds, water and cement are continuously consumed. Fortunately, the C–S–H and CH products occupy almost the same volume as the original cement and water; volume is approximately conserved, and shrinkage is manageable.

What is gauging time?

Gauging time is the time elapsing from the time of adding water to the dry cement until commencing to fill the mould. The test should be conducted at room temperature 27oC +/- 2oC. There should be no vibration on the working table. The plunger should be cleaned during every repetition. The time of gauging should not be less than 3 minutes and not more than 5 minutes.

What is the average particle size of cement ?

Approximately 95% of cement particles are smaller than 45 microns and the average particle size is 15 microns.

C. SPECIFIC GRAVITY OF CEMENT
(As per IS 2720- Part 3)

Objective

To determine the specific gravity of given cement sample

Apparatus

Le Chaterlier's flask, Kerosene (free from water), weighing balance
The specific gravity of kerosene is 0.79g/cc

IS code for Specific gravity test is IS 2720- Part 3

Theory

The specific gravity value of any substance gives the idea about how heavy or light is the substance compared to the standard substance. From the value, we can judge it will float or sink in another substance. All-natural material and substance have their own specific gravity value. It generally ranges from 1 to 100. Water has a specific gravity of around 1and If the specific gravity of other material is greater than 1, then it sinks in water. If the specific gravity of the material is less than 1 it floats in water. Therefore, the specific gravity of any material is an important property to know. So that we can use it in a proper way. Generally, the specific gravity of cement ranges from 3.1 to 3.16 g/cc. From this, we can say that the specific gravity of cement is more than the specific gravity of water is 1. It means cement will sink in water if we put it on the water. Also, we can say that cement is heavier than water. Cement particle has pore in them and they can absorb moisture from the atmosphere. Considering this behaviour of cement particles the specific gravity can either increase or decrease. While we are calculating cement for mix design we consider the specific gravity of cement as standard 3.14. So, any change in cement-specific gravity will affect the mix design. Hence, it is essential to test the specific gravity of the cement procured before the mixing process. This is the main reason behind we reject the old stored cement. Old cement has more liable to store external moisture which results in increased specific gravity of cement.

Procedure

1. Clean and dry the specific gravity bottle and weigh it with the stopper (W1).
2. Fill the specific gravity bottle with cement sample at least half of the bottle and weigh with stopper (W2).
3. Fill the specific gravity bottle containing the cement, with kerosene (free of water) and place the stopper and weigh it (W3).
4. While weighing ensure that there are no present air bubbles in the specific gravity bottle.
5. After weighing, the bottle shall be cleaned and dried again.
6. Then fill it with fresh kerosene and weigh it with stopper (W4).
7. This time, remove the kerosene from the bottle clean it and fill it with full of water and weigh it with stopper (W5).
8. All the above weighing should be done at the room temperature of 27c $\pm$ 1^0c.

Conduct test at least 3 times for accurate result. Clean the flask before using it again.

Observations and Calculations

1. Wt. of empty dry specific gravity bottle = W_1
2. Wt. of bottle + Cement (Partly filled) = W_2
3. Wt. of bottle + Cement (Partly filled) + Kerosene = W_3
4. Wt. of bottle + Kerosene (full). = W_4.
5. Wt. of bottle + water (full) = W_5

Specific gravity of kerosene S_k = $(W_4 - W_1) / (W_5 - W_1)$

$$\text{Specific gravity of Cement} = \frac{(W2 - W1) \times Sk}{(W4 - W1) - (W3 - W2)}$$

Result

Specific Gravity of cement =

Inference

Viva Questions

What is specific gravity of cement?

The specific gravity of cement is defined as the mass of cement of specified volume to the mass of water of the same volume of cement. It can also be defined as the density of cement to the density of water for the same volume. In both, the definitions volume of cement must be the same. If the volume does not remain the same then the specific gravity value may not be accurate. Because the mass and density of cement and water are liable to change with respect to its volume. Specific gravity is the comparison of the mass or density of any substance with the mass or density of the standard substance. Generally, water is considered the standard substance. The best method to determine the specific gravity cement is by using a liquid such as water-free kerosene, which does not react with cement.

For conducting this test, a standard Le Chatelier specific gravity flask or specific gravity bottle may be employed. The Le Chatelier specific gravity flask is also utilized to determine the specific gravity of dust, sand, and other fine materials. This specific gravity of cement is an essential parameter in concrete mix design material quantity calculations. This specific gravity of portland cement is about 3.15

Why kerosene used for specific gravity test of cement?

If we use water instead of kerosene, water will mix with cement and make a paste. As we know that cement is mixed with water, cement starts it heat of the hydration process. So, water can’t be used for cement-specific gravity tests. Kerosene is a very well-known polar liquid so it will not react with cement while doing the test. The specific gravity of kerosene is 0.79g/cc.

What is specific gravity of cement?

The specific gravity of cement is defined as the mass of cement of specified volume to the mass of water of the same volume of cement. OPC cement has a specific gravity of 3.15. Generally, the specific gravity of cement ranges from 3.1 to 3.16 g/cc. As per the study, the specific gravity of PPC is found to be 3.06 to 3.08 g/cm^3

Why specific gravity test is done?

The specific gravity value of any substance gives the idea about how heavy or light is the substance compared to the standard substance. From the value, we can judge it will float or sink in another substance.

What is the use of specific gravity of cement?

Cement particle has pore in it and they can absorb moisture from the atmosphere. Considering this behaviour of cement particles the specific gravity can either increase or decrease. While we are calculating cement for mix design we consider the specific gravity of cement as standard 3.14. So, any change in cement-specific gravity will affect the mix design. Hence, it is essential to test the specific gravity of the cement procured before the mixing process.

Notes

D.SOUNDNESS OF CEMENT
(As per IS 4031-1988 PART3)

Objective

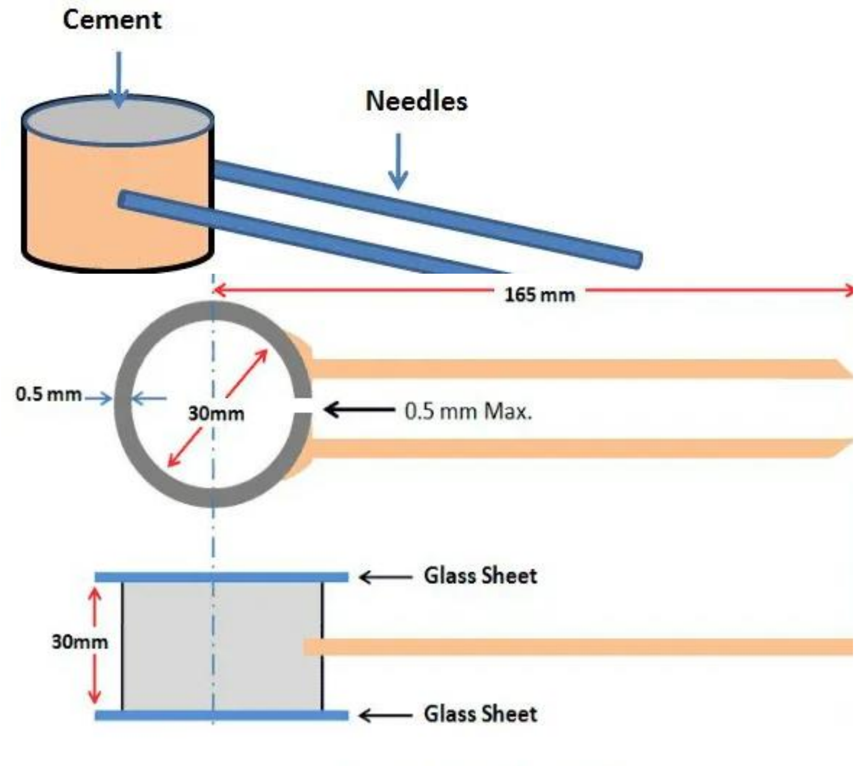
To determine the stability of any cement during the volume change in the process of setting and hardening.

Apparatus

Le Chatelier apparatus conforming to IS 5514-1969, Balance, Weights, Water bath.

The apparatus for conducting the test consists of small split cylinder of spring brass or other suitable metal of 0.5mm thickness forming a mould 30 mm internal diameter and 30mm high. On either side of the split mould are attached to indicators with pointed ends, the distance from these ends to the center of the cylinder being 165 mm. The mould shall be kept in good condition with the jaws not more than 50mm apart.

Water is added in cement as 0.78 P. where P is % of water for standard consistency of cement. Well, a mixed paste is filled in mold and covered with a glass plate on both faces of mold.



Le – Chatelier Apparatus

IS Code for soundness cement Test is **IS:4031-Part 3-1988**

Theory

It is essential that the cement concrete shall not undergo appreciable change in volume after setting. This is ensured by limiting the quantities of free lime, magnesia and sulphates in cement which are the causes of the change in volume known as unsoundness. Unsoundness in cement does not come to surface for a considerable period of time. This test is designed to accelerate the slaking process by the application of heat and discovering the defects in a short time. Unsoundness produces cracks, distortion and disintegration there by giving passage to water and atmospheric gases which may have injurious effects on concrete and reinforcement. The soundness test of cement determines the expansion of cement after it starts setting. Certain cement has been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This expansion of cement can cause serious problems for the durability of structures when such cement is used.

The difference between needle readings indicates the soundness of cement. The soundness limit must exceed 10 mm for ordinary, rapid hardening, and low heat Portland cement. If in case the c expansion is more than 10 mm as tested above, the cement is said to be unsound.

The Le Chatelier test has the drawback in that it detects on lime caused unsoundness. This method does not measure unsoundness caused by the presence of an excess of magnesia.

Indian Standard Specification stipulates that cement having a magnesia content of more than 3 percent shall be tested for soundness by Autoclave test which is sensitive to both free magnesia and free lime.

In this test, a neat cement specimen 25 x 25 mm is placed in a standard autoclave and the steam pressure inside the autoclave is raised at such a rate as to bring the gauge pressure of the steam to 21 kg/sq cm in 1 — 1'/4 hour from the time the heat is turned on.

This pressure is maintained for 3 hours, the autoclave is cooled and the length is measured again. The Stream pressure applied eventually accelerates the hydration of both magnesia and lime.

To determine the unsoundness due to excess calcium sulfate there is no satisfactory test is available. But, its amount present can be easily determined by chemical analysis.

Procedure

The Soundness test of the cementing procedure as follows,

1. The mould and the glass plates are oiled before conducting the test.
2. Take 400 grams of cement sample.
3. For this test to be performed we need standard consistency of cement. Water is taken as 0.78 x P (Where P is water required for Standard consistency in percentage)
4. For example, Standard consistency is 30% of water, then take water percentage for soundness is 0.78 x 30% = 23.4%. So water to mixed in 400 gm of cement will be 400 x (23.4/100) = 93.6ml.)
5. Make a well–mixed paste of cement and fill in Le- Chatelier mould taking care to keep the edges of the mould gently together during the operation.
6. Clean upper surface and make it smooth and place a small weight over the cover plate.
7. Put this assembly quickly in water at a temperature of 27º C + 2ºC and keep it there for 24 hours.
8. Take out mould from water and measure distance between the indicators points as Reading–1 .(Suppose it is 2 mm)
9. Now, again put this assembly in boiling water for 25 to 30 minutes and keep at boiling for 3 hours. The mould should be in boiled water during this period
10. Remove the mould from water and allow it to cool at room temperature.
11. Measure the distance between the indicator points as Reading-2. (Suppose it is 10mm)
12. Soundness of cement = (Reading-2) – (Reading-1)
    = 10 mm – 2mm
    = 8 mm

Observations

Initial distance between the indicator points in mm =

Final distance between the indicator points in mm =

Expansion in mm

= Final distance between the indicator points) – Initial distance between the indicator points)

=

Result
Expansion (mm)=

Inference

Viva Questions

What is soundness of cement?
The soundness of cement indicates the stability of any cement during the volume change in the process of setting and hardening. In case the volume change in cement is unstable after setting and hardening, the concrete element will crack, which can affect the quality of the structure or even cause serious accidents, known as poor dimensional stability.

Explain the significance of soundness of cement
The testing of the soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion of prime importance. The unsoundness is occurring mainly due to an excess lime that could be combined with acidic oxide at the kiln. This is also due to inadequate burning or insufficient fineness of grinding or thorough mixing of raw materials. It is also may occur due to too high proportion magnesium content or calcium sulfate content may cause unsoundness in cement.
For this reason, the magnesia content allowed in cement is limited to 6 percent, It can be recalled that to prevent flash setting, calcium sulfate is added to the clinker while grinding. The quantity of gypsum added will vary from 3 to 5 percent depending upon C_3A content. If the addition of gypsum is more than could be combined with C_3A, excess of gypsum will remain in the cement in Free State. This high percentage of gypsum leads to an expansion and consequent disruption of the set cement paste.The unsoundness in cement majorly occurs due to excess lime, excess magnesia, or excessive proportion of sulfates. The unsoundness effect of cement does not come to the surface for a considerable period of time. Therefore, accelerated tests are required to detect them. The soundness of cement is tested by is Le – chatelier's soundness test.

What is the purpose of the soundness test?
The testing of the soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion of prime importance. The unsoundness is occurring mainly due to an excess lime that could be combined with acidic oxide at the kiln. The most popular and simple instrument used to measure the Soundness Test of Cement is Le – chatelier's soundness test. IS Code for soundness test of cement is IS:4031-Part 3-1988. The soundness test of cement has measured the expansion of cement after it starts setting. Certain cement has been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This expansion of cement can cause serious problems for the durability of structures when such cement is used. The soundness of cement has measured the expansion of cement after it starts setting. If the volume change is unstable after setting and hardening, the concrete structures will crack, which can affect the quality of buildings or even cause serious accidents, known as poor dimensional stability.

Explain the roles of Bogue's compounds?

The strength developed by portland cement depends on its composition and the fineness to which it is ground. The C_3S is mainly responsible for the strength developed in the first week of hardening and the C_2S for the subsequent increase in strength. The alumina and iron compounds that are present only in lesser amounts make little direct contribution to strength.

Set cement and concrete can suffer deterioration from attack by some natural or artificial chemical agents. The alumina compound is the most vulnerable to chemical attack in soils containing sulfate salts or in seawater, while the iron compound and the two calcium silicates are more resistant. Calcium hydroxide released during the hydration of the calcium silicates is also vulnerable to attack. Because cement liberates heat when it hydrates, concrete placed in large masses, as in dams, can cause the temperature inside the mass to rise as much as 40 °C (70 °F) above the outside temperature. Subsequent cooling can be a cause of cracking. The highest heat of hydration is shown by C_3A, followed in descending order by C_3S, C_4AF, and C_2S.

E. COMPRESSIVE STRENGTH OF CEMENT

(As per IS 4031(Part 6):1988)

Objective

To find the compressive strength of given sample of cement.

Apparatus

7.07cm cube moulds (50cm^2 c/s area) conforming to IS: 10080-1982,, Compression testing machine conforms to IS: 14858(2000), Vibrating machine, Balance, Weights and Trays.

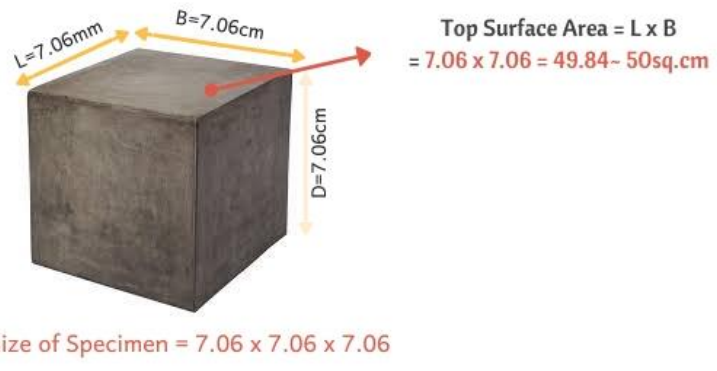
Materials required

Cement (say OPC), Indian Standard Sand is used for this testing conform to IS: 650-1966, the sand with no silt content and the sand which is passing through 2 mm IS sieve and retaining on 90 microns IS sieve, Water (for having a standard consistency)

IS 4031(Part 6):1988 Methods of Physical Tests for Hydraulic Cement- Determination of Compressive Strength of Hydraulic Cement other than Masonry Cement (First revision). Reaffirmed- May 2014

Theory

Compressive strength of the cement is the property of cement which specifies how much load it can withstand when cement is made into a hardened mass mixing with standard sand and water. The process of testing compressive strength of concrete and cement may be somewhat same but the materials required for preparing cubes are different.



Standard Sand

PROCEDURE:

1. Measure the given cement and standard sand in the proportion 1:3 by weight.
2. Standard sand: It shall pass the 850 micron I.S. sieve and not more than 10% by weight shall pass the 600 micron I.S. sieve.
3. Take 200 gms of cement and 600 gms of standard sand in a pan. Mix it dry with a trowel for one minute and then add water.
4. The quantity of water shall be **(P/4 + 3) %** of combined weight of cement and sand, where P is the % of water required to produce a paste of standard consistency determined earlier. Add water and mix it until the mixture is of uniform colour. The time of mixing shall not be less than 3 minutes and not greater than 4 minutes.
5. Immediately after mixing the mortar place the mortar in the cube mould and tamp with the help of the tamping rod. The mortar shall be rodded 20times in about 8 seconds to ensure elimination of entrained air.
6. If vibrator is used, the period of vibration shall be two minutes at the specified speed of 12000 vibrations per minutes.
7. Then place the cube moulds in an atmosphere of $27^0 \pm 2^0$c and 90% relative humidity, submerge in clear fresh water till testing.
8. Take out the cubes from water just before testing. Testing should be done on their sides without any packing. The cubes are placed in the compression testing machine and load is applied in the rate of 35 N/mm²/min.
9. Three cubes should be tested. The load at which the cube is crushed is noted and their average should be taken as the test result.

Precaution

1. The temperature of the room and cube should be maintained 27±2ºC.
2. The water used for curing should be changed every 7 days.
3. The cube should not be dried before the completion of the compressive strength test.
4. If the mixture of cement, sand and water does not obtain uniform colour within 4 minutes of mixing, then the mixture should be discarded and the operation should be started from the start.

5. Compressive strength depends upon the proportion and properties of raw materials used. So, the raw materials should be selected carefully.

Then compressive strength for each cube on their respective test day is calculated using the formula:

$$Compressive\ strength = \frac{Crushing\ load}{area\ of\ the\ cube}$$

Observations

S.No	Age of cube (in days)	Weight of cube (gm)	Density (gm/cc)	Area (mm^2)	Crushing load	Compressive strength (N/mm^2)	Average strength (N/mm^2)
1.	3						
2.	3						
3.	3						
4.	7						
5.	7						
6.	7						
7.	28						
8.	28						
9.	28						

As per IS, at least three cubes are tested at 7 days, 14 days, 28 days and the average of the three cubes are rounded to nearest $0.5 N/mm^2$. Do not consider the specimen which differs more than 10% of the average value of compressive strength.

Result

The average Compressive strength of cement cube at 7 days __________ N/mm^2
The average Compressive strength of cement cube at 14 days _________ N/mm^2
The average Compressive strength of cement cube at 28 days_________ N/mm^2

Inference

Viva Questions

Why should we do the compressive strength test of cement?

Strength is the most important property of cement. The compressive strength test of cement is done because, with an increase in compressive strength of cement strengths such as flexural strength, resistance to abrasion, and so on also increases. With one test we can determine various aspects of cement and can decide the suitable types of cement for the construction site.

What factors affect the compressive strength of cement?

1. Water-cement ratio
2. Cement-sand ratio
3. Type and grade of sand
4. Manner of mixing
5. Shape and size of the specimen
6. Curing condition
7. Age of specimen
8. Rate of loading

What is standard sand used for cement test?

Standard sand is used to assess the quality of cement, lime, pozzolana and other mineral admixture used in construction industry. Previously it was imported from U.K. Now it is available at Ennore, Madras. Standard sand shall be of quartz material, Colour of the standard sand is light grey or whitish, It should be free from silt and the sand grains should be angular, but a small percentage of flaky or rounded particle is permissible.

What is the particle size distribution of standard sand?

All the particles of standard sand fall within the size range of 2 mm to 90 micron (as mentioned in the table below)

Particle Size	**Percentage**
2 mm to 1 mm	33.33%
1 mm to 500 micron	33.33%
500 micron to 90 micron	33.33%

Why should we use the cube mould of the size mentioned above and not the larger one?

This is because if we choose large size cubes, shrinkage and cracks will develop. This will make us unable to perform the compressive strength test.

TESTS ON AGGREGATE

1. FINENESS MODULUS OF COARSE AGGREGATE

Objective

To determine the fineness modulus of Coarse aggregate.

Apparatus

1. A set of I.S sieves for fineness modulus 80mm,40mm.,20mm,16mm,10mm and 4.75mm
2. Weighing balance accurate up to 0.1 gram
3. Quartering shovel, trough, soft brush etc.

Material

Coarse aggregate- 10 kg

Theory

The purpose of Fineness Modulus test is to know the character of the aggregate to be used, as to whether it is fine, medium or coarse. It serves the purpose of comparing one aggregate with another in respect of fineness or coarseness.

Fineness modulus (FM) is an empirical factor which is $1/100^{th}$ of the sum of cumulative percentages of the sample retained when sieved successfully through the I.S.sieves of 80mm,40mm,20mm,16mm,10mm and 4.75mm.

Procedure

1. Take the required quantity of representative sample from stock piles.
2. Bring the sample to air dry condition before weighing and sieving, by allowing it to dry at room temperature or by heating
3. For sieving use clean sieves and use sieves starting from largest size to successively smaller and smaller sizes, as mentioned above
4. Shake each sieve separately over a clean tray or a period of not less than two minutes, move the sieve backwards and forwards, left to right , circular clockwise and anti-clockwise with frequent jarring , so as to keep the material moving over the sieve surface. Avoid spilling of aggregate during above operations.
5. Weigh the material retained on each sieve.
6. Record the weights retained on each sieve in the table.

OBSERVATIONS:

I.S sieve	Weight retained (gm)	percentage retained	Cumulative percentage retained	Percentage Passing (100- col.4)
1	2	3	4	5
80mm				
40mm				
20mm				
16mm				
10mm				
4.75mm				
Total				

Fineness Modulus = (Total cumulative percentage retained)/100

Result

Fineness Modulus of coarse aggregate=____________

The FM of coarse aggregate is usually more than 5.

Inference

B. FINENESS MODULUS OF FINE AGGREGATE

Objective

To determine the fineness modulus of sand

Apparatus and materials

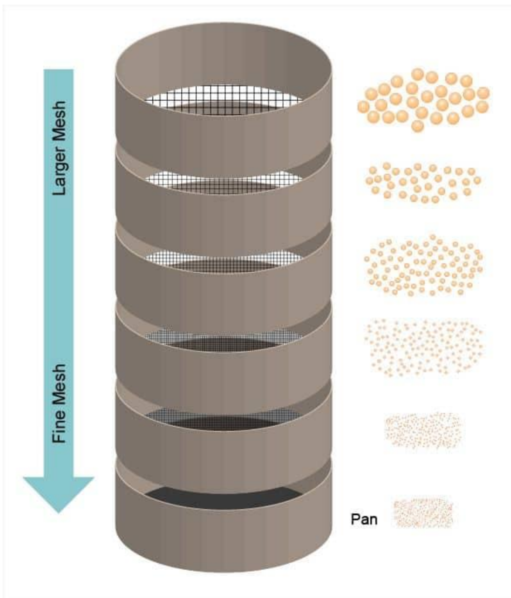
- Sieves as per IS standards
- Mechanical sieve shaker(optional)
- Dry oven
- Digital weight scale

IS Code for Fineness Modulus of fine aggregate **IS : 383 -1970**

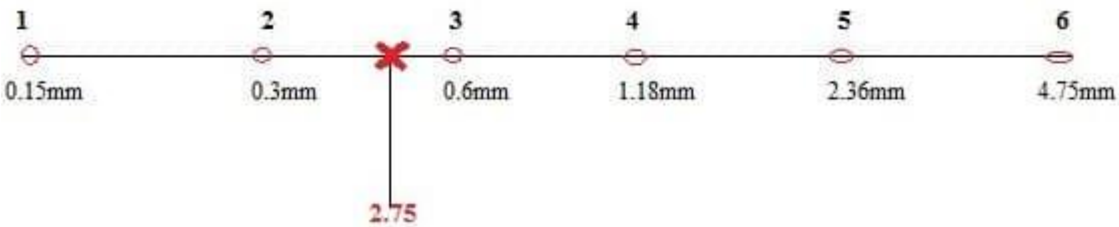
Sample preparation

Take a sample of fine aggregate in pan and placed it in dry oven at a temperature of 100 – 110°C. After drying take the sample and note down its weight.

Theory



Fineness modulus of fine aggregate is 2.75. It means the average value of aggregate is in between the 2nd sieve and 3rd sieve. It means the average aggregate size is in between 0.3mm to 0.6mm as shown in below figure.



Fineness modulus of fine aggregate varies from 2.0 to 3.5mm. Fine aggregate having fineness modulus more than 3.2 should not considered as fine aggregate. Various values of fineness modulus for different sands are detailed below.

Type of sand	Fineness modulus range
Fine sand	2.2 – 2.6
Medium sand	2.6 – 2.9
Coarse sand	2.9 – 3.2

Fineness modulus limits for various zones of sand according to IS 383-1970 are tabulated below.

Sieve size	Zone-1	Zone-2	Zone-3	Zone-4
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
0.6mm	15-34	35-59	60-79	80-100
0.3mm	5-20	8-30	12-40	15-50
0.15mm	0-10	0-10	0-10	0-15
Fineness modulus	4.0-2.71	3.37-2.1	2.78-1.71	2.25-1.35

Procedure

Take a sample of sand in a pan and placed it in the oven at a temperature of approximate 100-110°C. After drying, take the sample out from oven and note down its weight using digital weighing scale.

Following is the test procedure for fineness modulus of sand test,

1) Take the sieves and arrange them in descending order with the largest sieve on top.
2) If a mechanical shaker is using for shaking, then put the sieve set in position on the mechanical shaker and pour the sample in the top sieve & then close it with the sieve plate.
3) Then switch on the machine and shaking of sieves should be done at least for 5 minutes.
4) If the shaking is done manually (by the hands) then pour the sample in a top sieve and close it then hold the top two sieves and shake it inwards and outwards, vertically and horizontally.
5) After some time shake 3 and 4 and finally last sieves simultaneously.
6) After sieving, record the sample weights retained on each sieve. Then find the cumulative weight retained.
7) Finally, determine the cumulative percentage retained on each sieve.
8) Add the all cumulative percentage values and divide with 100 then we will get the value of fineness modulus.

Observations and calculations

Take the dry weight of sample = 1000gm. After sieve analysis the values appeared are tabulated below.

Sieve size	Weight retained (g)	Cumulative weight retained(g)	Cumulative percentage weight Retained (%)
4.75mm			
2.36mm			
1.18mm			
0.6mm			
0.3mm			
0.15mm			
Total			

Therefore, fineness modulus of aggregate = (cumulative % retained) / 100 =

Fineness modulus of fine aggregate is __________

Result

Inference

Viva Questions

What Is Fineness Modulus of Sand?

Fineness modulus of sand (fine aggregate) is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fineness modulus. Fine aggregate means the aggregate which passes through 4.75mm sieve. To find the fineness modulus of fine aggregate we need sieve sizes of 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm. Fineness modulus of finer aggregate is lower than fineness modulus of coarse aggregate. The Fineness Modulus of Sand is an index number that indicates the mean size of the sand particles. It is calculated by performing the sieve analysis test with standard IS sieves. The fineness modulus of sand ranges from 2.2 to 3.2. To find the fineness modulus of fine aggregate required IS sieve are sizes of 4.75mm. 2.36mm, 1.18mm.0.6mm, 0.3mm, and 0.15mm.

Add the Cumulative % Retained on all of the sieves except the 75 µm and the Pan.

How do you calculate fineness modulus of sand?

Fineness modulus of Sand = (Cumulative % retained) / 100

What is the range of fineness modulus?

Types of Sand and their fineness modulus (F. M) value
Fine Sand 2.6 – 2.6
Medium Sand 2.6 -2.9
Coarse Sand 2.9 -3.2

What is fineness modulus used for?

The fineness modulus specifies the average size of the sand and aggregate particles for the mixing of concrete. However, the size will be beneficial in understanding how easily the concrete pours and spreads, along with its strength and durability once cured.

What is the FM of sand?

The Fineness Modulus of Sand is an index number that indicates the mean size of the sand particles. It is calculated by performing the sieve analysis test with standard IS sieves. The fineness modulus of sand ranges from 2.2 to 3.2.

Which zone sand is the finest sand?

Sands belonging to Zone-IV are the finest of a type. And on the contrary to that Zone-I has Coarse Sand. As a result, Zone-IV has the lowest Fineness Modulus Value.

What is wet sieve test?

Wet sieving is a procedure used to evaluate particle size distribution or gradation of a granular material. Dry and Wet Sieve Analysis is carried out to quantitatively determine the Particle/Grain Size Distribution for soil particles of size 75 micron and bigger. For soil particles of size 4.75mm and bigger, dry sieve analysis is done and for soil particles of size above 75 micron and below 4.75mm, wet sieve analysis is also needed if the soil particles are coated by clay/silt. The sieves set should have lid at top and Pan at base.

The finest sieve used in the analysis is 75µ. If the portion passing through 75µ sieve, which we collect in the pan, is substantial, say 5 to 10%, then wet sieve analysis is carried out. The purpose of the wet sieve analysis is to remove all the particles which are finer than 75 micron particles from the sample so that we arrive at the correct sieve analysis results.

How many zones are in fine aggregate?
There are four grading zones for fine aggregates such as grading zone I, II, III, and IV. It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.
Zone 1: Coarse sand, with value of 2.9 - 3.2. 2. Zone 2: Sand is rather rough, with values of 2.6 - 2.9.

What is zoning of aggregate?
Grading of aggregates are determination of particle size distribution of aggregates. Grading of aggregates is an important factor for concrete mix design. These affect the concrete strength as well as durability. Proper grading is important for concrete construction. Zone I–Sand being very coarse and Zone 4 sand is very fine. It is generally recommended by code to use sands of zones I to Zone III for Structural concrete works.

What is difference between fine aggregate and coarse aggregate?
Fine aggregates are small size filler materials in construction. Coarse aggregates are larger size filler materials in construction. Fine aggregates are the particles that pass through 4.75 mm sieve and retain on 0.075 mm sieve. Coarse aggregates are the particles that retain on 4.75 mm sieve.

What is well graded aggregate?
Aggregate Grading - is a measure of how well distributed the sizes of the particles in an aggregate are. A well graded aggregate will have a good range of particle sizes and will have a fair representation from every size of particle. Poor-graded aggregate is characterized by small variation in size. It contains aggregate particles that are almost of the same size. This means that the particles pack together, leaving relatively large voids in the concrete. It is also called "uniform-graded".

What is the IS code for fine aggregate?
IS 383: Coarse and Fine Aggregate for Concrete - Specification.

Is sharp sand fine or coarse?
What is sharp sand? Also known as 'grit sand' or 'concrete sand', washed sharp sand is more coarse and has larger particles than other construction sands such as builder's sand, which consists of finer grains. Having a larger grain size than other types of sand means sharp sand is slightly heavier.

How can you tell the difference between sea sand and river sand?
Different Appearance. In terms of appearance color, the sea sand is darker, dark brown and lighter. The color of river sand is relatively brightly yellow. From the aspect of particle size, the grain size of river sand is coarser, with moderate surface roughness and less impurities. With deserts full of it, one can easily be fooled into thinking that sand is an almost infinite resource. However, desert sand has little use; the grains are too smooth and fine to bind together, so it is not suitable for the making of for instance concrete.

What is M sand?
M sand is a form of artificial sand, manufactured by crushing large hard stones, mainly rocks or granite, into fine particles, which is then washed and finely graded. It is widely used as a substitute for river sand for construction purposes, mostly in the production of concrete and mortar mix.

What is difference between M sand and P sand?
The size of M Sand ranges from 0 to 4.75mm based on the standard given by the Bureau of Indian Standards (BIS) adhering to IS 383 zone II. P Sand size is 0 to 2.36mm based on the standard given by BIS adhering to IS 1542. M Sand in the market is available at different prices depending upon the quality of the product.

C. BULKING OF FINE AGGREGATE

Objective

To determine the percentage bulking of fine aggregate in moisture condition.

Apparatus

1. Two identical cylindrical containers
2. Steel rule
3. Steel rod 6mm dia.

Materials

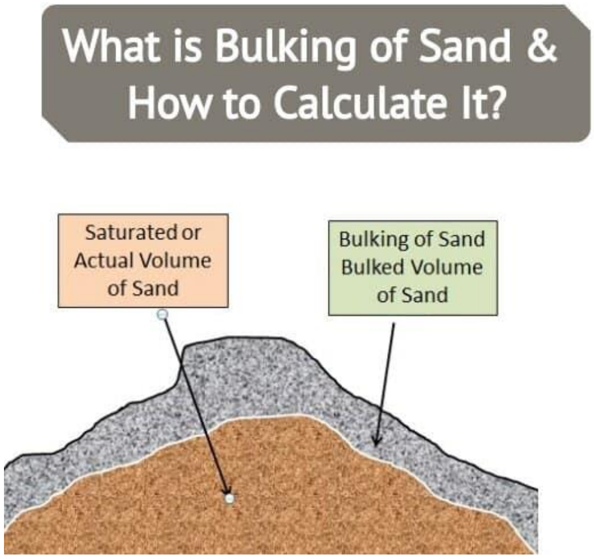
Wet sand 500 grams

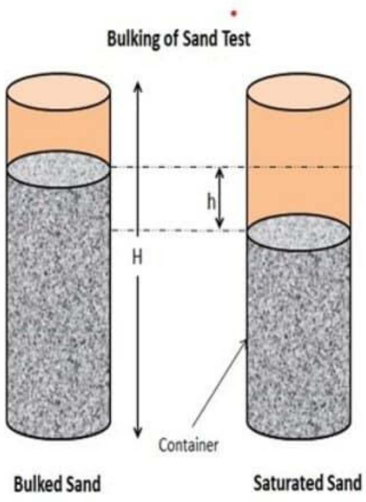
Theory

In volumetric batching, if sand is moist, it is necessary to increase the amount of sand to be added in each batch, to compensate for bulking i.e., increase in volume of sand which occurs if the sand is moist.

Bulking

Bulking is the increase in volume of fine aggregate in a loosely filled state, when it is moist due to the presence of moisture film around particles. There is no bulking when the sand is dry or when it is fully saturated with water. Fine sand bulks more than coarse sand. Coarse aggregate does not bulk.

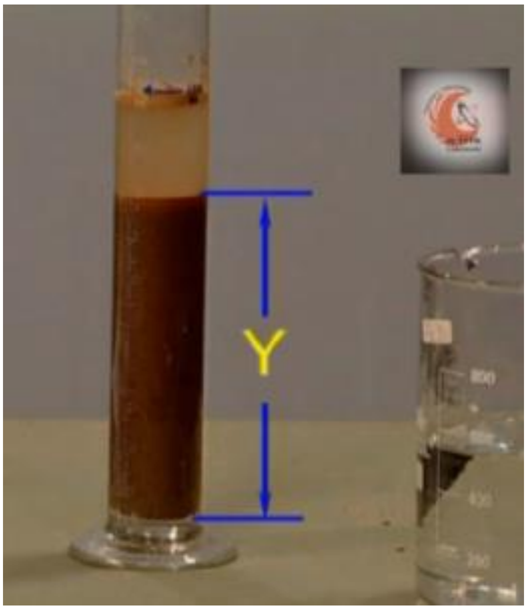




Procedure

1. Take the sample sand and fill the measuring cylinder up to 200 ml

2. To make the necessary correction use the steel rule but don’t compact the sand.
3. Transfer that sample to a container
4. Refill the measuring cylinder with 100ml water
5. Now refill the sand into measuring cylinder and stir it well with the help of steel rod.
6. Allow it to settle sometime.
7. The sand will be below the 200ml mark as shown in the below pic. Note this level as **Y**



8. Repeat the same procedure for 2 more samples

$$\text{Bulking of Sand} = \frac{200 - Y}{Y} \times 100\ \%$$

Observations

S.No	DESCRIPTION	SAMPLE No.		
		SAMPLE I	SAMPLE II	SAMPLE III
(i)	Volume of Loose Sand	200	200	200
(ii)	Volume of Saturated Sand			
	$\text{Bulking of Sand} = \frac{200 - Y}{Y} \times 100\ \%$			

So the sand bulkage for the average of above observations is = _______________%

Result

Percentage bulking =______________ %

Inference

Viva Questions

What is the importance of bulking of sand test?

The main purpose of adding sand in concrete is to minimise the segregation of concrete and to fill out the pores between the cement and coarse aggregate. This test (bulking of sand or bulking of fine aggregate) is to ensure that we are using the right amount of sand while concreting.

What is Bulking of sand?

Bulking of sand is nothing but the looseness of soil without compacting. Basically, water reduces the pores in the sand and compacts the soil. The difference between the volume of loose soil to saturated soil is known as bulking of sand. During concreting process, we continually give vibrate concrete to reduce the pores. This makes the sand more compact and reduces the pores between soil particles. However, while measuring we don't do this because it takes time.

How to evaluate sand bulkage?

If we need 1 m^3 of sand in concrete we need to know the approximate sand bulkage value. Say, for example, sample sand that we are going to use has 30% bulkage of sand then we need to take 30% more sand that is 1.3 times of sand while volume batching in order to get 1 m^3 of sand for concrete.

If we take 1 m^3 sand without adding bulkage then the sand volume lessen to 70% after adding water this is known as bulkage of sand.

As you know our whole concrete mix calculation and grade of concrete is based on the right amount of its ingredients. We may use 1.55 as constant on concrete calculation

Normally Wet Volume of concrete = 1.55 X Dry Volume of concrete.

Here are we using 35% for sand bulkage and 20% as wastage. Maybe differs sometimes.

If we didn't make consideration for sand bulkage then the end product (concrete quantity) becomes less quantity and quality which will adequately affect our concrete overall strength.

What us bulking of sand?

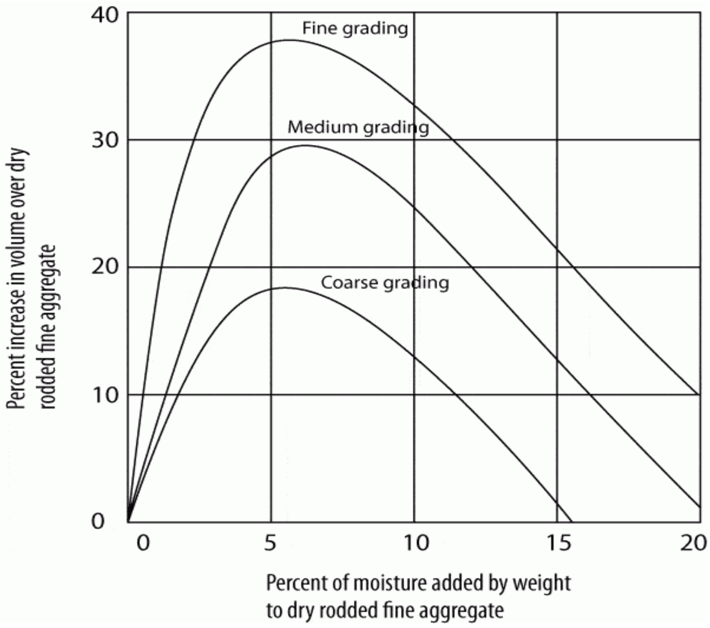
Thie phenomenon of the increasing volume of sand due to moisture in the sand is called 'Sand Bulking'. Bulking of sand is code: IS 2386-3 if the sand contains 4% moisture, then it will increase sand volume by 25%.

Moisture Content in Sand	Increase in Volume of Sand
2%	15%
3%	20%
4%	25%
5%	30%

Bulking is depends on sand particles' size. As the smaller the particle size of sand, the volume of bulking increases. Generally, Medium and coarse sand have lower bulking of sand. High bulking result in low quality concrete mix and ultimately reduce the strength of concrete.

What is the principle behind bulking of sand?

Bulking of sand test depends on the fact that the dry volume of sand and saturated volume of sand has almost the same volume. Therefore in this test sand is filled in a container and water is added to it up to its saturation point. As the sand is saturated in water its volume is reduced and shows the actual volume of sand or dry volume of sand. By measuring the difference between the volume of sand and saturated volume of sand we can calculate the bulking of sand value.



If we don’t take this extra amount of sand considering the bulkage value, the entire volume is going to be lessened to 75% after adding water. we all know that the standard of concrete depends tons on the right proportioning of the contents.

Generally, we consider the wet volume of concrete is 1.5 times the quantity of dry concrete, during this case, we are typically using approximately 30% of sand bulkage and 20% of wastage. If we don’t consider the bulkage of sand, the entire quantity is going to be lessened and can impact the general concrete quality.

Sand Bulking occurs when sand comes in contact with moisture, which forms a thin layer of water around the sand particle and this thin layer of water exert an outward force on each other which cause the sand particle to move away from each other and ultimately increase the volume of sand.

Bulking may be to the extent of 40 percent of the original dry volume of sand in the fine and 15 percent in the case of coarse sands.

How do you test the quality of sand?

Take a Sample of sand and add it in Sodium Hydroxide [NaOH] Solution, Stir the solution for few minutes, if the color of solution changes to brown, then the sand has organic impurities which are not suitable for construction. Good quality of sand shows lighter color when it is mixed with NaOH solution.

What are the various batching method?

The measurement of materials for making concrete is known as batching. There are two methods of batching:

(i) Volume batching (ii) Weigh batching

Volume Batching- Volume batching is not a good method for proportioning the material because of the difficulty it offers to measure granular material in terms of volume. However, for unimportant concrete or for any small job, concrete may be batched by volume.

Weigh batching- It is the correct method of measuring the materials. For important concrete, invariably, weigh batching system should be adopted. Use of weight system in batching, facilitates accuracy, flexibility and simplicity. Different types of weigh batchers are available, the particular type to be used, depends upon the nature of the job. Large weigh batching plants have automatic weighing equipment.

State the important facts in connection with the bulking of sand.

(1) When moisture content is increased by adding more water, the sand particles pack near each other and the amount of bulking of sand is decreased. Thus, the dry sand and the sand completely flooded with water have practically the same volume.

(2) The coarse aggregate is little affected by the moisture content.

(3) One of the reasons of adopting proportioning by weight is the bulking of sand as proportioning by weight avoids the difficulty due to the bulking of sand.

(4) The bulking of sand should be taken into account when volumetric proportioning of the aggregates is adopted. Otherwise, less quantity of concrete per bag of cement will be produced, which naturally will increase the cost of concrete. Also, there will be less quantity of line aggregate in the concrete mix which may make the concrete difficult to place.

(C) SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE

(As per IS: 2386 – part – 3)

Objective

To determine the specific gravity of given sample of coarse aggregates.

Apparatus

10 kg capacity balance with weights, cylindrical containers of litre and 5 litre capacities, measuring jar of 1000ml capacity.

As per IS: 2386 (Part III) – 1963 – (Indian Standard- Methods of Test for Aggregates for Concrete – Specific Gravity, Density, Voids, Absorption, and Bulking),

Theory

The specific gravity of an aggregate is generally required for calculations in connection with cement concrete design work for determination of moisture content and for the calculations of volume yield of concrete. The specific gravity also gives information on the quality and properties of aggregate. The specific gravity of an aggregate is considered to be a measure of strength of quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity values.

The bulk density of an aggregate is used for judging its quality by comparison with normal density for that type of aggregate. It is required for converting proportions by weight into proportions by volume and is used in calculating the percentage of voids in the aggregate.

1. Specific gravity is the weight of aggregate relative to the weight of equal volume of water.
2. Void ratio is the ratio of volume of voids to the volume of solids in an aggregate.
3. Percentage of voids or porosity is the ratio of volume of voids to the total volume of a sample of an aggregate.

There are three methods of testing for the determination of the specific gravity of aggregates, according to the size of the aggregates larger than 10 mm, 40 mm and smaller than 10 mm. For Samples larger than 10 mm, 40 mm, the below given test method is used and for samples smaller than 10 mm Pycnometer test is done.

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68. Water absorption shall not be more than 0.6 per unit by weight.

Specific gravity and Water Absorption Test of Aggregates are major important tests to be performed on aggregate. These two parameters or properties of aggregate play an important role in the mix design of concrete. As we know that aggregate occupies 70 to 80% volume of concrete, its testing becomes essential before use.

Procedure

Take sample of an aggregate sample (Aggregate which has been artificially heated shall not be used). The aggregates are thoroughly washed so, the finer particles of the dust are removed from their surface. Then the washed aggregates are placed in the wire basket and immersed in the distilled water at a temperature between 22° C to 32° C with cover from the water surface at least 5 cm top of the basket. The basket immersed in the water requires immediate removal of entrapped air. This entrapped air was removed by lifting the basket 25 mm above the base of the tank and allowing 25 drops at the rate of about 1 drop/sec. Then basket filled with aggregate is allowed to be immersed in water for a period of 24 hrs.

1. After 24 hours the basket and the aggregates are weighed in the water at a temperature of 22° C to 32° C. (W1)
2. Then the basket and the aggregates are taken out from the water and it allows to drain for a couple of minutes after these aggregates are removed from the basket and placed on the dry cloths.

3. After this the empty basket is again immersed in the water, apply 25 drops, and weighed in water. (W2)
4. The aggregates are placed on the dry cloth and are gently surface dried with a cloth if 1st cloth is not taken moisture then aggregates are transferred to the second one. After these aggregates are spread on the cloth and less exposed to the atmosphere away from direct sunlight or also away from the other source of the heat until it appears to be completely surface dried.
5. For accelerating the unheated air may be used after the first 10 minutes for those aggregates which are difficult to dry and weigh it. (W3)
6. Then the aggregates are placed in the shallow tray and put in the oven at a temperature of 100° C to 110° C for 24 hours.
7. After 24 hours the aggregates are removed from the oven and fill in the airtight container for the cooling of it and weighed. (W4)

Observations and calculations

Weight of saturated aggregate sample suspended in wire basket = W1
Weight of basket suspended in water = W2
Weight of saturating aggregate in water = (W1-W2) = Ws
Weight of surface dry aggregate in air = W3
Weight of water equal volume of aggregate = (W3 – Ws)

Specific Gravity of Aggregate = Dry Wt. Of Aggregate / Wt. Of Equal Volume Water
= W4 / (W3- Ws)

Apparent Specific Gravity = Dry. Wt. of Aggregate / Wt. Of the equal volume of water excluding air
= W4 / (W4-Ws)

Water Absorption of Aggregate = % by weight of water absorbed in terms of oven-dried weight of aggregate
= (W3 – W4) x 100) / W4

Specific gravity and water absorption of a coarse aggregate lab report are prepared after calculating the above values.

Precautions

While filling the container with water in determining void ratio and porosity of coarse aggregate, care should be taken that water should not be in excess of the level of coarse aggregate

Result

Specific gravity of coarse aggregate=

Inference

IS recommended values are

1. The specific gravity of coarse aggregate as per is code is 2.5 to 3.
2. The water absorption of aggregate ranges from 0.1 to 2% by weight of total aggregates

Viva Questions

What is specific gravity of aggregate?

Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. It is the measure of strength or quality of the specific material. Aggregates having low specific gravity are generally weaker than those with higher specific gravity values. The specific gravity of aggregates normally used in construction ranges from around 2.5 to 3.0 with an average value of about 2.68. Specific gravity of aggregates is considered as a measurement of strength. Aggregates having higher specific gravity are generally considered as having higher strength and aggregates having low specific gravity are generally considered as having weaker strength.

What is the need to evaluate the water absorption of the aggregate?

Water absorption gives an idea of strength of Coarse aggregate. Coarse aggregate having more water absorption are porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests. Water absorption of aggregates is the % of water absorbed by an air–dried aggregate when immersed in water at 27°C for a period of 24 hours. The water absorption test uses to find the water holding capacity of the aggregates. The water is absorbed by the aggregates or stones in their pores known as water absorption. Usually, water absorption gives an idea about the strength of the aggregates. That aggregate has more water absorption is usually unsuitable for the construction.

What are the factors affecting specific gravity test of aggregate?

The size, the number, and the continuity of the pores through an aggregate particle may affect the strength of the aggregate, abrasion resistance, surface texture, specific gravity, bonding capabilities, and resistance to freezing and thawing action.

What is the Specification of Absorption of Aggregates?

Water absorption gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature. These aggregates are generally considered unsuitable for construction, unless found to be acceptable based on strength, impact and hardness tests.

What is the IS Code of Specific Gravity Test of Coarse Aggregate?

IS:2386 (Part 3): 1963, Methods of test for aggregates for concrete (Determination of Specific Gravity of aggregates)

What is the purpose of specific gravity and absorption of coarse aggregate?

In Portland Cement Concrete the specific gravity of the aggregate is used in calculating the percentage of voids and the solid volume of aggregates in computations of yield. The absorption is important in determining the net water-cement ratio in the concrete mix. In the aggregates, some of the pores are permeable, whereas others are impermeable. Therefore, two types of specific gravities are defined: one is the absolute specific gravity, and second is the apparent specific gravity. In the determination of true or absolute specific gravity, both the permeable and impermeable voids are excluded. But it is not of much practical use as the volume of impermeable internal pores is too difficult to determine. On the other side, for the determination of the apparent specific gravity, the volume of impermeable internal pore is added to the effective volume of the aggregates. It does not include the permeable pores. Apparent Specific Gravity of Aggregates: It is calculated by measuring the weight of the oven-dry aggregate divided by its absolute volume excluding the natural voids in the aggregate particles. It is the realistic quantified data validated to use for the calculation of concrete mix proportioning.

Experiment No:2

DESIGN OF HIGH STRENGTH CONCRETE MIX

IS 10262: 2019 Concrete Mix Proportioning — Guidelines (Second Revision)

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council. This standard provides guidelines for proportioning concrete mixes as per the requirements using the concrete making materials including other supplementary materials identified for this purpose.
This standard was first published in 1982 and subsequently revised in 2009. In the first revision, the title of the standard was modified as 'Concrete mix proportioning — Guidelines' from 'Recommended guidelines for concrete mix design'. The major changes in the first revision had been, restricting the applicability of the standard to ordinary and standard grades of concrete, aligning the standard to IS 456: 2000 'Plain and reinforced concrete — Code of practice (*fourth revision*)'; review and modification of the requirements for selection of water cement ratio, water content and estimation of coarse aggregate content and fine aggregate content.

Salient features of IS 10262: 2019

Mix proportioning procedure for high strength concrete for M 65 or above (up to target strength of M 100) has been included
The target mean strength for mix proportioning formula has been refined to include a new factor based on the grade of concrete. This has been done to ensure a minimum margin between the characteristic compressive strength and the target mean compressive strength
A graph of water-cement ratio versus 28 days strength of concrete has been introduced for different grades and types of cement, as an alternate method for assuming the initial water-cement ratio.
Concrete has become an indispensable construction material. In the present scenario, concrete has bypassed the stage of mere four component system, that is, cement, water, coarse aggregate and fine aggregate. It can be a combination of far more number of ingredients, for example, a judicious combination of ingredients from as many as ten materials. Now, apart from the four ingredients mentioned above, fly ash, ground granulated blast furnace slag, silica fume, rice husk ash, metakaolin and superplasticizer are six more ingredients which are generally used in concrete produced in practice as the situation demands. Also, now high strength concrete, self-compacting concrete, apart from ordinary concrete and mass concrete, are also being produced and used in projects. Hence, it is all the more essential at this juncture to have general guidelines on proportioning concrete mixes to cover these aspects.
This standard is applicable for ordinary, standard and high strength concrete grades. The standard also covers provisions for the mix proportioning of self-compacting concrete and mass concrete. All requirements of IS 456 in so far as they apply, shall be deemed to form part of this standard.

Various important codes

IS 269: 2015 Specification for ordinary Portland cement (sixth revision)
IS 383: 2016 Specification for coarse and fine aggregates for concrete (second revision)
IS 456: 2000 Code of practice for plain and reinforced concrete (fourth revision)
IS 1199 (Part 6) : 2018 Fresh concrete — Methods of sampling, testing and analysis: Part 6 Tests on fresh self-compacting concrete (first revision) (under publication)

IS 1489 Specification for Portland- pozzolana cement
(Part 1) : 2015 Fly ash based (third revision)
(Part 2) : 2015 Calcined clay based (third revision)
IS 2386 (Part 3) : 1963 Methods of test for aggregates for concrete: Part 3 Specific gravity, voids, absorption and bulking
IS 3812 (Part 1) : 2013 Specification for pulverized fuel concrete (third revision)
IS 9103: 1999 Specification for admixtures for concrete (first revision)
IS 15388: 2003 Specification for silica fume
IS 16714: 2018 Ground granulated blast furnace slag for use in cement, mortar and concrete — Specification

Water-Cement Ratio (w/c) — The ratio is calculated by dividing the mass of the mixing water by the mass of the cement. It refers to the ratio corresponding to the saturated surface dry condition of aggregates.

Water-Cementitious Materials Ratio (w/cm) — The ratio (w/cm) is calculated by dividing the mass of the mixing water by the combined mass of the cement and fly ash or other cementitious materials or a combination thereof. It refers to the ratio corresponding to the saturated surface dry condition of aggregates.

Objective of proportioning concrete mixes

The objective of proportioning concrete mixes is to arrive at the most economical and practical combinations of different ingredients to produce concrete that will satisfy the performance requirements under specified conditions of use. An integral part of concrete mix proportioning is the preparation of trial mixes and marking adjustments to such trials to strike a balance between the requirements of placement, that is, workability and strength, concomitantly
satisfying durability requirements. Concrete has to be of satisfactory quality both in its fresh and hardened state. This task is best accomplished by trial mixes arrived at by the use of certain established relationships among different parameters and by analysis of data already generated thereby providing a basis for judicious combination of all the ingredients involved. The basic principles which underline the proportioning of mixes are Abram's law for strength development and Lyse's rule for making mix with adequate workability for placement in a dense state so as to enable the strength development as contemplated. From practical view point, compressive strength is often taken as an index of acceptability. This does not necessarily satisfy the requirements of durability unless examined under specific context. Mix proportioning is generally carried out for a particular compressive strength requirement, ensuring that fresh concrete of the proportioned mix possess adequate workability for placement without segregation and bleeding while attaining a dense state. In addition, the method has scope to consider the combination of wider spectrum of cement and mineral admixtures proposed to be used to meet the requirements of durability for the type of exposure conditions anticipated in service.

Proportioning of concrete mixes can be regarded as a procedure set to proportion the most economical concrete mix, for specified durability and grade, for required site conditions. As a guarantor of quality of concrete in the construction, the constructor should carry out mix proportioning and the engineer-in-charge should approve the mix so proportioned. The method given in this standard is to be regarded as the guidelines only to arrive at an acceptable product, which satisfies the requirements of placement required with development of strength with age and ensures the requirements of durability. It is suggested that the concrete mix proportioning in the laboratory may be carried out at a temperature of 27± 2°C, relative humidity of minimum 60 percent, and the temperature of concrete may be 27 ± 3°C.

This standard does not debar the adoption of any other established methods of concrete mix proportioning

What is the data required for mix proportioning?

The following data are required for mix proportioning of a particular grade of concrete:

a) Grade designation;

b) Type of cement, and grade of cement (if applicable);

c) Maximum nominal size of aggregate;

d) Minimum cement/cementitious materials content and maximum water cement/ cementitious materials ratio to be adopted; or Exposure conditions as per Table 3 and Table 5 of IS 456;

e) Workability required at the time of placement;

f) Transportation time;

g) Method of placing;

h) Degree of site control (good/fair) or value of established standard deviation, if any;

i) Type of coarse aggregate (angular/sub angular/ gravel with some crushed

j) particles/rounded gravel/manufactured coarse aggregate);

k) Type of fine aggregate (natural sand/ crushed stone or gravel sand/manufactured sand/ mixed sand);

l) Maximum cement content;

m) Whether a chemical admixture shall or shall not be used and the type of chemical admixture and the extent of use;

n) Whether a mineral admixture shall or shall not be used and the type of mineral admixture and the extent of use; and

o) Any other specific requirement like early age strength requirements.

NOTE — Suitable reduction in water cement or water cementitious material ratio shall be done after the mix has been finalized based on trial mixes, to achieve the specific requirement of high early strength, if any. The reduced ratio shall be fixed based on trials for the required early strength. These trials shall be carried out after recalculating all the mix proportions.

ILLUSTRATIVE EXAMPLE ON CONCRETE MIX PROPORTIONING FOR HIGH STRENGTH CONCRETE

An example illustrating the mix proportioning for a concrete of M70 grade using silica fume and fly ash is given below. Use of silica fume is generally advantageous for grades of concrete M50 and above and for high performance concrete with special requirements, like higher abrasion resistance of concrete.

Stipulations For Proportioning

a) Grade designation : M 70

b) Type of cement : OPC 53 grade conforming to IS 269

c) Silica fume : Conforming to IS 15388

d) Maximum nominal size of aggregate : 20 mm

e) Exposure conditions as per Table 3 and Table 5 of IS 456 : Severe (for reinforced concrete)

f) Workability : 120 mm (slump)

g) Method of concrete placing : Pumping

h) Degree of supervision : Good

j) Type of aggregate : Crushed angular aggregate

k) Maximum cement (OPC) content : 450 kg/m3
m) Chemical admixture type : Superplasticizer (Polycarboxylate ether based)

Test Data For Materials
a) Cement used : OPC 53 Grade conforming to IS 269
b) Specific gravity of cement : 3.15
c) Specific gravity of
1) Coarse aggregate (at SSD condition) : 2.74
2) Fine aggregate (at SSD condition) : 2.65
3) Fly ash : 2.20
4) Silica fume : 2.20
5) Chemical admixture : 1.08
d) Water absorption
1) Coarse aggregate : 0.5 percent
2) Fine aggregate : 1.0 percent
f) Moisture content
1) Coarse aggregate : Nil
2) Fine aggregate : Nil
g) Sieve analysis
Coarse aggregate :

IS Sieve Sizes mm	*Analysis of Aggregate Fraction*		*Percentage of Different Fractions*			*Remarks*
	I (20-10 mm)	I (10-4.75 mm)	I 50 Percent	II 50 Percent	100 Percent	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
20	100	100	50	50	100	Conforming to Table 7 of IS 383
10	2.8	78.3	1.4	39.15	40.55	
4.75	Nil	8.70	Nil	4.35	4.35	

Fine aggregate : Conforming to grading Zone II of Table 9 of IS 383

Target Strength For Mix Proportioning

$f'ck = fck + 1.65\,S$

or

$f'ck = fck + X$

whichever is higher.
Where $f'ck$ = target average compressive strength at 28 days,
fck = characteristic compressive strength at 28 days,
S = standard deviation, and X = factor based on grade of concrete.

Table 1 Value of X
(*Clause* 4.2)

Sl No.	Grade of Concrete	Value of X
(1)	(2)	(3)
i)	M10, M15	5.0
ii)	M20, M25	5.5
iii)	M30, M35, M40, M45, M50, M55, M60	6.5
iv)	M65 and above	8.0

Table 2 Assumed Standard Deviation
(*Clause* 4.2.1.3)

Sl No.	Grade of Concrete	Assumed Standard Deviation N/mm²
(1)	(2)	(3)
i)	M10, M15	3.5
ii)	M20, M25	4.0
iii)	M30, M35, M40, M45, M50, M55, M60	5.0
iv)	M65, M70, M75, M80	6.0

From Table 2, standard deviation, *S* = 6.0 N/mm2.
Therefore, target strength using both equations, that is,
a) *f'*ck = *f*ck+1.65 *S* = 70 +1.65 × 6.0 = 79.9 N/mm2
b) *f'ck* = *fck* + 8.0 (The value of X for M 70 grade as per Table 1 is 8.0 N/mm2)
= 70 + 8.0 = 78.0 N/mm2
The higher value is to be adopted. Therefore, target strength will be 79.9 N/mm2 as 79.9 N/mm2 > 78.0 N/mm2.

Approximate Air Content
From Table 6, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 0.5 percent for 20.0 mm nominal maximum size of aggregate.

Table 6 Approximate Air Content
(*Clause* 6.2.3)

Sl No.	Nominal Maximum Size of Aggregate mm	Entrapped Air, as Percentage of Volume of Concrete
(1)	(1)	(1)
i)	10.0	1.0
ii)	12.5	0.8
iii)	20.0	0.5

Selection Of Water-Cementious Materials Ratio
From Table 8, the water-cementitious materials ratio required for the target strength of 79.9 N/mm2 is 0.29 for maximum size aggregate 20 mm. This is lower than the maximum value of 0.45. 0.29< 0.45, hence O.K.

Table 8 Recommended w/cm for High Strength Concrete made with HRWRA
(*Clause* 6.2.5)

Sl No.	Target Compressive Strength at 28 Days N/mm^2	Water–Cementitious Materials Ratio: Nominal Maximum Size of Aggregate 10.0 mm	12.5 mm	20.0 mm
(1)	(2)	(3)	(4)	(5)
i)	70	0.36	0.35	0.33
ii)	75	0.34	0.33	0.31
iii)	80	0.32	0.31	0.29
iv)	85	0.30	0.29	0.27
v)	90	0.28	0.27	0.26
vi)	100	0.26	0.25	0.24

NOTE — The recommended w/cm are for 28 days cement strength 53 MPa and above; for cement of other strength values, suitable adjustments may be made by reducing the w/cm.

Selection Of Water Content

From Table 7, water content for 20 mm aggregate = 186 kg/m3 (for 50 mm slump without using superplasticiser).

Table 7 Water Content per Cubic Metre of Concrete for Nominal Maximum Sizes of Aggregate
(*Clause* 6.2.4)

Sl No.	Nominal Maximum Size of Aggregate mm	Maximum Water Content (see Note 1) kg/m^3
(1)	(2)	(3)
i)	10.0	200
ii)	12.5	195
iii)	20.0	186

NOTES

1 Water content corresponding to saturated surface dry aggregate.

2 These quantities of mixing water are for use in computing cement/cementitious material content for trial batches.

3 On account of long distances over which concrete needs to be carried from batching plant/RMC plant, the concrete mix is generally designed for a higher slump initially than the slump required at the time of placing. The initial slump value shall depend on the distance of transport and loss of slump with time. Accordingly the adjustment for water content/admixture dosage shall be made for the higher initial slump value.

Estimated water content for 120 mm slump

$$= 186 + \frac{8.4}{100} \times 186$$

$$= \mathbf{201.624 \approx 202\ kg/m^3}$$

As superplasticizer (Polycarboxylate ether based) is used, the water content can be reduced by 30 percent.

Hence, the reduced water content = 202 × 0.70

= **141.4 kg/m3 ≈ 141 kg/m3**

Calculation Of Cement Content

Water–cement ratio = 0.29

Water content = 141 kg/m3

Cement content = 141 / 0.29

= **486.2 ≈ 486 kg/m3**

It is proposed to add 15 percent fly ash in the mix, in such situations increase in cementitious material content may be warranted. The decision on increase in cementitious material content and its percentage may be based on experience and trial.

NOTE — This illustrative example is with an increase of 10 percent cementitious material content.

The cementitious material content = 486 × 1.10 = **534.6** ≈ **535 kg/m3**

Fly ash @ 15 percent by weight of cementitious material = 535 × 15 percent = 80.25 kg/m3

Silica fume content @ 5 percent by weight of revised cementitious material

= 535 × 5 percent = 26.75 kg/m3

Cement content = 535 – 26.75 – 80.25 = 428 kg/m3

Revised w/cm =141/535= 0.264

Check for minimum cementitious materials content,

320 kg/m3 < 535 kg/m3 (428 kg/m3 OPC + 26.75 kg/m3 silica fume + 80.25 kg/m3 fly ash) Hence OK

Check for maximum cement(OPC) content, 450 kg/m3 > 428 kg/m3. Hence OK.

Table 9 Recommended Dosages of Mineral Admixtures Materials for High Strength Mixes

(*Clause* 6.2.6)

Sl No.	Mineral Admixtures	Recommended Dosages, Percentage by Mass of Total Cementitious Materials
(1)	(2)	(3)
i)	Fly ash	15 - 30
ii)	Ground granulated blast furnace slag	25 - 50
iii)	Metakaoline	5 - 15
iv)	Silica fume	5 - 10

Proportion Of Volume Of Coarse Aggregate And Fine Aggregate Content

From Table 10, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate grading Zone II = 0.66 per unit volume of total aggregate. This is valid for water-cementitious materials ratio of 0.30. As water-cementitious material ratio is actually 0.264, the ratio is taken as 0.667.

Volume of fine aggregate content = 1 – 0.667 = 0.333 per unit volume of total aggregate

Table 10 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate for Water-Cement/Water-Cementitious Material Ratio of 0.30

(*Clause* 6.2.7)

Sl No.	Nominal Maximum Size of Aggregate mm	Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate		
		Zone III	Zone II	Zone I
(1)	(2)	(3)	(4)	(5)
i)	10.0	0.56	0.54	0.52
ii)	12.5	0.58	0.56	0.54
iii)	20.0	0.68	0.66	0.64

NOTES

1 Volumes are based on aggregates in saturated surface dry condition.

2 These volumes are for crushed (angular) coarse aggregate and suitable adjustments may be made for other shape of aggregate.

3 Suitable adjustments may also be made for fine aggregate from other than natural sources, normally, crushed sand or mixed sand having higher fine content (passing 150 micron sieve), which may need lesser fine aggregate content. In that case, the coarse aggregate volume may be suitably increased.

Mix Calculations

a) Total volume = 1 m3

b) Volume of entrapped air = 0.005 m3

in wet concrete

c) Volume of cement

$$= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1\,000}$$

$$= \frac{428}{3.15} \times \frac{1}{1\,000}$$

$= \mathbf{0.136\ m^3}$

d) Volume of water

$$= \frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1\,000}$$

$$= \frac{141}{1} \times \frac{1}{1\,000}$$

$= \mathbf{0.141\ m^3}$

e) Volume of silica fume

$$= \frac{\text{Mass of silica fume}}{\text{Specific gravity of silica fume}} \times \frac{1}{1\,000}$$

$$= \frac{26.75}{2.2} \times \frac{1}{1\,000}$$

$= \mathbf{0.012\ 2\ m^3}$

f) Volume of fly ash

$$= \frac{\text{Mass of fly ash}}{\text{Specific gravity of fly ash}} \times \frac{1}{1\,000}$$

$$= \frac{80.25}{2.2} \times \frac{1}{1\,000}$$

$= \mathbf{0.036\ 5\ m^3}$

g) Volume of chemical admixture (superplasticizer) (@ 0.5 percent by mass of cementitious material)

= Mass of chemical admixture x1

Specific gravity of admixturex 1 000

= (535 x 0.5%) /1,08 x (1/1000)

= 0.002 5 m3

h) Volume of all in aggregate

= [(a-b)-(c+d+e+ f+g)]

= [(1-0.005) – (0.136 + 0.141 + 0.012 2 + 0.036 5 + 0.002 5)]

= 0.66 7 m3

j) Mass of coarse aggregate = h × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1 000

= 0.667 × 0.667 × 2.74 × 1 000

= **1 218.9 kg** ≈ **1 219 kg**

k) Mass of fine aggregate

= *h* × volume of fine aggregate × Specific gravity of fine aggregate × 1 000

= 0.667 × 0.333 × 2.65 × 1 000

= **588.59 kg** ≈ **589 kg**

Mix Proportions For Trial Number 1 On Aggregate In Ssd Condition

Cement = 428 kg/m3
Fly ash = 80.25 kg
Silica fume = 26.75kg/m3
Water = 141 kg/m3
Fine aggregate = 589 kg/m3
Coarse aggregate = 1 219 kg/m3
Chemical admixture = 2.67 kg/m3
w/cm = 0.264

NOTE — Aggregates shall be used in saturated surface dry condition. If otherwise, when computing the requirement of mixing water, allowance shall be made for the free (surface) moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregates are dry, the amount of mixing water shall be increased by an amount equal to the moisture likely to be absorbed by the aggregates. Necessary adjustments are also required to be made in mass of aggregates. The surface water and percent water absorption of aggregates shall be determined according to IS 2386 (Part 3).
The total mass of coarse aggregate shall be divided into two fractions of 20 - 10 mm and 10 - 4.75 mm, in a suitable ratio, to satisfy the overall grading requirements for 20 mm max size aggregate as per Table 7 of IS 383. In this example, the ratio works out to be 50:50.
The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required.
The mix proportions shall be reworked for the actual water content and checked for durability requirements.
Two more trials having variation of ±10 percent of water-cementitious materials ratio shall be carried out and a graph between these water cementitious materials ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

ERNTROY AND SHACKLOCK'S METHOD FOR HIGH-STRENGTH CONCRETE

The range of the degrees of workability varying from extremely low to high corresponds to the compacting factor values of 0.65 and 0.95 respectively. Concrete hardens by the hydration reaction between the cement and the water in the mix. If there is no water, then the concrete will not harden. In fact, if the relative humidity drops below around 70 %, then the hydration will cease, and the hardening will cease.
For water/cement ratio below 0.4 the use of angular aggregate gives 38% higher strength than rounded aggregate. With an increase in water/cement ratio the influence of roughness of surface of the aggregate gets reduced, presumably because the strength of the paste itself becomes paramount, and at a water/cement ratio of 0.65, no difference in strength of concrete made with angular or rounded aggregate has been observed.
Strength of concrete is function mainly of the cement content of the mix and its water cement ratio. At water cement ratio of 0.38 complete hydration of cement takes place. And, should deliver concrete at its optimum strength and unit weight. As a rule of thumb each 1% increase in quantity of water added, reduces the strength of concrete by 5%.

Erntroy and Shacklock's Empirical Graphs: Erntroy and Shacklock have suggested empirical graphs relating the compressive strength to an arbitrary 'reference number' for concrete made with crushed granite, coarse aggregates and irregular gravel. These graphs are shown in figure 1 and 2 for mixes with ordinary Portland cement and in figure 3 and 4 for mixes with rapid hardening Portland cement. The relation between water cement ratio and the reference number for 20mm and 10mm maximum size aggregates is shown in figure 5, in which four different degrees of workability are considered. The range of the degrees of workability varying from extremely low to high corresponds to the compacting factor values of 0.65 and 0.95 respectively The relation between the aggregate-cement and water-cement ratios, to achieve the desired degree of workability with a given type and maximum size of aggregate are compiled in table-1 and 2 for two different types of cements. The limitations of these design tables being that they were obtained with aggregates containing 30 percent of the material passing the 4.75 mm IS sieve. Thus, if other ingredients are used suitable adjustments have to be made. Aggregates available at site may be suitably combined by the graphical method to satisfy the above requirement. In view of the considerable variations in the properties of aggregates, it is generally recommended that trial mixes must first be made and suitable adjustments in grading and mix proportions effected to achieve the desired results.

Table – 1: Aggregate cement ratio (by weight) required to give four degrees of workability with different water –cement ratios using ordinary Portland cement.

*Type of coarse aggregate**	*Irregular gravel*								*Crushed granite*							
Maximum size of aggregate	*20 mm*				*10 mm*				*20 mm*				*10mm*			
*Degree of workability ***	*EL*	*VL*	*L*	*M*	*EL*	*VL*	*L*	*M*	*EL*	*VL*	*L*	*M*	*EL*	*VL*	*L*	*M*
Water / cement ratio by weight																
0.30	3.0	–	–	–	2.4	–	–	–	3.3	–	–	–	2.9	–	–	–
0.32	3.8	2.5	–	–	3.2	–	–	–	4.0	2.6	–	–	3.6	2.3	–	–
0.34	4.5	3.0	2.5	–	3.9	2.6	–	–	4.6	3.2	2.6	–	4.2	2.8	2.3	–
0.36	5.2	3.5	3.0	2.5	4.6	3.1	2.6	–	5.2	3.6	3.1	2.6	4.7	3.2	2.7	2.3
0.38	–	4.0	3.4	2.9	5.2	3.5	3.0	2.5	–	4.1	3.5	2.9	5.2	3.6	3.0	2.6
0.40	–	4.4	3.8	3.2	–	3.9	3.3	2.7	–	4.5	3.8	3.2	–	4.0	3.3	2.9
0.42	–	4.9	4.1	3.5	–	4.3	3.6	3.0	–	4.9	4.2	3.5	–	4.4	3.6	3.1
0.44	–	5.3	4.5	3.8	–	4.7	3.9	3.3	–	5.3	4.5	3.7	–	4.8	3.9	3.3
0.46	–	–	4.8	4.0	–	5.1	4.2	3.6	–	–	4.8	4.0	–	5.1	4.2	3.6
0.48	–	–	5.2	4.4	–	5.4	4.5	3.8	–	–	5.1	4.2	–	5.5	4.5	3.8
0.50	–	–	5.5	4.7	–	–	4.8	4.0	–	–	5.4	4.5	–	–	4.7	4.0

*Natural sand used in combination with both types of coarse aggregate
**EL = extremely low
VL = very low
L = low
M = medium

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Table – 2: Aggregate cement ratio (by weight) required to give four degrees of workability with different water –cement ratios using rapid hardening cement

*Type of coarse aggregate**	*Irregular gravel*								*Crushed granite*							
Maximum size of aggregate	*20 mm*				*10 mm*				*20 mm*				*10mm*			
*Degree of workability ***	*EL*	*VL*	*L*	*M*	*EL*	*VL*	*L*	*M*	*EL*	*VL*	*L*	*M*	*EL*	*VL*	*L*	*M*
Water/cement ratio by weight																
0.32	2.6	–	–	–	–	–	–	–	2.9	–	–	–	3.5	–	–	–
0.34	3.4	2.2	–	–	2.8	–	–	–	3.6	2.4	–	–	2.2	–	–	–
0.36	4.1	2.7	2.3	–	3.5	2.4	–	–	4.3	2.9	2.4	–	3.9	2.5	–	–
0.38	4.8	3.2	2.8	2.3	4.2	2.9	2.4	–	4.9	3.4	2.9	2.4	4.5	3.0	2.5	–
0.40	5.5	3.7	3.2	2.7	4.9	3.3	2.8	2.3	5.5	3.9	3.3	2.7	5.0	3.4	2.9	2.4
0.42	–	4.2	3.6	3.0	–	3.7	3.0	2.6	–	4.2	3.6	3.0	5.5	3.8	3.2	2.7
0.44	–	4.6	4.0	3.4	–	4.1	3.5	2.9	–	4.7	4.0	3.3	–	4.2	3.5	3.0
0.46	–	5.0	4.3	3.7	–	4.5	3.8	3.2	–	5.1	4.3	3.6	–	4.6	3.8	3.2
0.48	–	5.5	4.7	4.0	–	4.9	4.1	3.5	–	5.5	4.6	3.9	–	5.0	4.1	3.4
0.50	–	–	5.0	4.3	–	5.2	4.4	3.7	–	–	4.9	4.1	–	5.3	4.4	3.7

*Natural sand used in combination with both types of coarse aggregate
**EL = extremely low
VL = very low
L = low
M = medium

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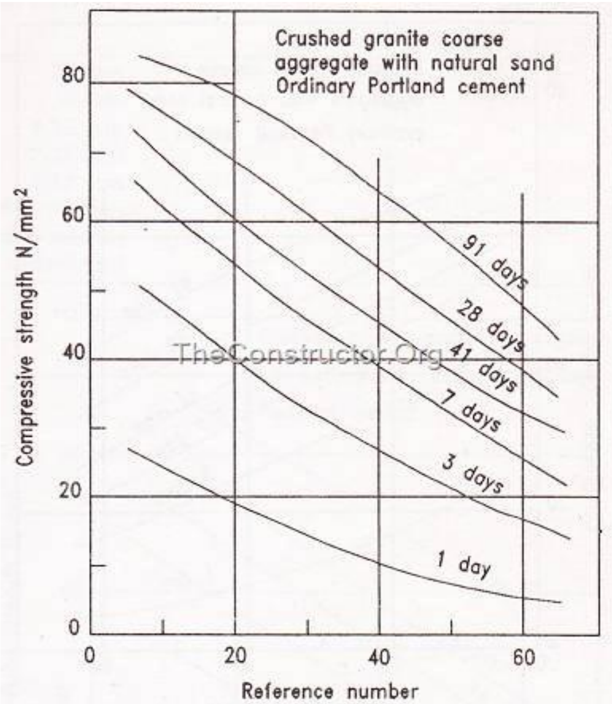
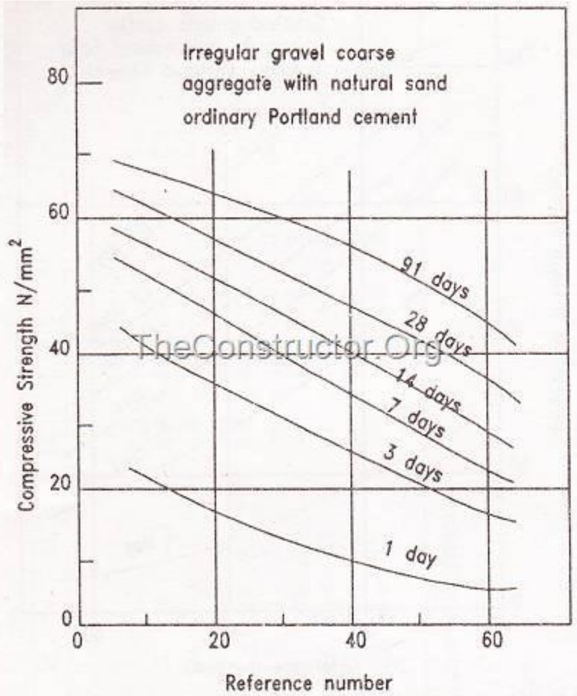
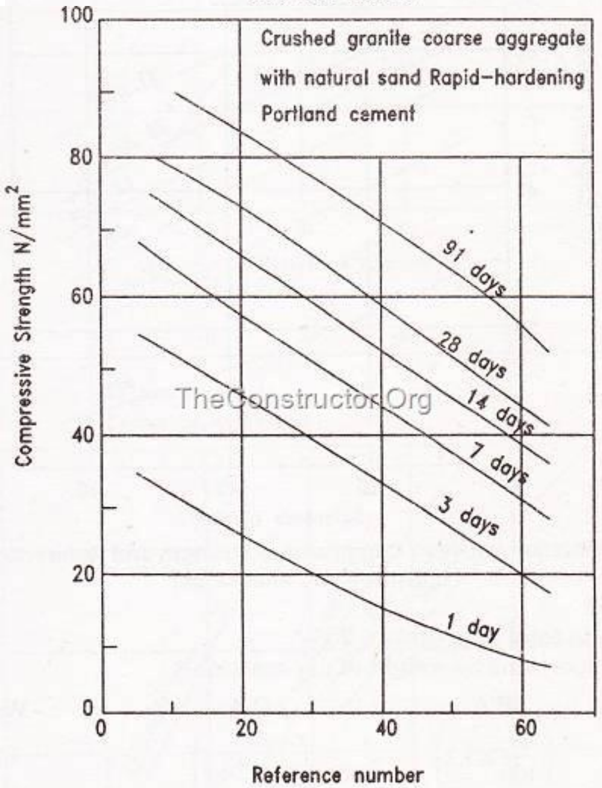
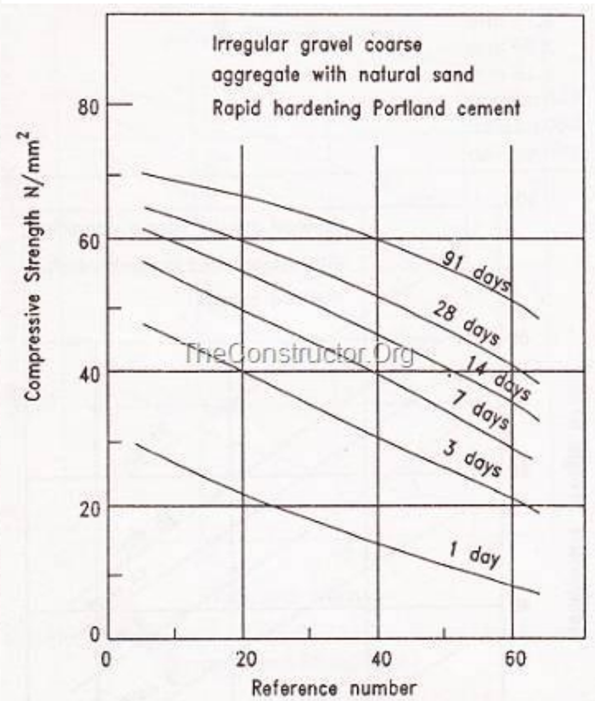
Mix Design of High Strength Concrete -Procedure

1. The mean design strength is obtained by applying suitable control factors to the specified minimum strength.
2. For a given type of cement and aggregates used, the reference number corresponding to the design strength at a particular age is interpolated from figure 1 to 4.
3. The water-cement ratio to achieve the required workability and corresponding to the reference number is obtained from figure 5 for aggregates with maximum sizes of 20mm and 10mm.
4. The aggregate-cement ratio to give the desired workability with the known water cement is obtained by absolute volume method.
5. Batch quantities are worked out after adjustments for moisture content in the aggregates.


Crushed granite coarse aggregate with natural sand Ordinary Portland cement
Compressive strength N/mm^2
Reference number
0
20
40
60
80
91 days
28 days
41 days
7 days
3 days
1 day


Irregular gravel coarse aggregate with natural sand ordinary Portland cement
Compressive Strength N/mm^2
Reference number
0
20
40
60
80
91 days
28 days
14 days
7 days
3 days
1 day


Crushed granite coarse aggregate with natural sand Rapid-hardening Portland cement
Compressive Strength N/mm^2
Reference number
0
20
40
60
80
100
91 days
28 days
14 days
7 days
3 days
1 day


Irregular gravel coarse aggregate with natural sand Rapid hardening Portland cement
Compressive Strength N/mm^2
Reference number
0
20
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91 days
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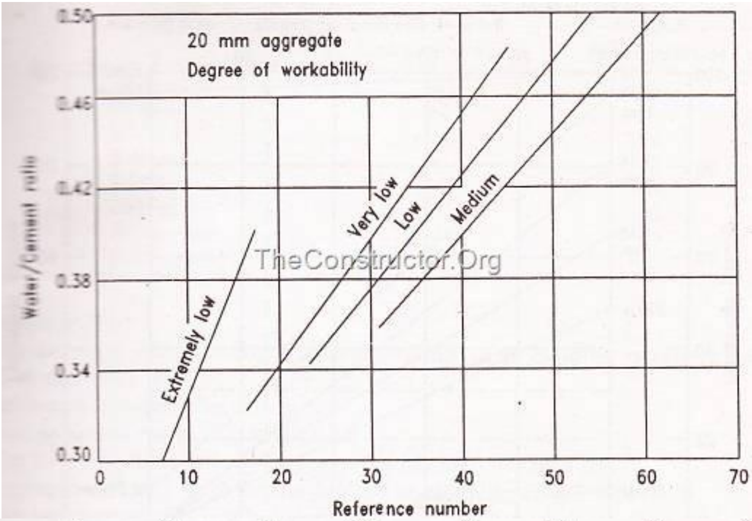
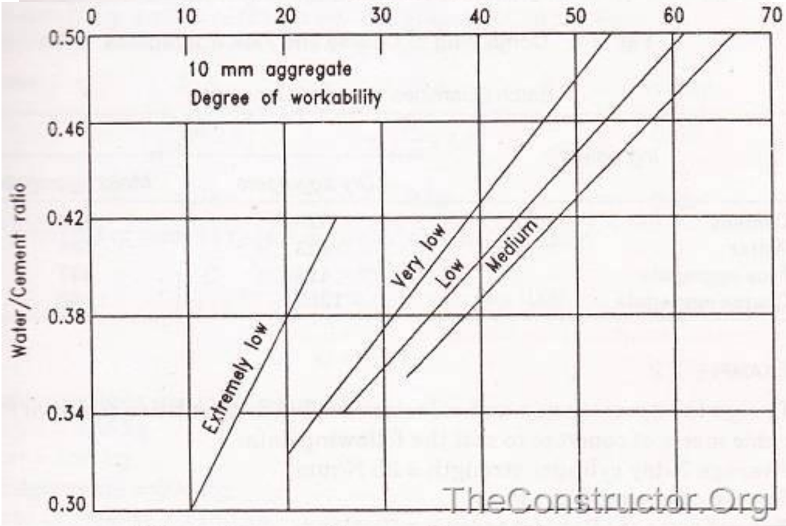
3 days
1 day





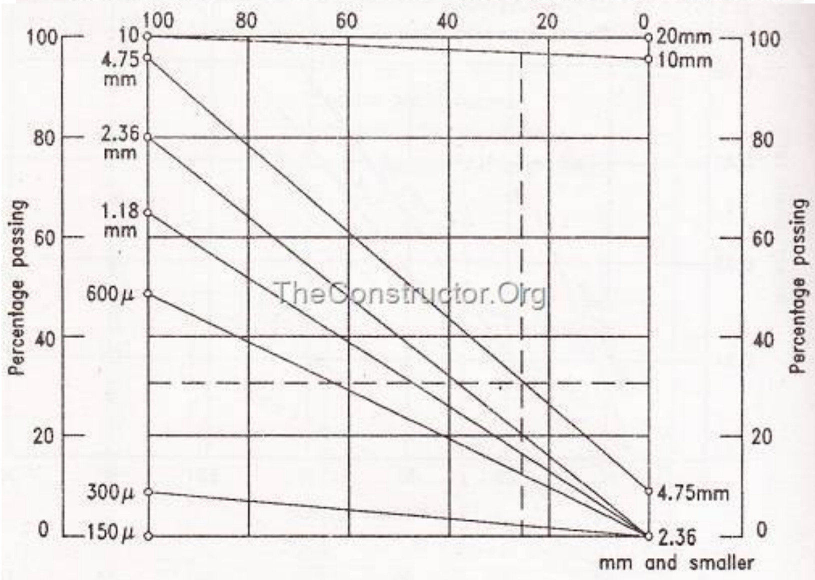


Fig.1: Relation between compressive strength and reference number (Erntroy and Shacklock)

Fig-2: between compressive strength and reference number (Erntroy and Shacklock)

Fig-3: Relation between compressive strength and reference number (Erntroy and Shacklock)

Fig-4: Relation between compressive strength and reference number (Erntroy and Shacklock)

Fig-5: Relation between water-cement ratio and Reference Number
Fig-6: Combining of Fine aggregates and Coarse aggregates

Table – 3: Batch Quantities per cubic metre of concrete

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Ingredient	*kg*	
	Dry aggregate	*Moist aggregate*
Cement	520	520
Water	182	148
Fine aggregate	416	437
Coarse aggregate	1250	1263

Viva Questions

What is compressive strength and characteristic compressive strength?

Compressive strength: The applied pressure at which a given concrete sample fails. Characteristic strength: Suppose you take a certain number of samples from a particular batch of concrete. Characteristic strength would be that compressive strength below which not more 5% of the samples are expected to fall.

Thus, while compressive strength gives us the strength of a single sample, characteristic strength would give us the probable strength based on a number of samples, which would be a more realistic assessment. It takes into account the variations due to improper mixing and distribution of the constituents of concrete. The units used to express both the parameters are the same.

What is the need for accelerated curing ?

Normally, the strength of concrete is found out after 7 days and 28 days. For some construction activities, it may be too late and need to know the strength earlier. The accelerated curing test is a method of curing concrete specimens to attain its ultimate strength quickly. So, we can know the 28 days of compressive strength of concrete within a 29 hrs. Most of the time, knowing the concrete strength earlier helps avoid dangerous accidents and saves a life. This Accelerated curing method is mostly used in the precast construction industry, where the formwork needs to be removed at the earliest for productivity. Accelerated curing is useful in the prefabrication industry wherein high early age strength enables the removal of the formwork within 24 hours thereby reducing the cycle time resulting in cost saving benefits.

How to achieve accelerated strength using boiling water method?

The 28 days can be found out using following formula.

Predicted 28 days compressive strength (R28) = 8.09 + 1.64 Ra

where Ra is accelerated compressive strength and R28 is predicted compressive strength at 28 days. The 8.09 is a constant value derived by correlating the test results of normal and accelerated concrete curing methods.

What is curing?

Curing of cement concrete is defined as the process of maintaining the moisture and temperature conditions of concrete for hydration reaction so that concrete develops hardened properties over time. The main components which need to be taken care of are moisture, heat, and time during the curing process.

How will the shape and size of aggregate affect the strength of a concrete?

The shapes of the coarse aggregate affect the strength of the concrete indirectly. If flaky or angular coarse aggregate is used, it will adversely affect workability. Poor workability means poor placement of concrete. Poor placement means that some weak spots or honeycombs or voids may be left in the concrete mass thus affecting adversely its strength. The size of the coarse aggregates in concrete if bigger than the spacing of the reinforcement will cause voids thus adversely affecting the strength. The texture of the coarse aggregate , if rough, will. increase its strength. If the texture is smooth, it will adversely affect the strength.

Why should flaky and elongated aggregates not be used in concrete?

Flaky particles crack easily which can lead to weak concrete, while elongated particles result in increased friction between the particles hence reduced workability of concrete. To overcome this reduced workability, water/cement ratio has to be increased which results in weak concrete. Hence, both flaky and elongated particles result in weak concrete as compared to concrete made from cubical aggregates. Therefore specifications limit the percentage of flaky and elongated particles which can be allowed in concrete aggregate. Generally, the limit for flaky or elongated particles is 10–15% of coarse aggregate to get good quality concrete.

Differentiate Between Nominal Mix and Design Mix

The nominal mix is site-level mixing small concrete mixer can be used to mix the ingredients. Whereas the design mix is designed from ready mix concrete plant that is RMC plant. There are many grade of nominal mix concrete like M-5, M-7.5, M-10, M-15 and M-20. Design mix – Design mix is a process to prepare concrete by testing all necessary properties (like properties of cement, fine aggregate and coarse aggregate) of concrete ingredients. The nominal mix is the process in which all the ingredients are prescribed as per specifications and their proportions are specified in the ratio of cement to aggregates for the certain strength achievement. Concrete mix design involves a process of preparation in which a mix of ingredients creates the required strength and durability for the concrete structure. Because every ingredient in the mix consists of different properties, it’s not an easy task to create a great concrete mix. Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. Design mix is a process to prepare concrete by testing all necessary properties (like properties of cement, fine aggregate and coarse aggregate) of concrete ingredients. Ingredients of concrete are mixed on the basis of weight. It is generally designed from ready Mix Concrete (RMC) plant .

Experiment No: 3

CORRELATION BETWEEN CUBE AND CYLINDER OF HIGH STRENGTH CONCRETE

Objective

To determine the compressive strength of the concrete cube or cylinder

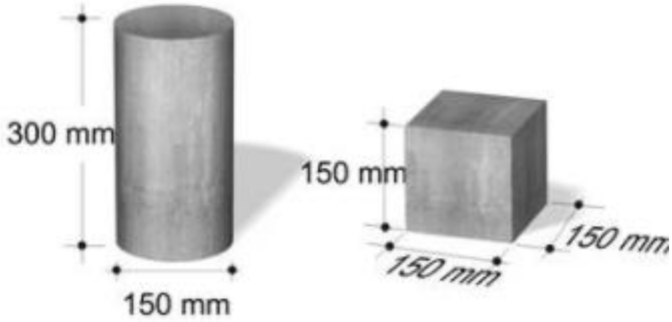
Apparatus and Materials

Cubes of size 15cm or 10cm and cylinders of 10cm ϕ x 20cm length or 15cm ϕ x 30cm length.

Cube or cylinder Test of Concrete as per IS Code IS 516 (1959): Method of Tests for Strength of Concrete and IS 456 2000: Concrete Strength Acceptance Criteria

Theory

The compressive strength of concrete can be calculated by dividing the load applied on the concrete cube at the point of failure by the cross-section area of the cube (15x15x15 cm) on which load was applied. The concrete compressive strength for normal construction work varies from 15 MPa to 30 MPa and more in commercial and industrial structures. The strength of concrete depends on factors such as water-cement ratio, the strength of cement use, quality of concrete materials, quality control during production of concrete, etc. For cube test of concrete two types of specimens either cubes of 15cm or 10cm depending upon the size of aggregate is used for concrete making and for cylinder test, the specimens of 10cm ϕ x 20cm length or 15cm ϕ x 30cm length . For most of the concrete works cubical moulds of size, 15cm x 15cm x 15cm are commonly used.



Procedure

1. Mix the concrete either by hand or in a laboratory batch mixer
2. Clean the mounds and apply oil. Fill the concrete in the moulds in layers approximately 5 cm thick. Compact each layer with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet-pointed at lower end). Level the top surface and smoothen it with a trowel.
3. After 24 hours these moulds are opened and test specimens are soaked in water for curing. The water for curing should be tested every 7 days and the temperature of the water must be at 27±2^{o}C.
4. Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
5. The upper surface of these specimen should be made even and smooth. This is done by spreading cement paste on the whole area of the specimen or place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
6. These cubes are tested by a compression testing machine after 7 days curing or 28 days curing.
7. The load on the cube should be applied gradually at the rate of 140 kg/cm2 per minute till the specimen fails.
8. Load at the failure of a cube divided by area of specimen gives the compressive strength of concrete.
9. Minimum three specimens should be tested at each selected age. If the strength of any specimen varies by more than 15 percent of average strength, the results of such specimens should be rejected. The average of three specimens gives the crushing strength of concrete.

Observations and Calculations

1. Identification mark=
2. Date of test=
3. Age of specimen=
4. Curing conditions, including date of manufacture of specimen=
5. Appearance of fractured faces of concrete and the type of fracture if they are unusual

Compressive Strength = Load at failure / Cross-sectional Area of specimen exposed to loading

S.No.	Size of the specimen	Area of the specimen	Age of the specimen	Maximum load applied (N)	Compressive Strength MPa
1					
2					
3					

Result

Average compressive strength of the concrete cube = ...N/ mm2 (at 7 days)

Average compressive strength of the concrete cube =.............. N/mm2 (at 28 days)

Inference

Viva Questions

What is compressive strength of concrete?
Compressive strength of Concrete can be defined as the ability of material or structure to carry the loads on it without any crack or deflection. A material under compressive load tends to reduce the size, while in tension, size elongates.

Why compressive strength test of concrete is important?
The compressive strength of the concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

What is compressive strength after 7 days and 14 days?
Compressive strength achieved by concrete at 7 days is about 65% and at 14 days is about 90% of the target strength.

Which test is most suitable for concrete strength?
A concrete cube test or concrete cylinder test is generally carried out to assess the strength of concrete after 7 days, 14 days or 28 days of casting.

What is the size of concrete cubes used for testing?
For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical molds of size 15cm x 15cm x 15cm are commonly used.

What is the rate of loading on compression testing machine?
Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails.

Why do we test concrete compressive strength after 28 days?
Concrete gains strength with time after casting. It takes much time for concrete to gain 100% strength and the time for same is still unknown. The rate of gain of concrete compressive strength in higher during the first 28 days of casting and then it slows down. Concrete gains 16 percent strength in one day, 40 percent in 3 days, 65% in 7 days, 90% in 14 days and 99% strength in 28 days. Thus, it is clear that concrete gains its strength rapidly in the initial days after casting, i.e. 90% in only 14 days. When, its strength have reached 99% in 28 days, still concrete continues to gain strength after that period, but that rate of gain in compressive strength is very less compared to that in 28 days.
After 14 days of casting concrete, concrete gains only 9% in next 14 days. So, rate of gain of strength decreases. We have no clear idea upto when the concrete gains the strength, 1 year or 2 year, but it is assumed that concrete may gain its final strength after 1 year. So, since the concrete strength is 99% at 28 days, it's almost close to its final strength, thus we rely upon the results of compressive strength test after 28 days and use this strength as the base for our design and evaluation. Though there are also some rapid method of testing concrete compressive strength which gives relation between rapid test methods and 28 day strength. This rapid test is done where time is limited for construction and strength of structural member must be known to carry out further construction work.

What is concrete mix design mean?
Mix design is a process of selecting suitable ingredients and determining their relative proportions with the objective of producing concrete of having certain minimum workability, strength and durability as economically as possible.

What is the difference between nominal mix and design mix concrete?
Nominal Mix- It is used for relatively unimportant and simpler concrete works. In this type of mix, all the ingredients are prescribed and their proportions are specified. Therefore, there is no scope for any deviation by the designer. Nominal mix concrete may be used for concrete of M-20 or lower.
Design Mix- It is a performance-based mix where choice of ingredients and proportioning are left to the designer to be decided. The user has to specify only the requirements of concrete in fresh as well as hardened state. The requirements in fresh concrete are workability and finishing characteristics, whereas in hardened concrete these are mainly the compressive strength and durability.

Why do we use sulfur compound in capping cylindrical concrete specimen?
Capping concrete cylinders and grout prisms with sulfur mortar helps to give them a plane, level surface, so that force is applied evenly to the entire end surface when the specimen is broken during the ASTM C39 procedure to test compressive strength.

Why are concrete cylinders capped?
Capping is the preparation of the ends of cylindrical concrete specimens to ensure that a test cylinder or core has smooth, parallel, uniform bearing surfaces that are perpendicular to the applied axial load during compressive strength testing.

Which strength is more cube or cylinder?
Cube compressive strength is approximately 15 % more than the cylinder compressive strength.

What is the effect of L D ratio on compressive strength?
The results obtained from these investigations have indicated that compressive strength decreases with an increase in L:D. ratio; however, it remains constant after the ratio reaches a certain value of 3

What is the recommended L D ratio for core test?
When taking core from concrete structures, sometimes the ratio of length to diameter [L/D] of cores for strength testing are shorter than 2.00. If the L/D of the specimen is less than 2.00, the strength correction factor should be used to estimate the compressive strength of concrete cores.

Name the methods for capping the cylindrical concrete test specimen.
1. Neat cement capping
2. Sulphur capping
3. Gypsum plaster capping
4. Cement mortar capping

What is SSD condition in concrete mix design?
SATURATED SURFACE DRY (SSD) - Saturated surface-dry is the condition of an absorptive material where the material is saturated but its surface is dry. Saturated surface dry aggregate neither absorbs water from or contributes water to the concrete mixture.

What is the difference between cube and cylinder strength?
The ratio between cylinder and cube strength is typically taken equal to 0.8 at lower to medium grades, and increasing up to 0.87 for cylinder strength of 90 MPa. There is a 20 to 30 % strength difference between cube and cylinder cast from the same concrete batch.

What is platen effect?
During compression tests, the contact between metal end platens and the concrete specimen creates a frictional resistance at the ends of the specimen (platen restraint), which affects the stress–strain behavior of concrete.

What happens to strength of concrete as sample size increases?
Generally, concrete compressive strength decreases with an increasing specimen section size. Meanwhile, a decreasing rate remains almost constant beyond a certain size limit.

Why a concrete cube is not tested when wet?
Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fins removed. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing
Remove the specimens from the water just before the testing and wiped off the surface water and grit from the specimens. Don't let dry it, cube test is conducted in wet condition of specimens. The cube specimens shall not be allowed to become dry at any time until they have been taken out and tested.
A wet specimen does not test higher in a compression test, but it does in a flexural test. Drying the specimen just before the test is performed will slightly increase the strength in compression and markedly decrease the strength in flexure. Partial or surface drying of specimens for flexural tests places the outer fibers in a state of tension even before the load is applied, thereby reducing the measured strength.

Why compressive test on cubes is not done on the casting side, and rather can be done on all remaining side?

Actually what happens when we cast cube samples, it's top surface is finished manually, whereas all the remaining surfaces are levelled by itself because of mould faces and tamping by tamping rod, so this top surface may have some undulations(You may observe this on the sample). So when you put this manually finished face of cube on top or bottom in CTM, the upper or lower plate may not fit properly and the contact area between cube sample and plates will be changed and the value which we will calculate will not be accurate.

What happens if we test a wet cube in a compressive strength testing machine? What will be the result compared to a dry cube?
The sample should not be completely dry at the time of test. They should be tested by drying only the surface. Fully dried cube exhibits strength up to 80 percent.

What is platen effect when test specimen is subjected to compression?
Due to lateral expansion of the specimen when subjected to compression, there is a restraining force acting in opposite direction to the tensile force. This is known to be called platen effect. The amount of restraint the specimen can achieve is a function of its modulus of elasticity and strength of concrete. More is the modulus of elasticity more capable the specimen to restrain lateral expansion. Because concrete is weak in tension it ensures that the

specimen is capable of taking in more load. Thus good capping material and higher modulus of elasticity ensures good compressive strength results. That is why compressive strength of cylinder is less than that of cube.

Why concrete cube is kept in wet conditions for 24 hours prior to conduct compressive strength tests on the 28th day?

First, slump test is conducted on the fresh concrete mixture to determine the flowability and rheological characteristics. Then, standard samples are fabricated for mechanical (compressive) examinations. The fabricated standard cube samples must be stored in standard conditions of temperature (in the range of 22–33 °C, usually at 27 °C), ambient pressure and wet. Then, the cubes are examined on days 7, 14, and 28 to get information about the progress of hydration process. Because the cubes are tested on days 7 and 14 while the concrete is still experiencing hydration reaction, they are obviously wet. To keep all environmental conditions identical, the examinations on day 28 must also be performed on the wet cube samples. Moreover, concrete is a material with porous microstructure. If during hydration process the samples become dry, there is a chance of growth of some microcracks in the cured concrete from the pores and getting wrong results. Therefore, for the sack of consistency and to be comparable with the results obtained from examination of cube samples on days 7 and 14, we perform the examination on day 28 on wet conditions.

Why do we prefer concrete cubes to cylinders (in India) for the compressive strength test?

Cubes are ease to cast. Cylinders need capping.

All the Indian Standard design codes are based on cube strength of concrete. IS codes are based on British codes OS 456:2000 mandates usage of 1.5 as factor of safety for concrete where as American codes mandate use of 1.2 as Factor of safety for concrete as it uses cylinder for determining strength. The net effect is same. It is advisable to use cylinder for better repeatibility due to uniform stresses during compression but in india practice of using cubes prevails as these are easier to cast and can be stacked in random manner for curing which is difficult with cylinders

Why we don't use a 100mm cube for low strength concrete (below M50) for a compressive strength test?

Well it's all about the surface area, accuracy in determining the compressive strength and the limit of the compression testing machine to determine the compressive strength of the concrete cubes. Any compression testing machine has a limit of weight that it can exert on the concrete cube. Now, when we use a 100mm concrete cube it will have lesser surface area so lesser amount of load will be required to break the cube for the same compressive strength of concrete. However, when we use the 150mm concrete cube then in that case, the surface area is more hence more weight has to be applied to the concrete cube to get the required similar compressive strength. But, since the compression testing machine has a limit of putting greater weight so for all cubes greater than M50 we use 100mm cubes since for a lesser area and a lesser load we can get the same compressive strength which otherwise can't be obtained using a 150mm cube. Even if 100mm cube is cheaper, it is generally not preferred due to the only reason that, we need a greater accuracy while finding out the compressive strength. Obviously, the greater is the surface area of the cube the greater is the accuracy of getting the required compressive strength.

Notes

Experiment No.: 4

SPLIT TENSILE STRENGTH OF HIGH STRENGTH CONCRETE

Objective

To determine the splitting tensile strength of given concrete.

Apparatus and materials

1. Testing machine
2. Bearing strips
3. Plate or supplementary bearing bar
4. Cylindrical concrete specimen having diameter 150 mm and length 300mm conforming to IS 10086-1982

Reference Code

IS 5816 1999 Method of test for split tensile strength of concrete

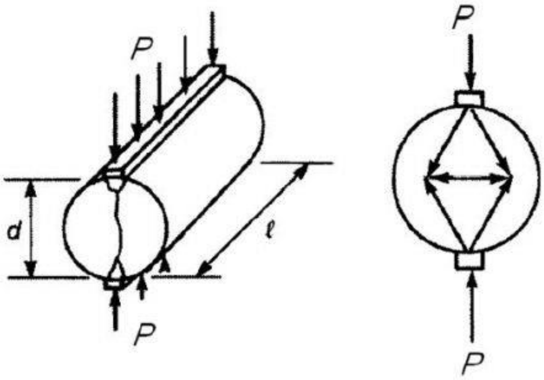
Theory

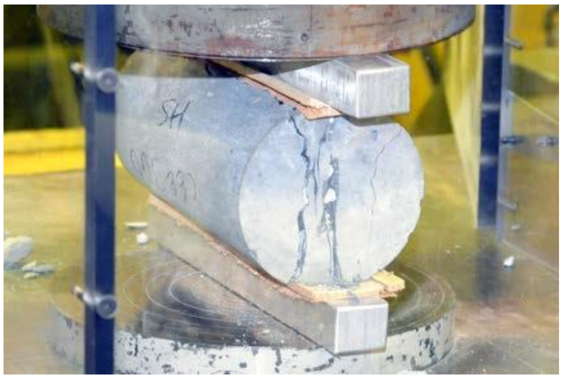
The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature. Hence. it is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The procedure based on the ASTM C496 (Standard Test Method of Cylindrical Concrete Specimen) which similar to other codes IS 5816 1999. Tensile strength of concrete is measured by split cylinder test of concrete method and it one of the major properties of concrete is especially in the case of making roads and runways. The tensile strength of concrete generally varies from 10 % to 12% of its compressive strength. For determination of compressive strength of concrete cube, samples are used and for testing tensile strength generally, cylindrical samples are cast.

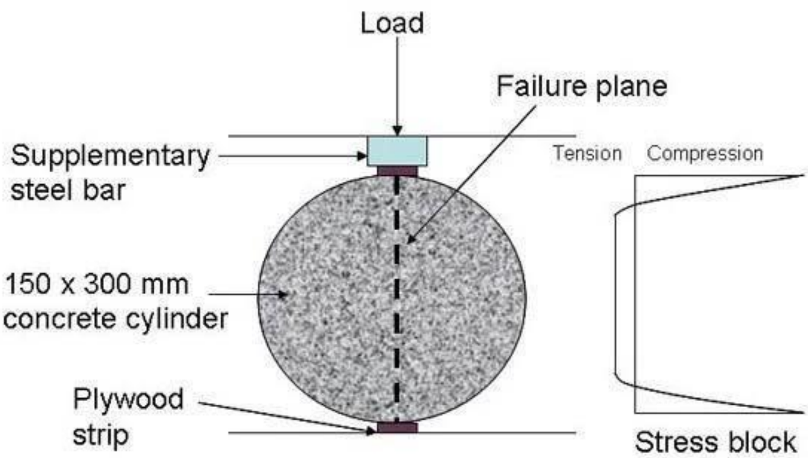
Procedure

1. Initially, take the wet specimen from water after 7, 28 days of curing; or any desired age at which tensile strength to be estimated. Then, wipe out water from the surface of specimen
2. After that, draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.
3. Next, record the weight and dimension of the specimen.
4. Set the compression testing machine for the required range.
5. Place plywood strip on the lower plate and place the specimen.
6. Align the specimen so that the lines marked on the ends are vertical and centred over the bottom plate.
7. Place the other plywood strip above the specimen.
8. Bring down the upper plate so that it just touch the plywood strip.
9. Apply the load continuously without shock at a rate within the range 0.7 to 1.4 MPa/min (1.2 to 2.4 MPa/min based on IS 5816 1999)
10. Finally, note down the breaking load (P)

11. For better results comparison at least 3 specimens should be tested.







Observations

1. Maximum applied load indicated by testing machine (P) =...................................
2. Diameter of the specimen (D) =................................
3. Length of specimen in mm (L)=............................

Calculations

1. Age of the Test=
2. Date of specimen cast=
3. The weight of the specimen=
4. Grade of the concrete=

S.No.	Diameter of the specimen D	Length of the specimen L	Age of the specimen	Maximum load applied (P) N	Compressive Strength MPa
1					
2					
3					

Splitting tensile strength in MPa=T= $\frac{2P}{\Pi LD}$

Result

Splitting tensile strength of given concrete at 7 days =……………….N/mm²
Splitting tensile strength of given concrete at 28 days =……………….N/mm²

Inference

<u>Viva Questions</u>

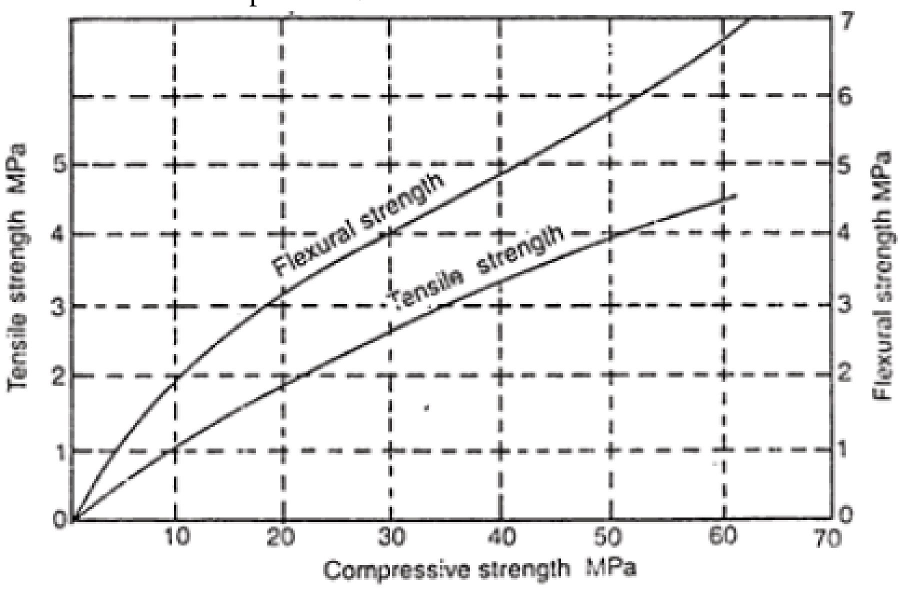
What is tensile strength of concrete?
The concrete tensile strength is the ability of concrete to resist tensile force or stress applied to it. The tensile strength of concrete is measured by the split cylinder test of concrete method. The tensile strength of concrete is measured by the Units of Force per Cross-Sectional area (N/Sq.mm. or MPa). As we know that concrete performance in compression is good, but weak in tension force. For counterbalance, this situation reinforcement has been provided in concrete to prevent crack formation.

Why Concrete Weak in Tension?
Concrete is not a single solid material like steel which is strong in both tensions as well as compression. It is manufactured by mixing cementing materials, water, and aggregate (and sometimes admixtures). The "interface transition zone" is the weakest link in the structure. When compressive stress or force is applied to the zone, aggregate transfers the load from one to another. So, concrete in compression does not require much strength to resist

compression stresses. In the case of tensile stresses developed in concrete, the aggregates are trying to pull away from each other so this interfacial transition zone has to bear tensile stresses to holds the whole system together. Since the strength of this interface zone is weaker than the aggregates, so the failure starts at much lower stresses. As per IS 456:2000, the tensile strength of concrete is given by the equation.

$$f_{cr} = 0.7 \sqrt{f_{ck}} \quad \text{in N/mm}^2$$

The tensile strength of concrete under direct tension is roughly taken as one-tenth of the strength of concrete under compression.



What are the tests available to determine the tensile strength of concrete?

For the tensile strength of concrete, we can use the following test methods

1. Uniaxial Tensile Test: This is a direct tension test in which a concrete specimen is held at the ends and pulled apart, inducing uniaxial tensile stress in it. uniaxial tensile test id one of the difficult and complicated tests to perfume on concrete but gives the true tensile strength of concrete.
2. Split Cylinder Test: In this test, a concrete cylinder is placed horizontally between loading surfaces and loaded along its diameter. This loading results in producing lateral tensile stress in the cylinder and its splits in tension along its diameter. Refer ASTM C 496 for the split cylinder test procedure.
3. Flexure Test: In this test, a concrete beam is subjected to four-point loading and loaded to rupture. The specimen cracks due to tensile stresses induced in the bottom fibers under pure bending. This gives Modulus of Rupture of Concrete. It is performed as per ASTM C78. For flexure test another test available in which load is applied by center point loading as per ASTM C 293. This test also provides flexural strength which will be slightly higher than the 4 point load test.

It is found that split tensile strength is closer to the true tensile strength of the concrete and it gives about 5 to 12% higher value than the direct tensile strength.

Experiment No: 5

MODULUS OF RUPTURE OF A CONCRETE BEAM
(As per IS:516-1959)

Objective

To determine the Flexural Strength or Modulus of rupture of Concrete

Reference Standards

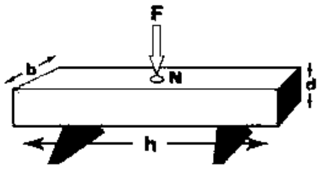
IS: 516-1959 – Methods of tests for strength of concrete

Theory

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of yield. It is measured in terms of stress. Flexural Strength of Concrete comes into play when a road slab with inadequate sub-grade support is subjected to wheel loads and / or there are volume changes due to temperature / shrinking. In order to test the flexural strength of a concrete beam, its span length should be at least three times the depth. The flexural strength is expressed as the modulus of rupture (MR) in MPa. There are two standard test methods to determine the flexural strength of a concrete beam,

1. Centre point loading test (as per ASTM C 293)

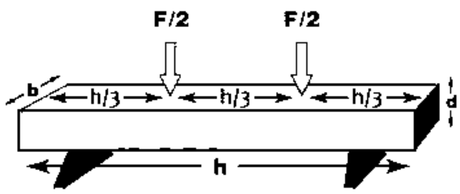
In this test method, the entire load is applied at the center of the beam's span length. Here the flexural strength or modulus of rupture is higher than the modulus of rupture of the third point loading test. The maximum stress is present only at the center of the beam.



$$\sigma = \frac{3Fh}{2b \times d^2}$$

2. Third point loading test (as per ASTM C 78)

In this test method, half the load is applied at each third of the beam's span length. Here the flexural strength or modulus of rupture is lower than that of the modulus of rupture found in the center point loading test. In this test, the maximum stress is present over the center one-third portion of the beam.

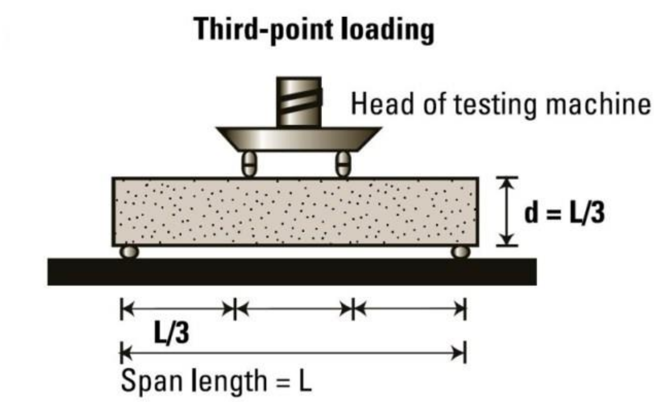


$$\sigma = \frac{Fh}{bd^2}$$

Flexural modulus of rupture is about 10% to 20% of the compressive strength depending on the type, size and volume of coarse aggregate used in a concrete beam. However, the best correlation for specific materials is obtained by laboratory tests for the given materials and mix design. The modulus of rupture determined by third point loading is lower than the modulus of rupture determined by center point loading, sometimes by as much as 15%.

Apparatus

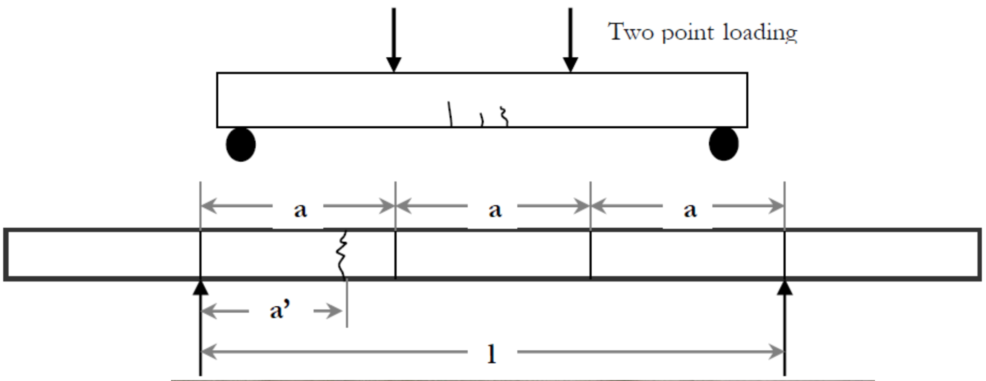
1. Beam mould of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm)
2. Tamping bar (40 cm long, weighing 2 kg and tamping section having size of 25 mm x 25 mm)
3. Flexural test machine– The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

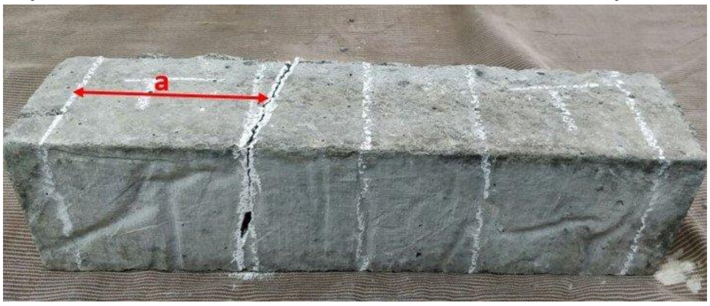


Procedure

1. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross-section of the beam mould and throughout the depth of each layer.

2. Clean the bearing surfaces of the supporting and loading rollers , and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
3. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be **3d** and the distance between the inner rollers shall be **d**. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
4. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
5. Reference lines are drawn using chalks at 5 cm from the edges of the specimen on either side to indicate the position of the roller supports
5. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.
6. The testing is done immediately after removal of the specimen from the water and while the specimens are in wet condition.





Calculation

The Flexural Strength or modulus of rupture (f_b) is given by

$f_b = pl/bd^2$

(when a > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen)

or

$f_b = 3pa/bd^2$

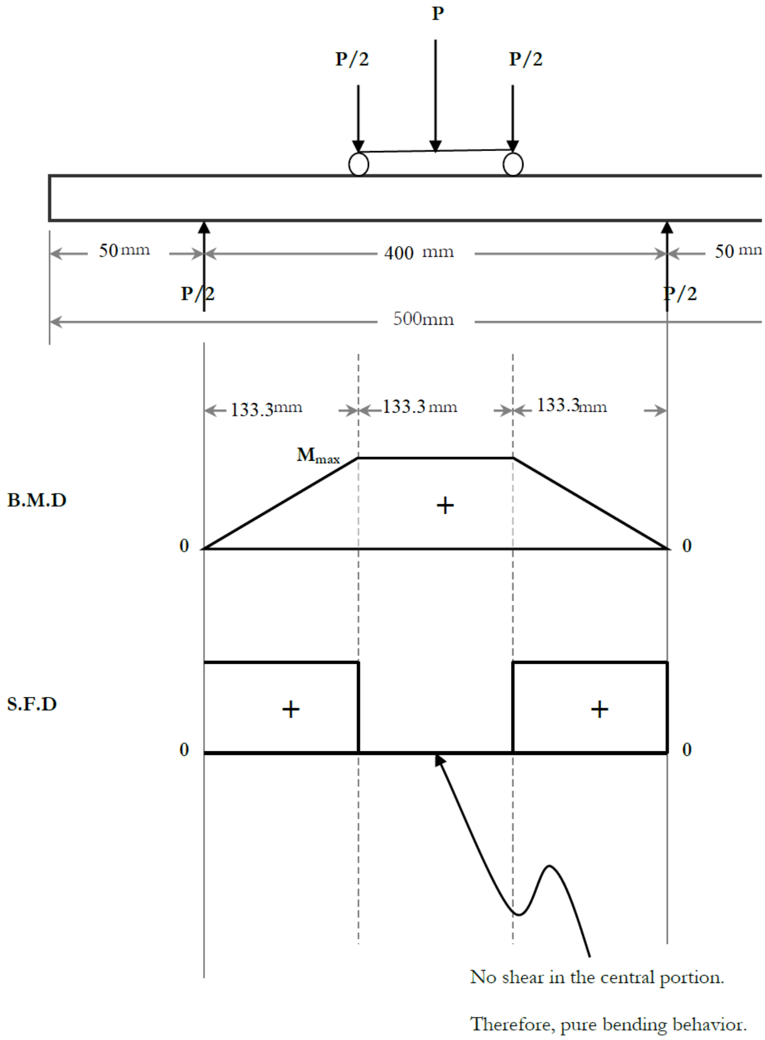
(when a < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)
l = supported length (cm)
p = max. Load (kg)



Observations

1. Ultimate load indicated by testing machine (P) =..................................
2. Average depth of specimen at the facture (d) =...............................
3. Average width of specimen at the facture (b) =...............................
4. Span Length (L) =............................

Result

Modulus of rupture given sample is MR=___________N/mm2

Inference

As per IS 456 2000, the flexural strength of the concrete can be computed by the characteristic compressive strength of the concrete
Flexural strength of concrete = $0.7\sqrt{fck}$

Viva Questions

What is Modulus of rupture?
Modulus of rupture is a measure of the tensile strength of concrete beams or slabs. Flexural strength identifies the amount of stress and force an unreinforced concrete slab, beam or other structure can withstand such that it resists any bending failures. Modulus of rupture is also known as flexural strength,bend strength or fracture strength.

What is difference between rupture and tensile strength?
There is always the possibility of some local defects being present in any object. When an object is put under tensile stress it tends to 'expand'. All the fibers or regions of an object experience an equal force. Any weak regions in such a case may give up and undergo deformation. Flexural stress, on the other hand, exerts both tensile and compressive force upon an object. This results in unequal distribution of forces among the fibers of the objects. The 'extreme fibers', i.e., the fibers at the surface of the object tend to experience maximum forces. Therefore, they are most vulnerable to breakage or rupture.

What is the importance of Modulus of Rupture?
The calculation of modulus of rupture is considered crucial in structural mechanics,
1. It helps in designing structural elements like beams, cantilevers, shafts, etc.
2. Aids in the study of materials and their properties.
3. Provides a parameter for development of stronger constructional materials.
4. Flexural strength helps in judging the quality of structures being used for construction.
5. It is a tool to predict both resistance and durability of objects.

How to Increase the Flexural Strength of Concrete?
The use of crushed aggregates in the place of rounded aggregates increases the bond strength between the aggregates and the cement matrix and therefore increases the flexural strength. When reactive aggregates like the Calcareous aggregates are used, it reacts with the excess calcium hydroxide among the products of hydration to yield by-products which increases the flexural strength of the member. Another way of increasing the flexural strength is by replacing a part of cement with pozzolanic additives like fly ash or Ground Granulated Blast Furnace Slag (GGBS). The pozzolanic additives play a major role in reducing the size and concentration of the Calcium Hydroxide crystals and invoking the formation of the most vital Calcium Silicate Hydrate Gel (CSH gel). The other ways of increasing the flexural strength includes the overall strengthening of the member by reducing the total porosity and by reducing the water cement ratio of the concrete mix.

What is characteristic compressive strength?
Characteristic compressive strength of concrete is the strength below which not more than 5% of the test results should fall. It is denoted by fck.

Why is tensile strength smaller than flexural strength?
Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The flexural strength would be the same as the tensile strength if the material were homogeneous. In fact, most materials have small or large defects in them which act to concentrate the stresses locally, effectively causing a localized weakness.
When a material is bent, only the extreme fibers are at the largest stress so, if those fibers are free from defects, the flexural strength will be controlled by the strength of those intact

'fibers'. However, if the same material was subjected to only tensile forces then all the fibers in the material are at the same stress and failure will initiate when the weakest fiber reaches its limiting tensile stress. Therefore, it is common for flexural strengths to be higher than tensile strengths for the same material. Conversely, a homogeneous material with defects only on its surfaces (e.g., due to scratches) might have a higher tensile strength than flexural strength.

Why flexural test is to be performed on wet specimen?

To specimen preparation, handling, and curing procedure flexural tests are extremely sensitive and beam specimens are very heavy and there will be yield lower strengths by allowing a beam to dry. Beams must be tested while wet and must be cured in a standard manner. A sharp drop in flexural strength is produced due to a short period of drying. For control and acceptance of concrete, the concrete industry and inspection agencies are much more familiar with traditional cylinder compression tests and for design purposes flexural can be used.

Experiment No.:6

STRESS-STRAIN CURVE OF HIGH STRENGTH CONCRETE

Objective

To determine modulus of elasticity of concrete from stress-strain curve

Apparatus and Material

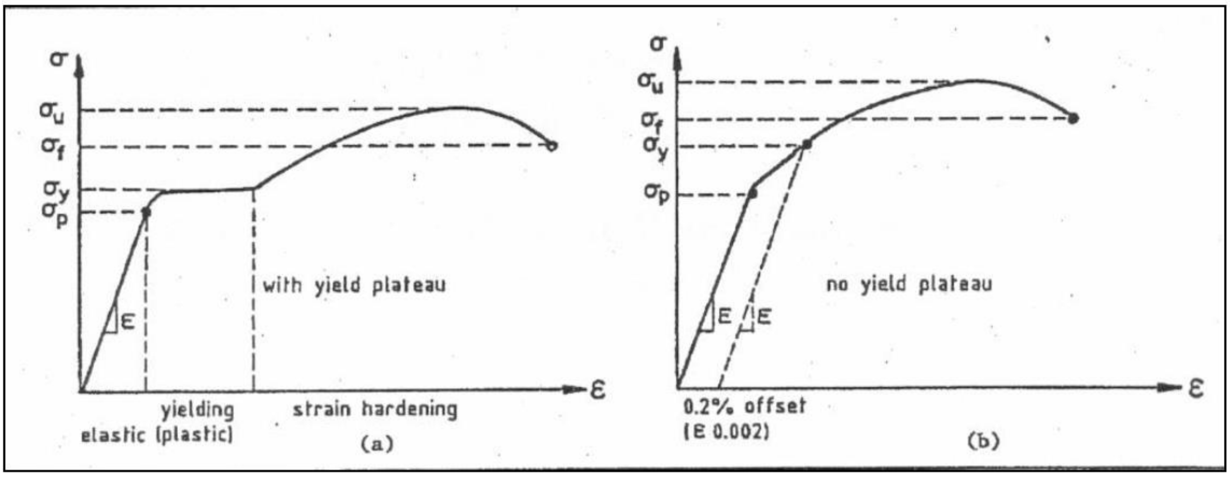
1. Compression testing machine (Deflection or displacement controlled)
2. Cylinder specimen 150mm ϕ and 300mm length

Theory

The stress-strain (σ-ε) curve for a material can yield a great deal of valuable properties (mechanical properties) about the material and its suitability for the different applications.
From the σ-ε curve we can determine the following properties:

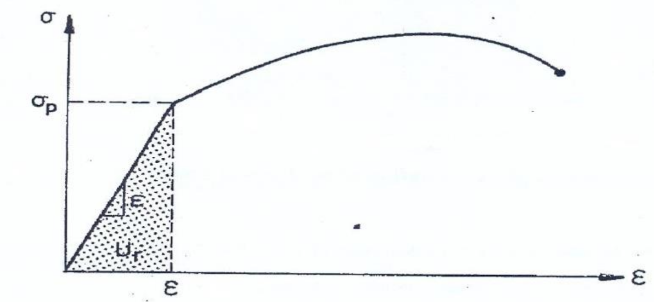
1. The proportional limit (P.L), σp : The value of stress beyond which the material is not linearly elastic (i.e. * Eε stress is not proportional to strain, No P.L for Brittle material)
2. Elastic Limit (E.L): Maximum stress that may be developed during a simple tension test such that there is no permanent or residual deformation. When the load is entirely removed.
3. Modulus of Elasticity,E : It is the constant of proportionality between stress and strain in the linear portion of the σ-ε curve. “Ratio of the unit stress to the unit strain”
   E = σ/ε or σ = E ε (Hooke's Law) or Slope of straight line from zero to P.L
4. Yield stress, σy: It is the stress at which there is appreciable increase in the strain with no or little increase in the stress; the stress may even decrease slightly. Materials exhibit different behavior with regard to yielding.
5. Ultimate strength, σu: It is the maximum stress (based on original cross sectional area of the specimen) which can develop in the material before rupture. Hence σu can be computed as:

$$\sigma_u = \frac{P_u}{A_o}$$



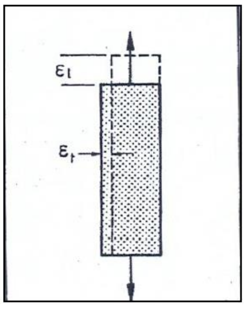
Typical stress-strain curves

Resilience: It is the ability of a material to absorb energy when elastically deformed and return it when unloaded. Resilience is measured by Modulus of Resilience**,** **U**r which is equal to the area under the elastic portion of the σ - ε curve

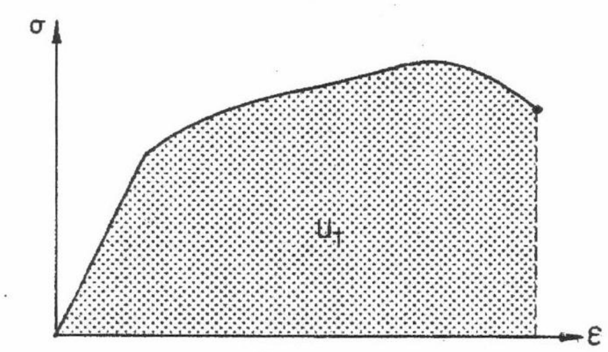


Poisson's Ratio, v: It is the ratio of the lateral (transverse) strain to the longitudinal strain for uniaxial loading

$$v = \frac{-\varepsilon_t}{\varepsilon_l}$$



Toughness: It is the ability of material to absorb energy in the plastic range of the material. Toughness is measured by Modulus of Toughness, **Ut** which is equal to the area under the whole σ - ε curve



For rigorous analysis of concrete structure, a complete stress-strain equation is needed. Low and medium strength concrete is ratherly easier than high strength concrete to get a full stress-strain curve. Due to the brittleness of high strength concrete, it needs special technique to get a full curve. The axial deformation has been used for test control. But for high strength concrete, the large energy release during failure causes unstable descending branch.
Even though lots of stress-strain curves are proposed, there is insufficient information on the shape of curve, especially in high strength concrete. One of the reasons why there are insufficient experimental results on the complete stress-strain curve is that it is very difficult to get descending part of the curve. The problem is that the interaction between the testing machine and the specimen is unclear, After the specimen reaches peak strength, the load is decreased. However the strain energy stored in the machine needs path to release. This causes an impulsive failure.

Stress strain curve of concrete is a graphical representation of concrete behavior under load. It is produced by plotting concrete compress strain at various interval of concrete compressive loading (stress). Concrete is mostly used in compression that is why its compressive stress strain curve is of major interest. The stress strain curve of concrete allows designers and engineers to anticipate the behavior of concrete used in building constructions. Finally, the performance of concrete structure is controlled by the stress strain curve relationship and the type of stress to which the concrete is subjected in the structure.
The stress and strain of concrete is obtained by testing concrete cylinder specimen at age of 28days, using compressive test machine.
Initially, all stress strain curves are fairly straight; stress and strain are proportional. With this stage, the material should be able to retain its original shape if the load is removed. The elastic range of concrete stress strain curve continues up to 0.45fc' (maximum concrete compressive strength). The slope of elastic part of stress strain curve is concrete modulus of elasticity. The modulus of elasticity of concrete increases as its strength is increased.
The elastic range is exceeded and concrete begin to show plastic behavior (Nonlinear), when a load is further increased. After elastic range, the curve starts to horizontal; reaching maximum compress stress (maximum compressive strength). For normal weight concrete, the maximum stress is realized at compressive strain ranges from 0.002 to 0.003. however, for lightweight concrete, the maximum stress reached at strain ranges from 0.003 to 0. 0035.The higher results of strain in both curves represent larger strength.
After reaching maximum stress, all the curves show descending trend. The characteristics of the stress strain curve in descending part is based on the method of testing. Long stable descending part is achieved if special testing procedure is employed to guarantee a constant strain rate while cylinder resistance is decreasing. However, if special testing procedure is not followed, then unloading after peak point would be quick and the descending portion of the curve would not be the same.
After an initial linear portion lasting up to about 30 – 40% of the ultimate load, the curve becomes non-linear, with large strains being registered for small increments of stress. The non-linearity is primarily a function of the coalescence of microcracks at the paste-aggregate interface. The ultimate stress is reached when a large crack network is formed within the concrete, consisting of the coalesced microcracks and the cracks in the cement paste matrix. The strain corresponding to ultimate stress is usually around 0.003 for normal strength concrete. The stress-strain behaviour in tension is similar to that in compression.
The descending portion of the stress-strain curve, or in other words, the post-peak response of the concrete, can be obtained by a displacement or a strain controlled testing machine. In typical load controlled machines, a constant rate of load is applied to the specimen. Thus any extra load beyond the ultimate capacity leads to a catastrophic failure of the specimen. In a displacement controlled machine, small increments of displacement are given to the specimen. Thus, the decreasing load beyond the peak load can also be registered. The strain at failure is typically around 0.005 for normal strength concrete. The post peak behaviour is actually a function of the stiffness of the testing machine in relation to the stiffness of the test specimen, and the rate of strain. With increasing strength of concrete, its brittleness also increases, and this is shown by a reduction in the strain at failure. It is interesting to note that although cement paste and aggregates individually have linear stress-strain relationships, the behaviour for concrete is non-linear. This is due to the mismatch and microcracking created at the interfacial transition zone.
A displacement controlled test is possible using a machine with a servo valve, in a closed loop. The machine compresses the concrete specimen at a constant displacement rate of the specimen – the LVDT on the specimen provides feedback to the controller, which then indicates to the servo valve the degree of piston movement to be provided (to keep the specimen displacement constant). In this way, the load response of the specimen is

continuously studied as it undergoes incremental displacements. Failure occurs when the cracks in the specimen grow to an ‘unstable’ size.
Modulus of elasticity of concrete is defined as the ratio of stress applied on the concrete to the respective strain caused. The accurate value of modulus of elasticity of concrete can be determined by conducting a laboratory test called compression test on a cylindrical concrete specimen. In the test, the deformation of the specimen with respect to different load variation is analyzed. These observations produce Stress-Strain graph (load-deflection graph) from which the modulus of elasticity of concrete is determined. The slope of a line that is drawn in the stress-strain curve from a stress value of zero to the compressive stress value of 0.45f’c(working stress) gives the modulus of elasticity of concrete.
The stress and strain of concrete is obtained by testing concrete cylinder specimen at age of 28days, using compressive test machine. To understand and predict the performance of any mix designed concrete, the parameters such as Modulus of Elasticity, ultimate strength, strain are key options.
Compressometer is used to find the strain with respect to stress. The strain is calculated by compressometer gauge value to the gauge length and graphs are plotted for analysis. The strain is analyzed by Compressometer by the ratio of gauge value to the gauge length of the cylinders.
Strain = Gauge value/Gauge length i.e. Gauge value is the reading on the dial gauge.
Gauge length is equal to 150mm which is the diameter of the cylinder.
Stress is calculated by the formula load to the area. Stress = Load/area
The modulus of elasticity is obtained by the ratio of stress to the strain. Modulus of elasticity E = Stress/strain. The higher the modulus of elasticity, the greater the stiffness of the specimen

Procedure

The test procedure involves two stages. Initially, the compressor meter is set-up, followed by the application of load and testing.

1. Setting up compressometer

A compressometer is a device used in the compression test of the concrete cylinder to determine its strain and deformation characteristics. The set up involves the following procedures.

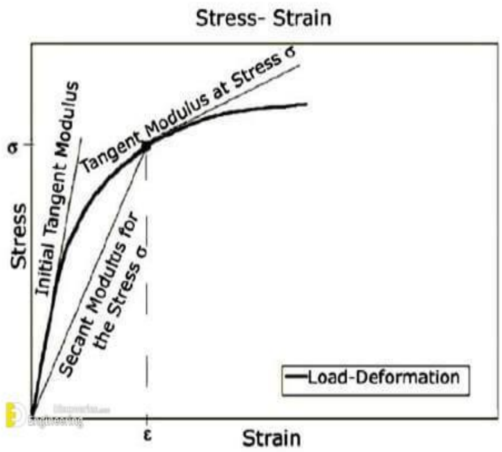
a) The compressometer consists of two frames(top and bottom. The frames are initially assembled by the help of spacers. The spacers are held in position during the assembling.
b) The pivot rod is kept on the screws which are then locked in position. The tightening screws of the top and bottom frames are kept in loose condition.
c) Once the compressometer is arranged, it is placed on the concrete specimen kept on a level surface. The compressor meter is centrally placed on the specimen.
d) Once the position is set, the screws are tightened and the compressometer is held on the specimen.
e) Once the setup is done, the spacers can be unscrewed and removed.

2. Testing the Specimen

The test procedure involves the following steps:

a) The specimen with the compressor meter set up is placed over the compression testing machine platform. It is centred properly.
b) The load application is performed continuously at a rate of 140kg/cm²/minute without any obstruction.
c) The load application is continued until a stress value equal to (c+5) kg/cm² is attained. Here c is the 1/3rd of average compressive strength of the cube (The strength value of cube calculated to the nearest of 5kg /cm²) which is a load of 12.4T.

d) Once this stress value is reached, it is maintained for a period of 60 seconds and then reduced to the stress of 1.5 kg/cm² which is a load value of 0.3T.
e) Again, the load is further increased until the stress of (c+1.5)kg/cm² is reached which is a load of 11.8T. At this point, the compressor meter reading is recorded.
f) Now, the load is gradually reduced and the readings are recorded at an 1T intervals i.e. 11.8T,10.8T,9.8T,8.8T,7.8T,…………,1.8T,0.3T
g) Repeat the test by applying the load for the third time and record the compressometer readings at an 1T intervals i.e. 11.8T,10.8T,9.8T,8.8T,7.8T,…………,1.8T,0.3T is determined



Load-Deflection Graph
From the observations, the load-deflection graph is plotted for the loading conditions. Tangents are drawn at the initial portion of the graph and at the point of value equal to the working stress of the concrete mix. A line is drawn joining both points.

Observations and Calculations
1. Date of test=
2. Shape and nominal dimensions of the specimen=
3. Age of specimen=
4. Modulus of Elasticity=_______________MPa
5. Peak stress=_____________MPa
6. Strain at peak stress=____________

Result

Modulus of Elasticity of the given sample is________________MPa

Inference

Viva Questions

What is stress-strain curve of concrete?
Stress strain curve of concrete is a graphical representation of concrete behavior under load. It is produced by plotting concrete compress strain at various interval of concrete compressive loading (stress). Concrete is mostly used in compression that is why its compressive stress strain curve is of major interest.

What is the need for stress-strain analysis ?
The stress-strain analysis guides the engineer to predict the behaviour of the concrete with different loadings, here are some benefits of the stress-strain analysis.
- It analysis the mechanical behaviour of the concrete.
- Stiffness can be easily computed by stress to strain.
- It helps to find maximum stress and strain in the concrete.

What is the difference between high strength concrete and high-performance concrete?
High-strength concrete is defined based on its compressive strength at a given age whereas high-performance concrete is defined based on performance criteria namely: high durability, high strength, and high workability.

What is the maximum strain of concrete?
The maximum strain in concrete at the outermost compression fiber is taken as 0.0035 in bending. For design purposes. the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor = 1.5 shall be applied in addition to this.

What are the disadvantages of high strength concrete?
High-strength concrete must meet high-performance standards consistently in order for it to be effective. Second, careful materials selection is necessary. High quality materials must be used. These materials may cost more than materials of lower quality.

What is the difference between high strength concrete and normal concrete?
The normal strength concrete possesses having good workability that all concrete ingredients are in proper and accurate proportions. These aggregates must be of a proper gradation. The high strength concrete mix is often sticky and also found difficult to be handled and placed. This is even if the plasticizes are used.

Why the stress-strain curve of concrete is highly non-linear?
It is obvious that nonlinear nature of the stress-strain curve is due to the change in modulus of elasticity at every points of strain in stress function. ... It is the ratio of the stress to the strain of a material or combination of materials. Concrete is much stronger in compression than in tension (tensile strength is of the order of one-tenth of compressive strength). While its tensile stress-strain relationship is almost linear, the stress-strain relationship in compression is nonlinear from the beginning.

Does high strength concrete have more aggregate?
Aggregates should be strong and durable. They need not necessarily be hard and of high strength but need to be compatible, in terms of stiffness and strength, with the cement paste. Generally smaller maximum size coarse aggregate is used for higher strength concretes.

Does high strength concrete have more cement?
The high strength concrete has a lower value of permeability compared to normal strength concrete. This is because the high – strength concrete is designed with lower water cement ratio.

Why is high strength concrete brittle?
Due to the shape of the stress-strain curve and the typical fracture phenomenon, high strength concrete (HSC) is considered as a brittle material.

How is super high strength concrete made?
Ultra-High Performance Concrete (UHPC), is also known as reactive powder concrete (RPC). The material is typically formulated by combining portland cement, supplementary cementitious materials, reactive powders, limestone and or quartz flour, fine sand, high-range water reducers, and water.

How does the stress-strain of concrete in tension differ from the stress-strain curve of concrete in compression?
stress-strain behavior of the concrete is different in tension and in compression under uniaxial and biaxial loading. Hence the concrete in tension and compression is modelled separately. The concrete for all purpose is assumed isotropic and linear within the elastic range under monotonic loading**.**

What is Duff Abrams law?
The law states the strength of a concrete mix is inversely related to the mass ratio of water to cement. As the water content increases, the strength of concrete decreases.

What is high strength concrete?
According to IS 456-1978. There are only 7 Grades.
But According to IS 456-2000;
(M10-M20) = nominal mix.
(M25-M60) = standard mix M60 was added to standard mix from high mix in amendment of IS 456:2000 code in 2013).
M65 - M100 = High strength concrete
So, there are 19 grades of concrete mix.
In this designation, the letter M refers to the mix and the number to the specified 28-day cube strength of mix in N/mm2.

What are the advantages of the high strength concrete?
Greater stiffness • High resistance to abrasion • Greater load resistance • High durability and long life • Low permeability • Safety against chemical attack

Experiment No: 7

REBOUND HAMMER - NON-DESTRUCTIVE TESTING ON CONCRETE

(As per IS: 13311(2)-1992)

Objective

To determine the compressive strength of the concrete by relating the rebound index and the compressive strength

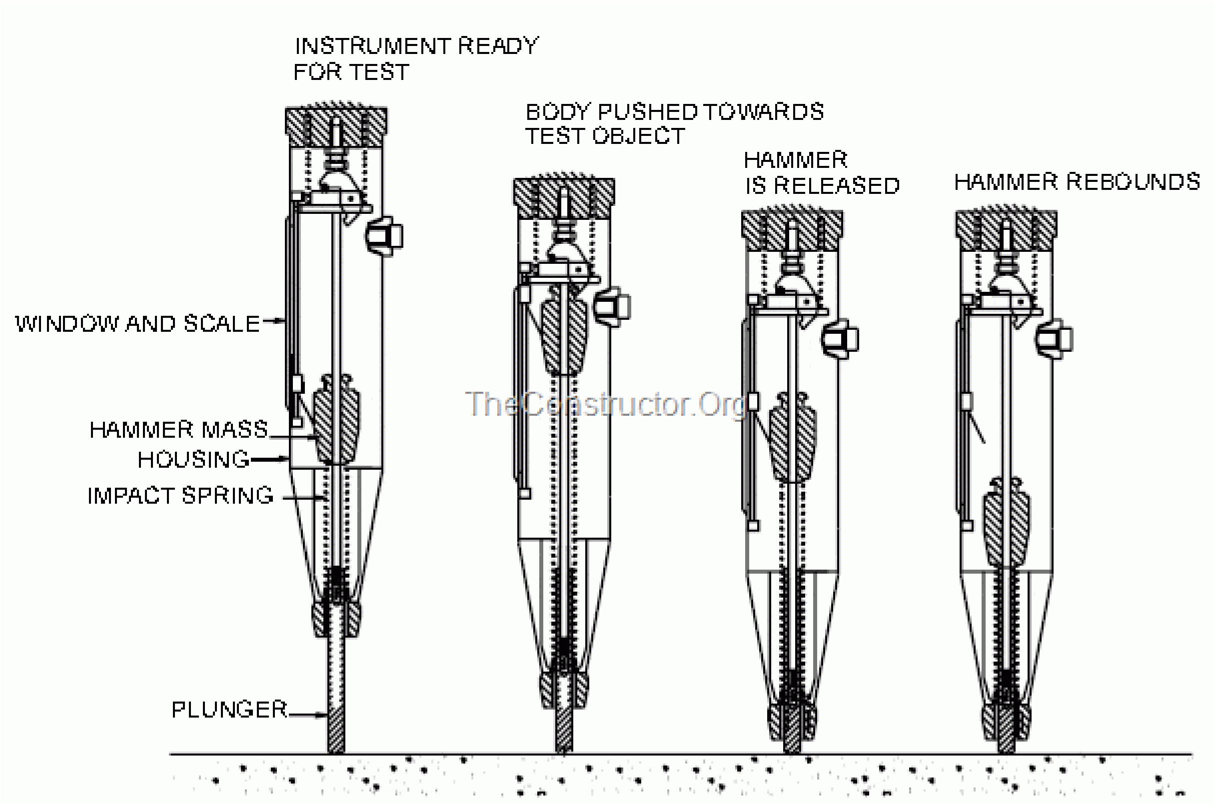
Apparatus

Schmidt Rebound Hammer

Rebound Hammer Test IS Code is IS 13311-1 (1992): Method of Non-destructive Test

Theory

Rebound Hammer test is a Non-destructive testing method of concrete which provide a convenient and rapid indication of the compressive strength of the concrete. The rebound hammer is also called as Schmidt hammer that consist of a spring controlled mass that slides on a plunger within a tubular housing. The operation of rebound hammer is shown in the figure below. When the plunger of rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made to hit concrete surface to rebound back. The extent of rebound, which is a measure of surface hardness, is measured on a graduated scale. This measured value is designated as Rebound Number (rebound index). A concrete with low strength and low stiffness will absorb more energy to yield in a lower rebound value.



As per the Indian code IS: 13311(2)-1992, the rebound hammer test have the following objectives:

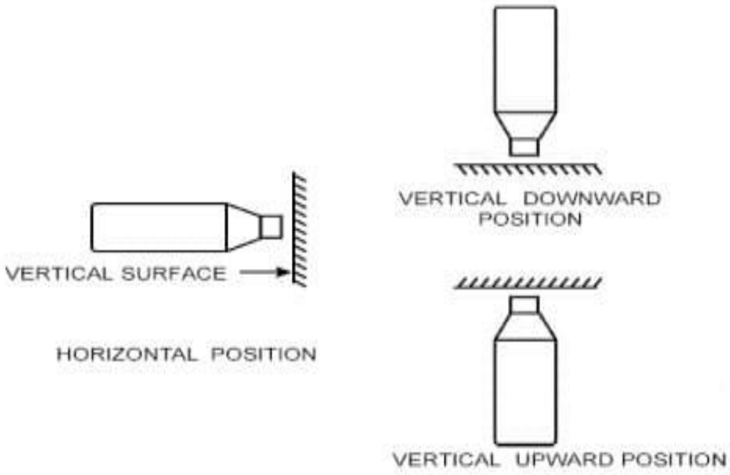
1. To determine the compressive strength of the concrete by relating the rebound index and the compressive strength
2. To assess the uniformity of the concrete
3. To assess the quality of the concrete based on the standard specifications
4. To relate one concrete element with other in terms of quality

Rebound hammer test method can be used to differentiate the acceptable and questionable parts of the structure or to compare two different structures based on strength.

Principle of Rebound Hammer Test

Rebound hammer test method is based on the principle that the rebound of an elastic mass depends on the hardness of the concrete surface against which the mass strikes. The operation of the rebound hammer is shown in figure. When the plunger of rebound hammer is pressed against the concrete surface, the spring controlled mass in the hammer rebounds. The amount of rebound of the mass depends on the hardness of concrete surface. Thus, the hardness of concrete and rebound hammer reading can be correlated with compressive strength of concrete. The rebound value is read off along a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Procedure for rebound hammer test on concrete structure starts with calibration of the rebound hammer. For this, the rebound hammer is tested against the test anvil made of steel having Brinell hardness number of about 5000 N/mm2. After the rebound hammer is tested for accuracy on the test anvil, the rebound hammer is held at right angles to the surface of the concrete structure for taking the readings. The test thus can be conducted horizontally on vertical surface and vertically upwards or downwards on horizontal surfaces as shown in figure below If the rebound hammer is held at intermediate angle, the rebound number will be different for the same concrete.



The impact energy required for the rebound hammer is different for different applications. Approximate Impact energy levels are mentioned in the table below for different applications.

Table-1: Impact Energy for Rebound Hammers for Different Applications As per IS: 13311(2)-1992

Sl.No	Applications	Approximate Impact Energy for Rebound Hammer in Nm
1	For Normal Weight Concrete	2.25
2	For light weight concrete / For small and impact resistive concrete parts	0.75
3	For mass concrete testing Eg: In roads, hydraulic structures and pavements	30.00

Points to Remember in Rebound Hammer Test

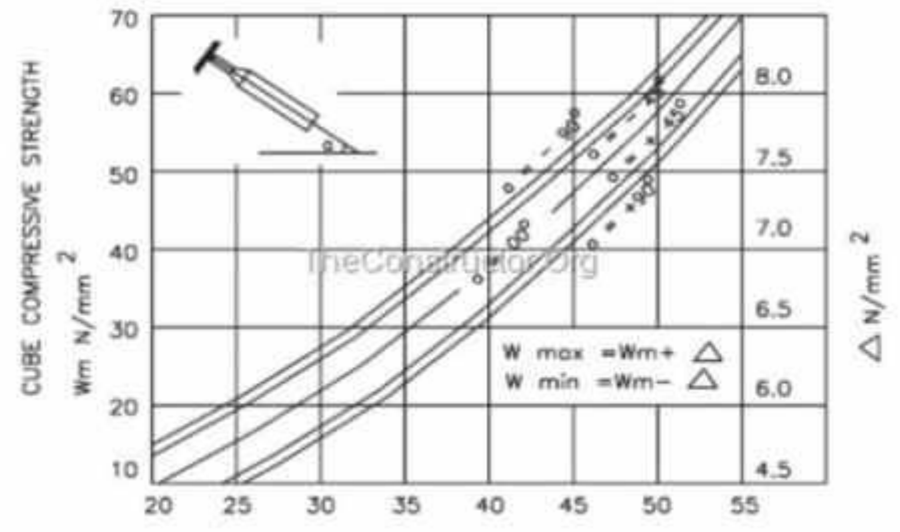
1. The concrete surface should be smooth, clean and dry.
2. Ant loose particles should be rubbed off from the concrete surface with a grinding wheel or stone, before hammer testing.
3. Rebound hammer test should not be conducted on rough surfaces as a result of incomplete compaction, loss of grout, spalled or tooled concrete surface.
4. The point of impact of rebound hammer on concrete surface should be at least 20mm away from edge or shape discontinuity.
5. Six readings of rebound number is taken at each point of testing and an average of value of the readings is taken as rebound index for the corresponding point of observation on concrete surface.

Correlation between compressive strength of concrete and rebound number

The most suitable method of obtaining the correlation between compressive strength of concrete and rebound number is to test the concrete cubes using compression testing machine as well as using rebound hammer simultaneously. First the rebound number of concrete cube is taken and then the compressive strength is tested on compression testing machine. The fixed load required is of the order of 7 N/ mm2 when the impact energy of the hammer is about 2.2 Nm. The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. The test specimens should be as large a mass as possible in order to minimize the size effect on the test result of a full scale structure. 150mm cube specimens are preferred for calibrating rebound hammers of lower impact energy (2.2Nm), whereas for rebound hammers of higher impact energy, for example 30 Nm, the test cubes should not be smaller than 300mm. The concrete cube specimens should be kept at room temperature for about 24 hours after taking it out from the curing pond, before testing it with the rebound hammer. To obtain a correlation between rebound numbers and strength of wet cured and wet tested cubes, it is necessary to establish a correlation between the strength of wet tested cubes and the strength of dry tested cubes on which rebound readings are taken. A direct correlation between rebound numbers on wet cubes and the strength of wet cubes is not recommended. Only the vertical faces of the cubes as cast should be tested. At least nine readings should be taken on each of the two vertical faces accessible in the compression testing machine when using the rebound hammers. The points of impact on the specimen must not be nearer an edge than 20mm and should be not less than 20mm from each other. The same points must not be impacted more than once.

Interpretation of Rebound Hammer Test Results

After obtaining the correlation between compressive strength and rebound number, the strength of structure can be assessed. In general, the rebound number increases as the strength increases and is also affected by a number of parameters i.e. type of cement, type of aggregate, surface condition and moisture content of the concrete, curing and age of concrete, carbonation of concrete surface etc.



Relationship Between Cube Strength and the Rebound Number

Moreover the rebound index is indicative of compressive strength of concrete up to a limited depth from the surface. The internal cracks, flaws etc. or heterogeneity across the cross section will not be indicated by rebound numbers. Table below shows the quality of concrete for respective average rebound number.

As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ± 25 percent. If the relationship between rebound index and compressive strength can be found by tests on core samples obtained from the structure or standard specimens made with the same concrete materials and mix proportion, then the accuracy of results and confidence thereon gets greatly increased.

Quality of Concrete for different values of rebound number

Average Rebound Number	Quality of Concrete
> 40	Very Good Hard Layer
30 to 40	Good Layer
20 to 30	Fair
< 20	Poor Concrete
0	Delaminated

Procedure

A concrete test hammer of impact energy of 2.207 N.m (0.225 kgm) is quite suitable for testing concrete in ordinary building and bridge construction. The procedure for testing a concrete structure is given below:

1. All members and points of a concrete structure selected for testing should be marked for identification; they should also be in dry condition.
2. Testing should be conducted on surfaces that are smooth and uniform, preferably surfaces created by casting against a form. Avoid rough spots, honey-comb or porous areas. Free or trowelled surface may also be satisfactory if appropriate corrections are applied or a special calibration is prepared. If loosely adhering scale, plaster work or coating is present, this should be rubbed off with a grinding wheel or stone.
3. For concrete section less than 100 mm thick, the rebound of the hammer will be affected by the elastic deformation of the section, and it should be backed up by a heavy mass placed on the back side.
4. At each of selected points, made smooth and clean, take six rebound readings. For each reading shift the hammer 25 mm and take care not to rebound the same spot twice. The point of impact should be at least 20 mm away from any edge or sharp discontinuity. Small air pockets near the surface under the point of impact cause low rebound, on the other hand, immediately over a hard aggregate the impact will result in a high rebound.
5. The usual directions of test are either horizontal or vertically down, but any direction of test can be used a long as it is consistent. Calibration or corrections for a given direction of test are supplied with the hammer or can be derived.
6. The rebound values usually are considered reliable when at least six readings deviate not more than +2.5 to 3.5 on the impact scale. The compressive strength is then determined by taking average of rebound reading.
7. Compressive strength of the concrete can be determined from the relationship between the rebound number and the strength given by the curve.
8. For reliable results the calibration curve shall be derived from the given set of materials and conditions. If cubes are available from the structure to be tested, the hammer should be checked first on Anvil then upon these cubes, if need be the hammer should be adjusted accordingly and re-checked for satisfactory performance. If it is found that hammer performance is doubtful, the hammer should be changed.

Observations

Type of the Structure/Specimen=

Age of the Structure/Specimen=

Column No:	Rebound values	Mean	Compressive strength MPa	Remarks
BOTTOM	1) 2) 3)			
MIDDLE	1) 2) 3)			
TOP	1) 2) 3)			

Beam No:	Rebound value	Mean	Compressive strength MPa	Remarks
1 ST SUPPORT	1) 2) 3)			
MID SPAN	1) 2) 3)			
2ND SUPPORT	1) 2) 3)			

Slab No:	Rebound value	Mean	Compressive strength MPa	Remarks
EDGES	1) 2) 3)			
MID SPAN ALONG EDGES	1) 2) 3)			
CENTRE OF SLAB	1) 2) 3)			

Note:

1. The instruments used for the survey are Rebound Hammer (Schmidt Hammer) (Type N hammer having the impact energy of the hammer is about 2.2 Nm)
2. At some places over plaster in columns USPV may give no results or indicates that the velocity was out of range. In such a place the rebound value may also be very low. This place will iave a unique sound on striking softly with a hard material like iron which clearly indicated a void between the concrete of pillar and its plastering.

– A general trend will be obtained in the columns. The trend was such that towards the base of the column the tests always showed a higher quality of concrete i.e., higher compressive strength. The compressive strength went on decreasing as we go up towards the roof. The reason for this variation is better compaction at the base. Since all the weight of the column acts at the base higher compaction is achieved and also better compaction facilities are available near the base and process compaction becomes difficult as we go up.

– As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ± 25 percent. If the relationship between rebound index and compressive strength can be found by tests on core samples obtained from the structure then the accuracy of results can be established.

- The Rebound hammer showed erratic result when the compressive strength was below 15 N/mm2. Above 15 N/mm2 the predicted compressive strength varied almost linearly with the actual compressive strength.
- It is clear then that the rebound number reflects only the surface of concrete. The results obtained are only representative of the outer concrete layer with a thickness of 30–50 mm.
- If details of material and mix proportions adopted in the particular structure are available, then estimate of concrete strength can be made by establishing suitable correlation between the pulse velocity and the compressive strength of concrete specimens made with such material and mix proportions, under environmental conditions similar to that in the structure. The estimated strength may vary from the actual strength by ± 20 percent
- The Schmidt hammer provides an inexpensive, simple and quick method of obtaining an indication of concrete strength, but accuracy of ±15 to ±20 per cent is possible only for specimens cast cured and tested under conditions for which calibration curves have been established. The results are affected by factors such as smoothness of surface, size and shape of specimen, moisture condition of the concrete, type of cement and coarse aggregate, and extent of carbonation of surface.

Inference

Viva Questions

What are the limitations of rebound hammer test?

Rebound hammer test should not be conducted on rough surfaces as a result of incomplete compaction, loss of grout, spalled or tooled concrete surface. The point of impact of rebound hammer on concrete surface should be at least 20mm away from edge or shape discontinuity. Rebound hammer test should not be carried out on low strength concrete at early ages. When the concrete strength is less than 7 N/mm2, the concrete surface could be damaged by the hammer. Hence we can conclude that rebound hammer test results do not give the accurate strength of concrete. It is only useful for repairs as the strength of different elements at different locations can be compared relatively.

How accurate is the rebound hammer test?

The results show that the compressive strength prediction using rebound hammer was accurate in the range of 48 to 58 MPa with an error of 15.32%, but underestimates the actual strength of the samples in the upper and lower regions.

What is correction factor in rebound hammer test?

Therefore, the correction factors ranging from **0.50 - 0.80** are suggested to be used for the strength values of old concrete. Schmidt Hammer test results can be influenced by many factors; such as the characteristics of the mixture, surface carbonation, moisture condition, rate of hardening and curing type.

How do you read rebound hammer results?

Keep the Rebound Hammer firmly pressed against the concrete surface and read the rebound number on the scale. As long as you hold the Rebound Hammer firmly against the concrete, the rebound number will remain on the scale. Record your reading.

Which of the following requires destructive testing?

Destructive testing methods are commonly used for materials characterisation, fabrication validation, failure investigation, and can form a key part of engineering critical assessments, which also involves non-destructive testing (NDT) techniques such as digital radiography.

How to you calibrate and use the rebound hammer?

The procedure for rebound hammer test on hardened concrete starts with the calibration of the rebound hammer.

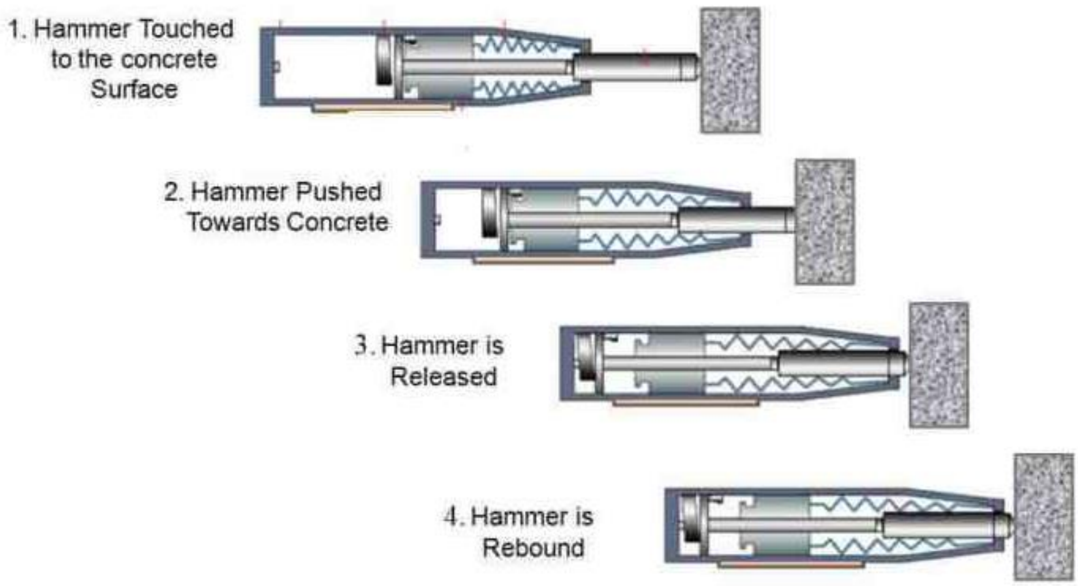
1) The rebound hammer is tested against the anvil made of steel having a Brinell hardness of about 5000 N/mm^2.

2) After the rebound hammer is calibrated for accuracy on the test anvil, the rebound hammer is held at the right angle to the surface of the concrete structure for taking the readings.

3) The test thus can be conducted horizontally on a vertical surface and vertically downwards or upwards on horizontal surfaces as shown in the figure below.

4) If the rebound hammer is held at an intermediate angle, the rebound number (rebound index) will give differentiated results for the same surface and concrete.

5) The impact energy required for the hammer test is different for different applications. Approximate Impact energy levels are mentioned in the below table for different applications.



How to Calculate Compressive Strength From Rebound Number

To Calculate compressive strength from rebound number first, the rebound number of the concrete cube is calculated. Then the compressive strength of the cube is tested on the compression testing machine. The fixed load necessary is of the order of 7 N/mm2 when the impact energy of the hammer is about 2.2 N.m.

The impact load has to increase for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. The test should be as large a mass as possible in order to minimize the size effect on the result of a full-scale structure.

Minimum 80-100 dry concrete cube specimens are required for calibrating the rebound hammers of lower impact energy (2.3Nm), whereas for rebound hammers of higher impact energy, for e.g.30 Nm, the test cubes of concrete should not be smaller than 300mm.

The entire concrete cube specimen should be kept at room temperature at least for about 24 hours after taking it out from the curing period, before testing it with the rebound hammer.

To establish and get a correlation between rebound numbers and strength of wet cured and wet tested cubes, it is necessary to establish a correlation between the strength of wet tested cubes & the strength of dry tested concrete cubes on which rebound readings are taken.

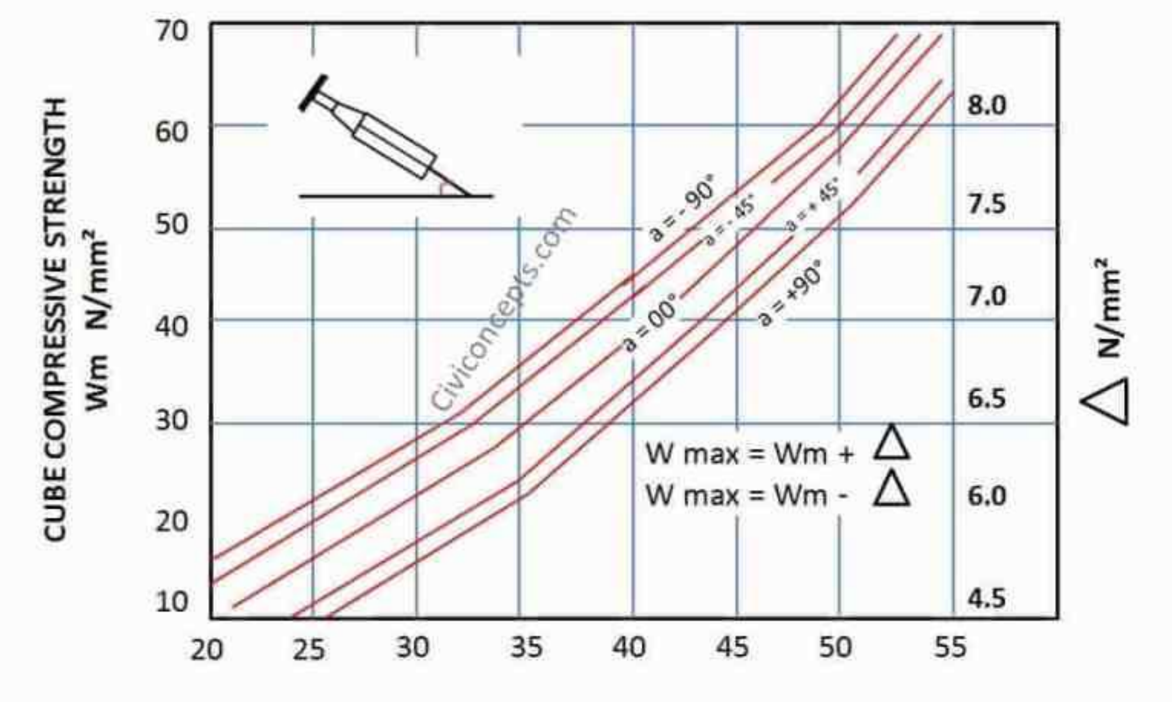
A direct correlation to rebound numbers on wet concrete cubes and the strength of wet concrete cubes is not recommended. Only the vertical faces (excluding horizontal) of the concrete cubes as cast should be tested.

At least ten readings should be taken on each of the two vertical faces accessible in the compression testing machine when using the rebound hammers. The points of impact on the specimen must not be nearer an edge than 20mm and should be not less than 20mm from each other. The same points of the application must not be impacted more than once.

How to prepare Rebound hammer test graph?

A Rebound hammer test graph is prepared after obtaining the correlation between compressive strength and rebound number (rebound index), the strength of the structure can be assessed.

In general, the rebound number increases as the strength increases and is also affected by a number of parameters i.e. types of cement, types of aggregate, surface condition of the concrete, and moisture content of the concrete, curing, and age of concrete, carbonation of concrete surface, etc.



Moreover, the rebound index is indicative of the compressive strength of concrete up to limited depth from the surface. The internal cracks, flaws, etc., or heterogeneity among the cross–section will not be indicated by rebound numbers. rebound hammer test values should be taken into account.

The correlation between rebound index (rebound number) & compressive strength can be found by tests on core samples obtained from the concrete structure or standards specimens made with the same concrete ingredients and mix proportion, then the accuracy of test results and confidence thereon gets greatly increased.

Notes

Experiment No: 8

ULTRASONIC PULSE VELOCITY - NON-DESTRUCTIVE TESTING ON CONCRETE

(As per IS: 13311 (Part 1) – 1992)

Objective

To assess the homogeneity and integrity of concrete

Apparatus

Ultrasonic Pulse Velocity Meter

Theory

The pulse velocity in concrete may be influenced by:

a. Path length
b. Lateral dimension of the specimen tested
c. Presence of reinforcement steel
d. Moisture content of the concrete

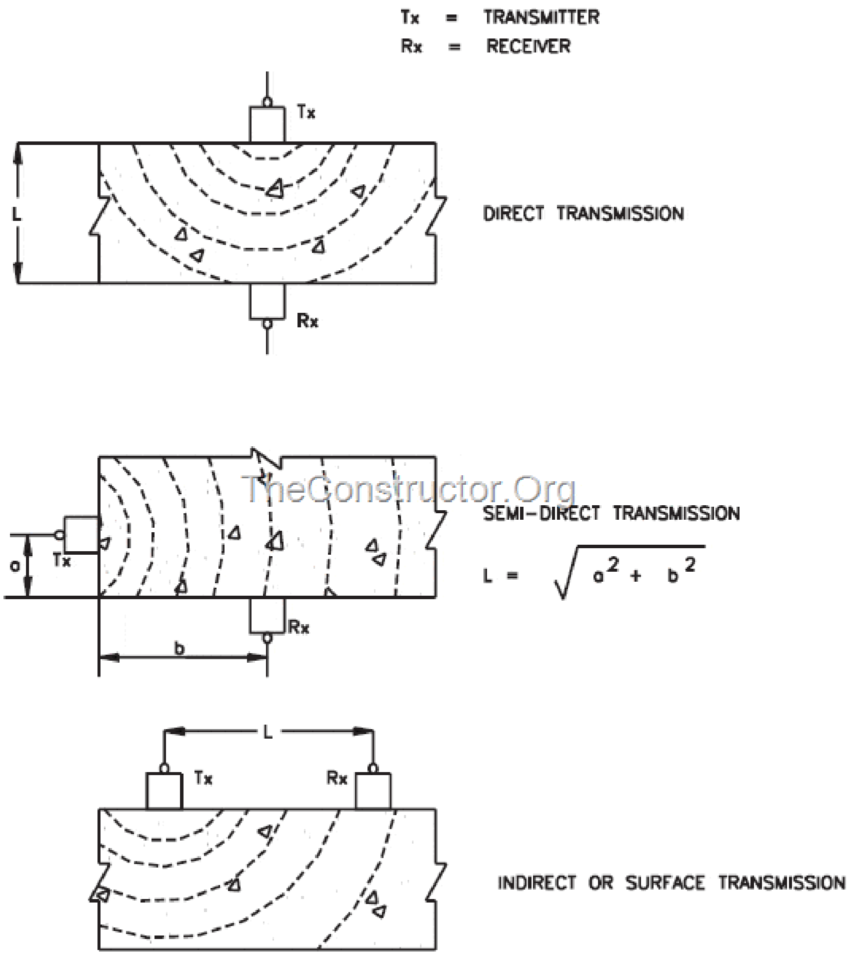
The influence of path length will be negligible provided it is not less than 100mm when 20mm size aggregate is used or less than 150mm for 40mm size aggregate.

Pulse velocity will not be influenced by the shape of the specimen, provided its least lateral dimension (i.e. its dimension measured at right angles to the pulse path) is not less than the wavelength of the pulse vibrations.

For pulse of 50Hz frequency, this corresponds to a least lateral dimension of about 80mm. the velocity of pulses in steel bar is generally higher than they are in concrete. For this reason pulse velocity measurements made in the vicinity of reinforcing steel may be high and not representative of the concrete. The influence of the reinforcement is generally small if the bars runs in a direction at right angles to the pulse path and the quantity of steel is small in relation to the path length. The moisture content of the concrete can have a small but significant influence on the pulse velocity.

In general, the velocity is increased with increased moisture content, the influence being more marked for lower quality concrete.

Measurement of pulse velocities at points on a regular grid on the surface of a concrete structure provides a reliable method of assessing the homogeneity of the concrete. The size of the grid chosen will depend on the size of the structure and the amount of variability encountered.



Method of propagating and receiving pulses

Concrete Quality based on Ultrasonic Pulse Velocity Test

Pulse velocity	Concrete quality
>4.0 km/s	Very good to excellent
3.5 – 4.0 km/s	Good to very good, slight porosity may exist
3.0 – 3.5 km/s	Satisfactory but loss of integrity is suspected
<3.0 km/s	Poor and loss of integrity exist.

To make a more realistic assessment of the condition of surface of a structural member, the pulse velocity can be combined with rebound number.

Ultrasonic Pulse Velocity Testing Instrument

Procedure

i) Preparing for use: Before switching on the 'V' meter, the transducers should be connected to the sockets marked "TRAN" and " REC".

The 'V' meter may be operated with either:

- The internal battery,
- An external battery or
- The A.C line.

ii) Set reference: A reference bar is provided to check the instrument zero. The pulse time for the bar is engraved on it. Apply a smear of grease to the transducer faces before placing it on the opposite ends of the bar. Adjust the 'SET REF' control until the reference bar transit time is obtained on the instrument read-out.

iii) Range selection: For maximum accuracy, it is recommended that the 0.1 microsecond range be selected for path length upto 400mm.

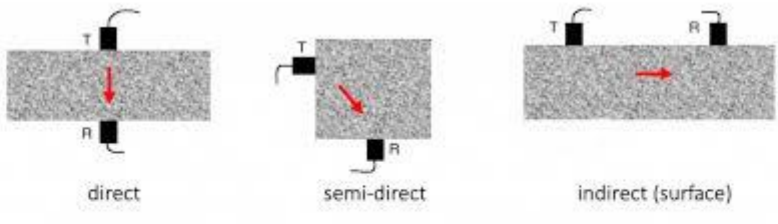
iv) Pulse velocity: Having determined the most suitable test points on the material to be tested, make careful measurement of the path length 'L'. Apply couplant to the surfaces of the transducers and press it hard onto the surface of the material.

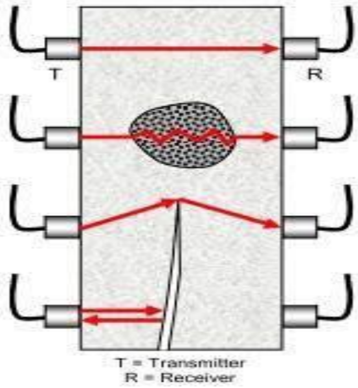
Do not move the transducers while a reading is being taken, as this can generate noise signals and errors in measurements. Continue holding the transducers onto the surface of the material until a consistent reading appears on the display, which is the time in microsecond for the ultrasonic pulse to travel the distance 'L'.The mean value of the display readings should be taken when the units digit hunts between two values.

Pulse velocity= (Path length/Travel time)

v) Separation of transducer leads: It is advisable to prevent the two transducer leads from coming into close contact with each other when the transit time measurements are being taken.

If this is not done, the receiver lead might pick-up unwanted signals from the transmitter lead and this would result in an incorrect display of the transit time.





Observations

Type of the Structure/Specimen=
Age of the Structure/Specimen=

Column No:	USPV (m/s) or (km/sec)	Mean	Compressive strength MPa	Remarks
BOTTOM	1) 2) 3)			
MIDDLE	1) 2) 3)			
TOP	1) 2) 3)			

Beam No:	USPV (m/s) or (km/sec)	Mean	Compressive strength MPa	Remarks
1 ST SUPPORT	1) 2) 3)			
MID SPAN	1) 2) 3)			
2ND SUPPORT	1) 2) 3)			

Slab No:	USPV (m/s) or (km/sec)	Mean	Compressive strength MPa	Remarks
EDGES	1) 2) 3)			
MID SPAN ALONG EDGES	1) 2) 3)			
CENTRE OF SLAB	1) 2) 3)			

Note:

- At some places over plaster in columns USPV may give no results or indicates that the velocity was out of range. In such a place the rebound value was also very low. This place gives a unique sound on striking softly with a hard material like iron which clearly indicated a void between the concrete of pillar and its plastering.
- A general trend was obtained in the columns. The trend was such that towards the base of the column the tests always showed a higher quality of concrete i.e., higher compressive strength. The compressive strength went on decreasing as we go up towards the roof. The reason for this variation is better compaction at the base. Since all the weight of the column acts at the base higher compaction is achieved and also better compaction facilities are available near the base and process compaction becomes difficult as we go up. No such regular trend will be observed for beams or slabs.
- It is recommended that the minimum path length should be 100mm for concrete with 20mm or less nominal maximum size of aggregate and 150mm for concrete with 20mm and 40mm nominal maximum size of aggregate.
- Reinforcement, if present, should be avoided during pulse velocity measurements, because the pulse velocity in the reinforcing bars is usually higher than in plain concrete. This is because the pulse velocity in steel is 1.9 times of that in concrete. It is reported that the influence of reinforcement is generally small if the bar runs in the direction right angle to the pulse path for bar diameter less than12 mm. But if percentage of steel is quite high or the axis of the bars are parallel to direction of propagation, then the correction factor has to be applied to the measured values.
- Combination of USPV and rebound hammer methods can be used for the assessment of the quality and likely compressive strength of in-situ concrete. Assessment of likely compressive strength of concrete is made from the rebound indices and this is taken to be indicative of the entire mass only when the overall quality of concrete judged by the UPV is ‘good’. When the quality assessed is ‘medium’, the estimation of compressive strength by rebound indices is extended to the entire mass only on the basis of other collateral measurement e.g. strength of controlled cube specimen, cement content of hardened concrete by chemical analysis or concrete core testing. When the quality of concrete is ‘poor’, no assessment of the strength of concrete is made from rebound indices.
- If details of material and mix proportions adopted in the particular structure are available, then estimate of concrete strength can be made by establishing suitable correlation between the pulse velocity and the compressive strength of concrete specimens made with such material and mix proportions, under environmental conditions similar to that in the structure. The estimated strength may vary from the actual strength by ± 20 percent
- When variation in properties of concrete affect the test results, (especially in opposite directions), the use of one method alone would not be sufficient to study and evaluate the required property. Therefore, the use of more than one method yields more reliable results. For example, the increase in moisture content of concrete increases the ultrasonic pulse velocity but decreases the rebound number. Hence, using both methods together will reduce the errors produced by using one method alone to evaluate concrete. Attempts have been done to relate rebound number and ultrasonic pulse velocity to concrete strength. Unfortunately, the equation requires previous knowledge of concrete constituents in order to obtain reliable and predictable results.
- The pulse velocity method is an ideal tool for establishing whether concrete is uniform. It can be used on both existing structures and those under construction. Usually, if large differences in pulse velocity are found within a structure for no apparent reason, there is strong reason to presume that defective or deteriorated concrete is present. Fairly good correlation can be obtained between cube compressive strength and pulse velocity. These

relations enable the strength of structural concrete to be predicted within ±20 per cent, provided the types of aggregate and mix proportions are constant.

- Ultrasonic pulse velocity tests have a great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects. Its use for predicting strength is much more limited, owing to the large number of variables affecting the relation between strength and pulse velocity

Inference

Viva Questions

Why do we do UPV test on concrete?
Ultrasonic pulse velocity (UPV) test is used to check the quality of concrete also defects within concrete by passing electronic waves through the concrete. In general, UPV value increases with the increase in WFS content in concrete mixes as well as with age.

What will be the quality of concrete if the value of UPV test of concrete member is more than 4.5 km/sec ?
When UPV of concrete is higher than 4.5 km/s, the concretes are classified as good and high-quality concrete grade, the concrete are in a good concrete grade with UPV of 3.5–4.5 km/s

Can we use UPV to monitor the quality of concrete during construction?
UPV results can be used to check uniformity, detect voids or estimate the depth of a surface crack. Amongst well-known and commercially available NDT methods, UPV measurements can be considered as one of the most promising for the evaluation of concrete structures.

Which of the following NDT test is most commonly used?
Here are the eight most commonly used NDT techniques:

1. Visual NDT (VT)
2. Ultrasonic NDT (UT)
3. Radiography NDT (RT)
4. Eddy Current NDT (ET)
5. Magnetic Particle NDT (MT)
6. Acoustic Emission NDT (AE)
7. Dye Penetrant NDT (PT)
8. Leak Testing (LT)

What is the difference between destructive and non-destructive testing?
The difference between destructive and non destructive testing. Destructive testing is conducted by damaging the specimen that is being tested. In contrast, during non-destructive testing (NDT), the tested item does not suffer any physical damage and can be used in active operation after the testing.

Why is destructive testing so important?
The purpose of destructive testing is ultimately to understand how a material will react to extreme stress or loads. Knowing how much stress a material can withstand before complete failure is critical when planning on using that material for key engineering design, manufacturing processes, and product design.

Why is NDT test done in concrete?
Non-destructive testing methods are used to evaluate concrete properties by assessing the strength and other properties such as corrosion of reinforcement, permeability, cracking, and void structure. This type of testing is important for the evaluation of both new and old structures.

Why is 28 days compressive strength cement concrete taken as the standard in the civil engineering construction industry?
The 28 day strength of concrete is the reference strength used in the design of (reinforced) concrete structures and is also the required strength in the quality control of concrete production. However it bears little resemblance to the actual strength of the concrete in service because the curing regime is completely different; concrete quality control test

specimens are cured under water for 28 days as a way of standardising the curing process. 28 days was chosen because concrete reaches about 90% of its full strength after this time and allows any fluctuations of strength gain during the curing process to even out. The 7 day strength is also a useful guide of when the formwork can be stripped because at this stage the concrete carries only its self weight and no imposed load.

Why compressive test on cubes is not done on the casting side, and rather can be done on all remaining side?

Ans: Actually what happens when we cast cube samples, it's top surface is finished manually, whereas all the remaining surfaces are levelled by itself because of mould faces and tamping by tamping rod, so this top surface may have some undulations (You may observe this on the sample). So when you put this manually finished face of cube on top or bottom in CTM, the upper or lower plate may not fit properly and the contact area between cube sample and plates will be changed and the value which we will calculate will not be accurate.

Experiment No.: 9

FLOW TESTS ON SELF COMPACTING CONCRETE
(As per EFNARC Guideline)

(A). SLUMP FLOW TEST

Objective
To investigate the filling ability by measure the slump flow value

Apparatus
1. Base plate of size at least 900 × 900 mm
2. Abrams cone with the internal upper/lower diameter equal to 100/200 mm and the height of 300 mm
3. Weight ring (>9 kg) for keeping Abrams cone in place during sample filling
4. Stopwatch
5. Ruler (graduated in mm)
6. Bucket with a capacity of larger than 6 liters
7. Moist sponge or towel for wetting the inner surface of the cone

Theory
Self-compacting concrete (SCC) 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. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.
Workability tests on Self-Compacting Concrete are slightly different from the tests that are conduction on normal concrete. There are three basic characteristics of self-compacting concrete namely filling ability (flowability), passing ability (free from blocking due to the presence of reinforcement), and resistance to segregation (stability/homogeneity). Therefore, it is very necessary to carry out field or mock trials to assess these characteristics. Unfortunately, so far not a single test has been devised to confidently measure anyone of these properties. A number of tests have been developed and used by many organizations but all these tests are elementary in nature and none of the tests have been standardized.
The most commonly used tests are the Slump Flow Test, V Funnel Test, L Box Test, 'U' Box Test, and Fill Box Test. In addition to these tests, there are other tests like the 'J' ring test, etc. Slump Flow Test is one of the simplest tests initially developed in Japan for the assessment of underwater concrete. It is the most commonly used test for SCC and gives a good assessment of filling ability. However, it gives no indication of the ability of the concrete to pass between the reinforcement without blocking but may give some indications of resistance to segregation. This test can be used at the site to assess the consistency of supply of ready-mix concrete, which has been designed after assessment of various characteristics based on the above-mentioned five tests or more. The centre of the plate is marked with circles of 210 ± 1 mm diameter and 500 ± 1 mm as shown below:

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Place the sample in the cone and fill the cone steadily up to top of cone without any compaction. Lift the cone vertically in 1s to 3s and start the stopwatch. Note the time taken to touch the 500 mm circle on base plate. Measure the dimension of stabilised flow circle in two directions and get the average flow. A high slump flow value indicates greater flowability and lesser resistance to segregation. If the time value is observed to be less than the minimum range value specified then it indicates that viscosity is very low leading to segregation. If the time value is observed to be more than the maximum range value specified, it indicates very stiff and non-flowable concrete. The permissible range of values for slump flow is 650 mm to 800 mm. It is the most commonly used test, and gives a good assessment of filling ability. The T50 time is secondary indication of flow. A lower time indicates greater flow ability. In case of severe segregation most coarse aggregate will remain in the centre of the pool of concrete and mortar and cement paste at the concrete periphery.

Determination of Visual Stability Index (VSI) for Self-Compacting Concrete is the best practice adopted for self-consolidating concrete. Visual Stability Index (VSI) – The stability of self-consolidating concrete can be assessed by visually evaluating the distribution of the coarse aggregate within the concrete mass after the spreading of the concrete has stopped.

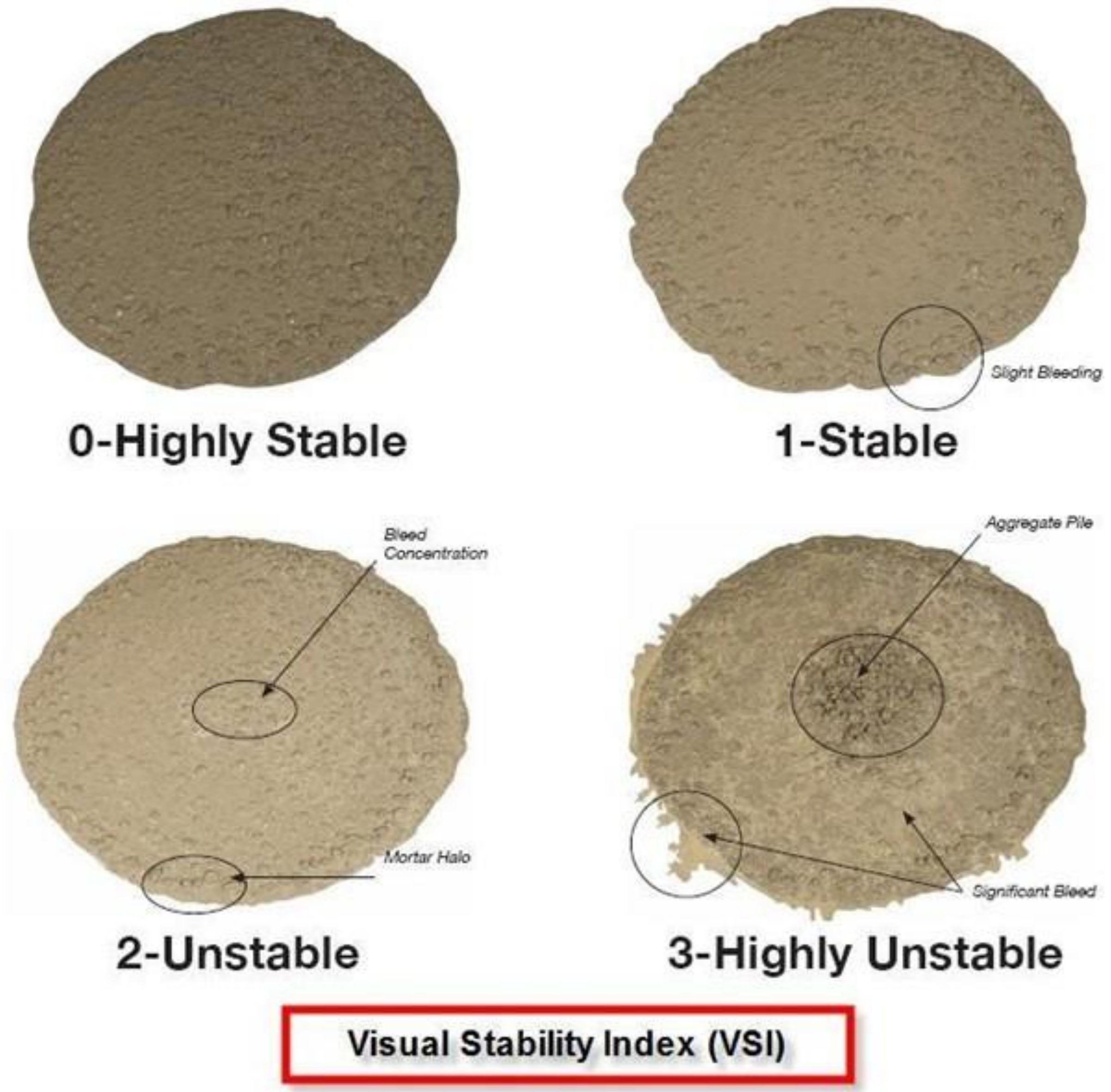
The VSI values range from 0 to 3 and are defined as follows:

0 = Highly Stable – No evidence of segregation or bleeding.

1 = Stable – No evidence of segregation and slight bleeding observed as a sheen on the concrete mass.

2 = Unstable – A slight mortar halo (≤ 10 mm) and/or aggregate pile in the centre of the concrete mass.

3 = Highly Unstable – Clearly segregated by evidence of a large mortar halo (≥ 10 mm) and/or a large aggregate pile in the center of the concrete mass



- VSI values of 0 or 1 indicate acceptable SCC.
- VSI values of 3 clearly indicate SCC that should be rejected.
- VSI values of 2 indicate that the concrete is unstable, and the mix design should be immediately modified to obtain a VSI value of 0 or 1.

Procedure

The procedure for execution of this test is as follows:

1. About 6 liter of concrete is needed to perform the test, sampled normally. Moisten the base plate and inside of slump cone, place base plate on level stable ground and the slump cone centrally on the base plate and hold down firmly.
2. Position the slump cone at center of the levelled flow table (base plate).
3. Pour the concrete with a scoop from top without any tamping to fill the slump cone completely. Strike off excess concrete.
4. Lift the cone vertically without any jerks and allow the concrete to flow freely on leveled surface.
5. Note the time required for the concrete to flow 50 cm diameter spread circle. The time is measured from the time lifting cone starts. The slump flow test is used assess the horizontal free flow of self-compacting concrete in the absence of obstructions. The slump flow time (T50 or T500) is the time taken for the concrete to spread by 50 cm.

6. After that measure the average flow diameter of concrete after concrete stops flowing. This value in mm is known as slump flow value (mm). Slump flow is the mean diameter in two perpendicular directions of the concrete spread after the concrete had stopped flowing.
   6. Measure the largest diameter of the flow spread, *d*max, and the one perpendicular to it, *d*perp, using the ruler (reading to nearest 5 mm). Care should be taken to prevent the ruler from bending.

Observation And Calculations

Date of Test:		Mixing time:	
Mix No.:	Reading 1	Reading 2	Average Value
Slump flow (mm)			
T50 or T500			
Concrete temperature			
VSI			

a. The slump flow spread *S* is the average of diameters *d*max and *d*perp, as shown in Equation. *S* is expressed in mm to the nearest 5 mm

b. The slump flow time T50 is the period between the moment the cone leaves the base plate and SCC first touches the circle of diameter 500 mm. T50 is expressed in seconds to the nearest 1/10 seconds

$$S = \frac{d_{max} + d_{perp}}{2}$$

Result

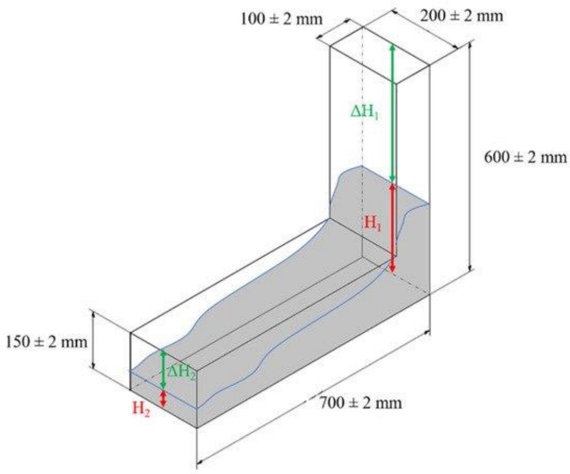
The slump flow value for the concrete is____________

Inference

<u>**(B) L BOX TEST**</u>

Objective
To determine the passing ability of SCC by means of L Box method

Apparatus
1. Two types of gates can be used, one with 3 smooth bars and one with 2 smooth bars. The gaps are 41 and 59 mm, respectively
2. Suitable tool for ensuring that the box is level i.e. a spirit level
3. Suitable buckets for taking concrete sample



Theory
The L Box test for self-compacting concrete is based on a Japanese design for underwater concrete, has been described by Peterson. L-Box test is used mainly to assess the passing and filling ability of Self Compacting Concrete. The apparatus consists of an “L” shaped rectangular box section. This method aims at investigating the passing ability of SCC. It measures the reached height of fresh SCC after passing through the specified gaps of steel bars and flowing within a defined flow distance. With this reached height, the passing or blocking behavior of SCC can be estimated. The test assesses the flow of the concrete and also the extent to which it is subjected to blocking by reinforcement. The vertical section is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section. It indicates the slope of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted. The horizontal section of the box can be marked at 200mm and 400mm from the gate and the times taken to reach these points measured. These are known as the T20 and T40 times and are an indication for the filling ability. The section of bar can be of different diameters and are spaced at different intervals, in accordance with normal reinforcement considerations, 3x the maximum aggregate size might be appropriate. The bar can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. Concrete is designed to pass through the obstructions of known clearances. The vertical section is filled with concrete and the gate is lifted to let the concrete flow into the horizontal section through the vertically placed steel bars. When the flow stops the height of the concrete h2 at the end of the flow is measured along with height h1 in the vertical box next to the obstruction. The ratio h2/h1 is a measure of the passing ability of SCC. The blocking value for SCC should be between 0.80 to 1.0. if the blocking value is less than 0.80 it indicates viscosity is too high. A ratio close to 1, indicates false results. Both passing ability and segregation resistance can be detected during the test visually also. If concrete builds a plateau in front of reinforcement bars, concrete has either got blocked or has segregated. This is a widely used test, suitable for laboratory and perhaps

site use. It assess filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately there is no arrangement on materials or dimensions or reinforcing bar arrangement, so it is difficult to compare test results. There is no evidence of what effect the wall of the apparatus and the consequent 'wall effect' might have on the concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork. Two operators are required if times are measured, and a degree of operator error is inevitable. Fill the vertical section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Simultaneously, start the stopwatch and record the time for the concrete to reach the concrete 200 and 400 marks. When the concrete stops flowing, the heights 'H1' and 'H2' are measured and calculate H2/H1, the blocking ratio. The whole test has to be performed within 5 minutes. If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1=1. Therefore the nearest this test value, the 'blocking ratio', is unity, the better the flow of concrete. The EU research team suggested a minimum acceptable value of 0.8. T20 and T40 time can give some indication of ease of flow, but no suitable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcement bars can be detected visually.

Procedure

1. Place the L-box in a stable and level position. About 14 litre of concrete needed to perform the test, sampled normally
2. Fill the vertical part of the L-box, with the extra adapter mounted, with 12.7 liters of representative fresh SCC
3. Let the concrete rest in the vertical part for one minute (± 10 seconds). During this time the concrete will display whether it is stable or not (segregation).
4. Lift the sliding gate and let the concrete flow out of the vertical part into the horizontal part of the L-box.
5. When the concrete has stopped moving, measure the average distance, noted as Δh, between the top edge of the box and the concrete that reached the end of the box, at three positions, one at the centre and two at each side

Observations And Calculations

The passing ratio P_L or blocking ratio B_L is calculated using below equations, and expressed in dimensionless to the nearest 0.01

$$P_l = \frac{H}{H_{max}} \quad \text{or} \quad B_l = 1 - \frac{H}{H_{max}}$$

where Hmax = 91 mm and $H = 150 - \Delta h$

Result

The passing ratio P_L is_____________

Blocking ratio B_L is_____________

Inference

(C) V FUNNEL TEST

Objective
To assess the flowability and also segregation resistance of Self Compacting Concrete.

Apparatus

1. V-funnel, , made of steel, with a flat, horizontal top and placed on vertical supports, and with a momentary releasable, watertight opening gate
2. Stopwatch with the accuracy of 0.1 second for recording the flow time
3. Straight edge for levelling the concrete
4. Buckets with a capacity of 12∼14 litres for taking concrete sample
5. Moist sponge or towel for wetting the inner surface of the V-funnel

Theory
The V-funnel flow time is the period a defined volume of SCC needs to pass a narrow Opening and gives an indication of the filling ability of SCC provided that blocking and/or Segregation do not take place; the flow time of the V-funnel test is to some degree related to the plastic viscosity. The test was developed in Japan and used by Ozawa et al. The described V-funnel test is used to determine the filling ability (flowability) of the concrete with a maximum aggregate size of 20mm. Fill the apparatus completely with the concrete without compacting or tamping; simply strike off the concrete level with the top with the trowel.The funnel is filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled with concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increases significantly. High flow time can also be associated with low deformability due to a high paste viscosity, and with high inter-particle friction. While the apparatus is simple, the effect of the angle of the funnel and the wall effect on the flow of concrete is not clear.
Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity. Start the stopwatch when the trap door is opened, and record the time for the complete discharge (the flow time). This is taken to be when light is seen from above through the funnel. The whole test has to be performed within 5 minutes. If ‘V’ funnel results are less than 8 sec, decrease the water/powder ratio in the mix. If it is more than 12 sec., increase the water/powder ratio.
To know the flow time at T5 minutes, do not clean or moisten the inside surface of the funnel gain. Close the trapdoor and refill the V-funnel immediately after measuring the flow time. Place a bucket underneath. Fill the apparatus completely with concrete without compacting or tapping, simply strike off the concrete level with the top with the trowel. Open the trapdoor 5 minutes after the second fill of the funnel and allow the concrete to flow out under gravity. Simultaneously start the stopwatch when the trap door is opened and record the time discharge to complete flow (the flow time at T5 minutes). This is to be taken when light is seen from above through the funnel. This test measures the ease of flow of concrete, shorter flow time indicates greater flow ability. For SCC

a flow time of 10 seconds is considered appropriate. The V-funnel flow time T_V is the period from releasing the gate until first light enters the opening, expressed to the nearest 0.1 second

Procedure

1. Position the ‘V’ funnel along with supporting arrangement on firm or level ground.
2. Moisten the internal surface thoroughly with a wet sponge and close the trap door.
3. Pour the concrete from the top of the funnel without any external efforts either to compact or level it.
4. Open the trap door as quickly as possible after filling the funnel without giving any jerk to the test setup.
5. Note the time required to empty the funnel completely in seconds, which is T_0.
6. Repeat the same procedure with only change that the trap door is opened after 5 minutes of filling completely and note the time required to empty the funnel completely in seconds, which is T_5.
7. As per the present guidelines, T_0 from the test should be in the range of 8 to 12 seconds and T_5 should be less than 3 seconds over T_0.
8. If T_5 is more than 3 seconds over T_0 then there are chances that the SCC mix will segregate.

Result

The V-funnel flow time, T_V in seconds is____________________.

(D) U BOX TEST

Objective

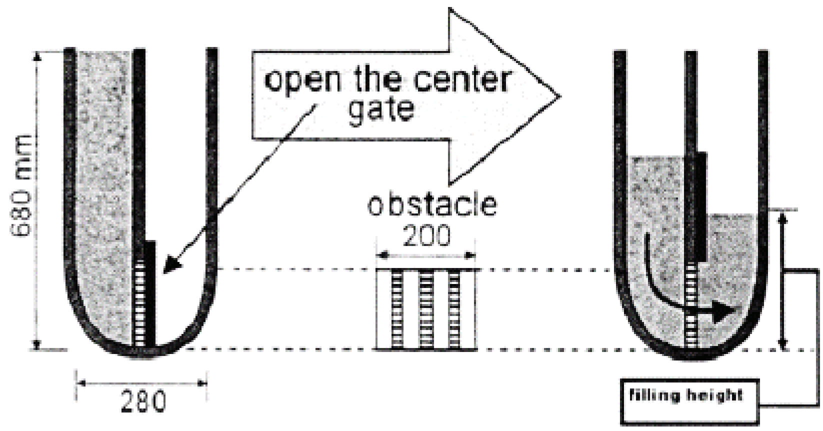
To measure the filing and passing ability of self-compacting concrete.

Apparatus

1. U Box apparatus
2. Stopwatch with the accuracy of 0.1 second for recording the flow time
3. Straightedge for leveling the concrete
4. Buckets with a capacity of 12~14 liters for taking concrete sample
5. Moist sponge or towel for wetting the inner surface of the U-Box.

Theory

U box test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Sometime the apparatus is called a “box shaped” test. U Box test is used to measure the filing and passing ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments; an opening with a sliding gate is fitted between the two sections. Reinforcing bar with nominal diameter of 134 mm are installed at the gate with centre to centre spacing of 50 mm. this create a clear spacing of 35 mm between bars. The left-hand section is filled with about 20 liter of concrete then the gate is lifted and the concrete flows upwards into the other section. The height of the concrete in both sections is measured. The permissible range for difference h1-h2is 30mm. a difference of more than 30mm indicates the possibility of blockage with viscosity being on the higher side. If h1-h2 is close to ‘0’, it indicates low viscosity and concrete could easily pass through. If the concrete flows as freely as water, at rest it will be horizontal, so H1-H2=0. Therefore, the nearest this test value, the ‘filling height’, is to zero, the better the flow and passing ability of the concrete. This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of filling ability. This is literally what the concrete has to do, modified by an unmeasured requirement for passing ability. The 35 mm gap between the sections of reinforcement may be considered too close. The question remains open of what filling height less than 30 cm is still acceptable.



Procedure

1. Place the ‘U’ box on firm/level ground. Moisten the internal surface thoroughly and close the central door.
2. About 20 liter of concrete is needed to perform the test, sampled normally. Fill the vertical section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the other compartment.
3. Gently wipe the slurry adhered to the face of the left compartment without disturbing the top surface of the concrete to enhance the visibility.
4. After the concrete has come to rest, measure the height of the concrete in the compartment that has been filled, in two places and calculate the mean (H1). Measure also the height in the other

equipment (H2). Calculate H1-H2, the filling height. The whole test has to be performed within 5 minutes.

Observations

H1=

H2=

H2- H1=

Result

The time in seconds for passing ability by U Box test is________________________________.

Inference

(E) J RING TEST

Objective

To assess the passing ability of the concrete

Apparatus

1. J Ring apparatus set up with slump cone
2. Stopwatch with the accuracy of 0.1 second for recording the flow time
3. Straightedge for levelling the concrete

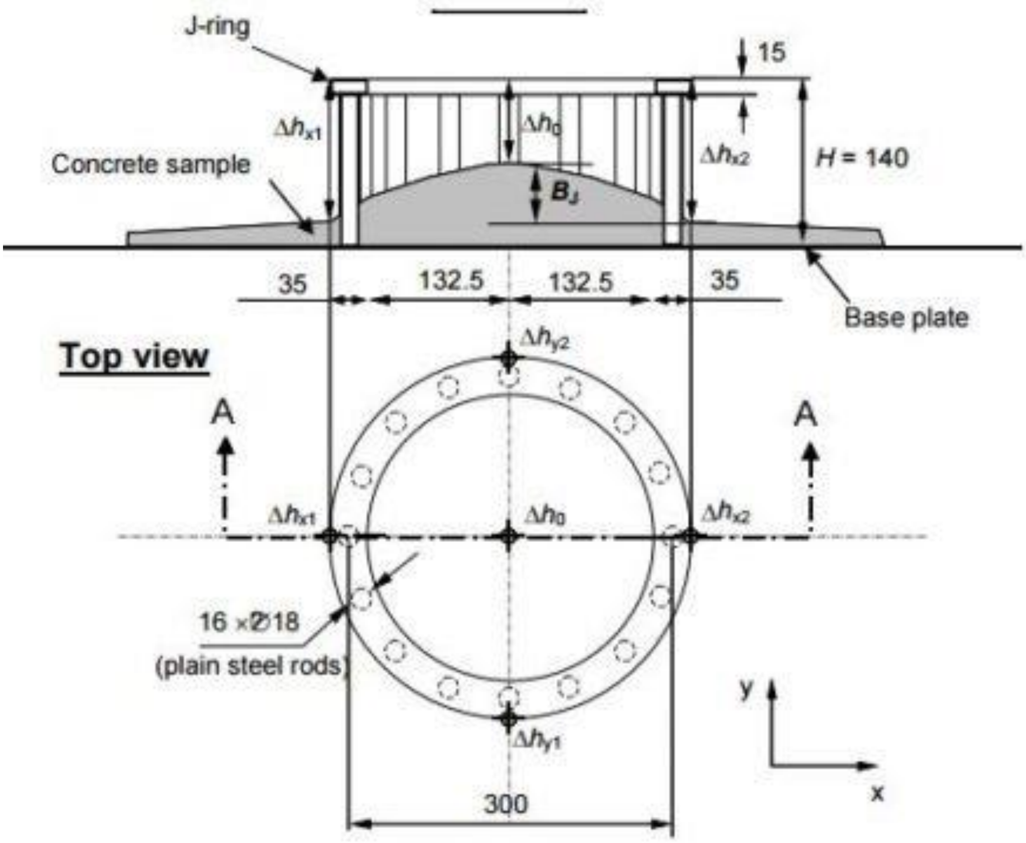
4. Buckets with a capacity of 12∼14 litres for taking concrete sample
5. Moist sponge or towel for wetting the inner surface of the V-funnel

Theory

The equipment consists of a rectangular section of 30 mm x 25 mm open steel ring drilled vertically with holes to accept threaded sections of reinforcing bars 10 mm diameter 100 mm in length. The bars and sections can be placed at different distances apart to simulate the congestion of reinforcement at the site. Generally, these sections are placed 3 x maximum size of aggregate. The diameter of the ring formed by vertical sections is 300 mm and height 100 mm.



The usual slump cone having a base diameter of 200 mm, top dia. 100 mm, and height 300 mm are used. Base Plate For J-ring Test is a stiff base plate square in shape is having at least a 700 mm side. Concentric circles are marked around the center point where the slump cone is to place. A firm circle is drawn at 500 mm diameter.



Procedure

1. Place the instrument on the stable, flat ground and also place the slump cone vertically. About 6 liters of concrete is needed for the test.
2. Moisten the inside of the slump cone and base plate.
3. Place the J-Ring centrally on the base plate and the slump cone centrally inside the J-ring. Fill the slump cone with a scoop. Pour the prepared sample of SCC into slump cone through the funnel by holding the slump cone. Do not tamp. Simply strike off the concrete level with a trowel. Remove all surplus concrete.
4. After filling the slump cone fully with SCC, slowly lift up. Raise the cone vertically and allow the concrete to flow out through the J-ring
5. Switch on the stop watch immediately after lifting up the slump cone.
6. Note down the time of flow when it reaches the outer line.
7. The J-ring flow spread SJ is the average of diameters dmax and dperp, SJ is expressed in mm to the nearest 5 mm.
8. The J-ring blocking step BJ is calculated as, BJ = (Δhx1+ Δhx2+ Δhy3+ Δhy2) / 4 -Δh0

   Where Δhx1 and Δhx2 are height differences between the lower edge of the straight rod and the concrete surface in the x-direction, Δhy1 and Δhy2 are height differences between the lower edge of the straight rod and the concrete surface in the y-direction (perpendicular to x as shown in the figure), Δh0 is the height difference between the lower edge of the straight rod and the concrete surface at the central position. Calculate the average of the difference in height at four locations in mm. The acceptable difference in height between inside and outside should be between 0 and 10 mm.

Observations

The J-ring flow spread SJ is the average of diameters dmax and dperp, SJ is expressed in mm to the nearest 5 mm.

SJ = (dmax + dperp) /2 = _________ mm

The J-ring blocking step BJ is calculated as, BJ = (Δhx1+ Δhx2+ Δhy3+ Δhy2) / 4 -Δh0

BJ = ________ mm

Calculate the difference between slump flow and J ring flow

Result

The flow spread SJ = _________ mm
The blocking step BJ = ________ mm
Difference between SJ and BJ=______mm

Inference

The difference between the slump flow and J-Ring flow is an indication of the passing ability of the concrete. A difference less than 25 mm indicates good passing ability and a difference greater than 50 mm indicates poor passing ability. The orientation of the mold for the J-Ring test and for the slump flow test without the J-Ring shall be the same.

This test method is limited to self-consolidating concrete with nominal maximum size of aggregate of up to 25 mm.

Viva Questions

What are the key benefits of Self Compacting Concrete?

1. Eliminate the need for internal vibration of the concrete.
2. Ease of placement and workability.
3. Ability to pass congested reinforcing steel in composite construction.
4. SCC use increase the progress of work by reducing time.
5. Low manpower requirement.
6. It has good pumpability.
7. Characteristics of the concrete gets improved.

What is Self-Compacting Concrete (SCC)?

SCC is an innovative concrete that does not require vibration for placing and compaction. It can flow under its own weight, completely filing formwork and achieving full compaction, without segregation, even in the presence of congested reinforcement.

What are the requirements of Self-Compacting Concrete (SCC)?

Passing Ability — Ability of fresh concrete to flow through tight openings such as spaces between steel reinforcing bars.
Powder Content — Powder content includes the materials of particle size smaller than 0.125 mm. It includes this size fraction in the cement, mineral admixtures and aggregate.
Segregation Resistance — The ability of concrete to remain homogeneous in composition while in its fresh state.

What is T_{500}.?

The time of spreading in diameter of 500 mm is noted during the flow process and it is called as T_{500}. The measurement of slump flow is taken twice in perpendicular direction and averaged out to find the mean flow.

What is the need for development of self-compacting concrete?

The concept of Self-compacting was proposed in 1986 by Professor Hajime Okamura. However the prototype was first developed in 1988 in Japan, by Professor Ozawa at the University of Tokyo. Self-Compacting Concrete is a High-Performance Concrete, which distinguishes itself with self-consolidation properties with high flowability. As the name suggests, it does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete. SCC has an improved quality of concrete and reduction of on-site repairs, faster construction times, lower overall costs and facilitation of introduction of automation into concrete construction. An important improvement of health and safety is also achieved through elimination of handling of vibrators and a substantial reduction of environmental noise loading in and around the site. The composition of SCC mix includes substantial proportion of fine-grained inorganic materials and this gives possibilities for utilization of mineral admixtures, which are currently waste products with no practical applications and are costly to dispose off. Due to its specific properties, SCC may contribute a significant improvement of the quality of concrete structure and open up new fields for the application of concrete and offer a rapid rate of concrete placement, with faster construction times and compacts into every corner of a formwork. It is also referred as self-leveling concrete, super workable concrete, self consolidating concrete, high flowability concrete, non-living concrete, etc.

List testing methods for workability properties of SCC

1. Slump-flow by Abrams cone -Filling ability
2. T50cm slump flow- Filling ability
3. J-ring- Passing ability

4. V-funnel-Filling ability
5. V-funnel at T5minutes-Segregation resistance
6. L-box-Passing ability
7. U-box-Passing ability

What is the acceptance test criteria for self-compacting concrete?

Typical acceptance test criteria for SCC with a maximum aggregate size up to 20mm are given in the below table.

Sr. No	Test	Unit	Acceptable Range of Values
1	Slump Flow Test T 50cm slump flow	mm sec	650-800 2-5
2	V Funnel T0 V Funnel T5	sec Increase over in sec.	8-12 sec 0-3 sec
3	L Box (h2/h1)	Ratio	0.8-1.0
4	U Box (h1-h2)	mm	30 maximum
5	J Ring	mm	0-10

There is no Indian Standard (BIS) on SCC so the above limits are as per EFNARC guidelines.

What is the difference between self-compacting concrete and normal concrete?

One of the key differences between the self-compacting concrete (SCC) and normal cement concrete (NCC) is the flowability property of SCC by it's on weight. Most of the differences shown by SCC is due to this variation of flowability from the normal concrete.

What is the slump value of self compacting concrete?

The minimum value of slump is to be 650mm and the maximum value 800 mm for a fresh SCC.

Experiment No- 10

AIR CONTENT OF FRESH CONCRETE
(As Per IS 1199 Part 4 -2018)

Objective
To determining the air content of freshly mixed concrete from observations of the change in volume with a change in pressure.

Apparatus

1. Air entrainment meter - a device incorporating a measuring bowl of sufficiently rigid construction to make a pressure-tight container of accurate volume and suitable to hold a representative sample of concrete. The bowl shall be fitted with a cover to provide an adequately rigid pressure-tight assembly. The volume of the measuring bowl shall be at least .006 cubic meters.
2. A calibration cylinder and adapters shall be provided.
3. Tamping rod - round, straight steel rod 16 mm in diameter and 600 mm in length with one end rounded to a hemispherical shape.
4. Trowel
5. Rubber mallet
6. Strike off bar
7. Scoop
8. Containers, etc.

Theory

- This method is to determine air content of freshly mixed concrete by pressure meter method. This method is considered adequate for all ordinary types of concrete, except for concrete or mortars made with highly porous aggregates.
- This method of test covers the determination the air content of freshly mixed concrete for all ranges of slump but not for non-plastic concrete such as is commonly used in the manufacture of pipe and concrete masonry units.
- This is the only method allowed for concrete containing aggregates greater than 40mm. This method shall only be used for concrete containing aggregates with absorption less than 4.0%.
- This method is not applicable to concrete made with lightweight aggregates or air-cooled blast furnace slag.
- The principle of this method consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample.
- The dial on the pressure gage shall be calibrated in terms of percent air for the observed pressure at which equalization takes place

Watch this video:
https://www.youtube.com/watch?v=JNym1l1rzDs

Calibration Test to Check the Air Content Graduations on the Pressure Gage

- Fill the measuring bowl with water. Screw the short piece of tubing or pipe furnished with the apparatus into the threaded petcock hole on the underside of the cover assembly.
- Assemble the apparatus. Close the air valve between the air chamber and the measuring bowl and open the two petcocks on holes through the cover assembly.
- Add water through the petcock on the cover assembly having the extension below until all air is expelled from the second petcock.
- Pump air into the air chamber until the pressure reaches the indicated initial pressure line.
- Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gage hand at the initial pressure line by pumping or bleeding off air as necessary tapping the gage lightly. Close the petcock opposite the tube or pipe extension on the under side of the cover.
- Remove water from the assembly to the calibrating vessel controlling the flow.
- Perform the calibration at an air content which is within the normal range of use.
- With some meters, the calibrating vessel is quite small and it will be necessary to remove several times that volume to obtain air content within the norm range of use. In this instance, carefully collect the water in an auxiliary container and determine the amount removed by weighing to the nearest 0.1%. Calculate the correct air content, R.
- Release the air from the apparatus at the petcock not used for filling the calibration vessel.
- Pump air into the air chamber until the pressure reaches the initial pressure line marked on the pressure gage, close both petcocks in the cover assembly, and then open the valve between the air chamber and the measuring bowl.
- If two or more determinations show the same variation from the correct air content, reset the dial hand to the correct air content and repeat the test until the gage reading corresponds to the calibrated air content within 0.1%.
- If the dial hand was reset to obtain the correct air content, recheck the initial pressure mark.
- If a new initial pressure reading is required, repeat the calibration to check the accuracy of the graduation on the pressure gage described earlier

Determine the aggregate correction factor, G, on a combined sample of fine and coarse aggregated as follows:

- Mix representative samples of fine aggregate of weight, Fs, and coarse aggregate of weight, Cs, and place in the measuring bowl.
- Fill the bowl ⅓ full of water.
- Add the mixed aggregate a small amount at a time until all of the aggregate is covered with water.
- Add each scoopful in a manner that will entrap as little air as possible and remove accumulations of foam promptly.
- Tap the sides of the bowl and lightly rod the upper inch (25mm) of the aggregate about 10 times and stir after each addition of aggregate to eliminate entrapped air.
- When all aggregate has been placed in the bowl and allowed to soak for at least 5 minutes, strike off all foam and excess water.
- Thoroughly clean the flanges of both the bowl and conical cover so that when the cover is clamped in place, a pressure-tight seal will be obtained.
- Attach the cover assembly to the measuring bowl.
- With both petcocks open, pump air into the air chamber until the predetermined initial pressure line is reached.
- Close both petcocks and open the main air valve between the air chamber and measuring bowl.
- Read the air content scale and record as the aggregate correction factor, G.

Precautions

- If difficulty is encountered in obtaining consistent readings, check for leaks, for the presence of water inside the air chamber, or the presence of air bubbles clinging to the inside surfaces of the meter from the use of cool aerated water. In this latter instance, use de-aerated water which can be obtained by cooling hot water to room temperature.
- Ensure all petcocks and bleeder valves are closed to prevent water from entering pump chamber.
- The aggregate correction factor must be determined for each portland cement concrete mix design, at the beginning of each project, or whenever there is a change in the aggregate properties

Sample

Obtain a representative sample of the concrete to be tested and meet the minimum sample quantity of 0.01 cu.m.

Procedure

1. Place a representative sample of the concrete in the measuring bowl in three equal layers.
2. Each layer in the bowl will be rodded 25 times evenly distributed over the cross-section.
3. In rodding the first layer, the rod will not forcibly strike the bottom of the bowl.
4. In succeeding layers, the rodding will penetrate only slightly into the next lower layer.
5. Smartly tap the side of the bowl ten to fifteen times with the mallet after rodding until the cavities left by rodding are levelled out and no large bubbles of air appear on the surface.
6. Remove the excess concrete by sliding the strike-off bar across the top flange with a sawing motion until the bowl is just level full.
7. Clean the edges of the bowl and cover.
8. Clamp the cover tightly in place to form a pressure tight seal with petcocks open.
9. Close the outer valve and open the inner valve to fill the apparatus with water and tap lightly with the mallet to remove the air adhering to the interior surfaces of the cover.

10. Bring the level of water in the standpipe to zero by bleeding through the outer valve with the air vent open. Lightly tap sides and then add more water to expel air and make sure level of water is at zero.
11. Apply pressure using built-in pump, which pushes water into the concrete as evident form the change in water level in standpipe. Apply the desired pressure (0.02 kg/cm²) with the help of rubber bulb.
12. Apply pressure till water level won't move down anymore. Reading at pressure (h1) is noted down (say 2.6%) then release the pressure and take the reading (h2) (say 0.2%). Apparent air content (A_1) =h1-h2=2.6-0.2=2.4%
13. Remove the cover. Obtain the sample of aggregate by washing the cement through a 150-micron sieve from the concrete sample tested.
14. Partially fill the container of the apparatus with water, then introduced the combined sample of aggregate in small scoopfuls. Tap gently on all sides with mallet to expel air trapped. If necessary, add additional water to inundate all of the aggregate.
15. When all the aggregate has been placed in the container and inundated for at least 5 min. Wipe and clean the flanges of the container and the cover assembly thoroughly.
16. Clamp the cover assembly into position, so that a pressure tight seal is obtained. Open the entry valve and fill up the water. Release the water by opening the valve so that water level comes to zero in graduated water column. Now apply pressure. After applying pressure reading h1 is noted down (say 0.4%)
17. Now release the pressure and take reading. After release of pressure the reading h2 is 0%. Aggregate correction factor(G)= h2-h1=0.40-0=0.40
18. Air content of the sample tested (A) can be found as A= A_1-G=2.4-0.4=2.0%

Calculation

Calculate the air content of the concrete as follows:

$$\boldsymbol{A = A_1 - G}$$

Where,

A=air content, percentage by volume of concrete,.

A_1=apparent air content; percentage by volume of concrete

G = aggregate correction factor, percentage by volume of concrete (Determined as per **IS 1199:1959**)

$$A = \frac{\text{Air content}}{\text{Volume of concrete}} \times 100\%$$

$$a_1 = \frac{\text{Apparent air content}}{\text{Volume of concrete}} \times 100\ \%$$

$$g = \frac{\text{Aggregate correction factor}}{\text{Volume of concrete}} \times 100\ \%$$

Observations

Date of test:

SL.No.	Type	Apparent air content (A_1)			G			A
		h1	h2	A_1=h1-h2	h1	h2	A_1=h1-h2	
1	Sample 1							
2	Sample 2							
3	Sample 3							

Results:

The air content will be reported as percentage by volume of concrete, Air content of the given sample is_____%.

Viva Questions

1. What is air-entrained concrete used for?

Ans: The primary use of air-entraining concrete is for freeze-thaw resistance. The air voids provide pressure relief sites during a freeze event, allowing the water inside the concrete to freeze without inducing large internal stresses. Another related use is for deicer-scaling resistance.

2. Distinguish between entrapped air and entrained air?

Ans: Entrained air refers to microscopic air bubbles intentionally incorporated into concrete during mixing, usually by use of a surface-active agent. ... By contrast, entrapped air voids are present in all concrete, irregular in shape, typically larger than 1mm.

3. What is meant by entrapped air?

Ans: Entrapped air is created during improper mixing, consolidating and placement of the concrete. Air pockets, or irregularly sized air voids, are spread throughout the concrete and have negative effects on product appearance, strength and durability.

4. Why do you test for air in concrete?

Ans: The primary purpose of entraining air in concrete is to increase its durability when exposed to freeze/thaw cycles with water present. Air-entraining admixtures for concrete create small, uniform, and stable air bubbles from around 0.01mm to 1mm diameter in the cement matrix throughout a concrete mix.

5. What are the limitations of determining the air content using pressure meter method ?

Ans: This method is considered adequate for all ordinary types of concrete, except for concrete or mortars made with highly porous aggregates.

6. How does air content affect concrete?

Ans: They increase the freeze-thaw durability of concrete, increase resistance to scaling caused by deicing chemicals, and improve workability. Air entrainment will reduce concrete strength. As a general rule, a 1% increase in the concrete air content will decrease the 28-day compressive strength by about 3 to 5%.

7. Why do we test for air content in concrete?

Ans: The primary purpose of entraining air in concrete is to increase its durability when exposed to freeze/thaw cycles with water present. Air-entraining admixtures for concrete create small, uniform, and stable air bubbles from around 0.01mm to 1mm diameter in the cement matrix throughout a concrete mix.

8. How do you reduce air voids in concrete?

Ans: Lower the viscosity of cement by adding sand or fly ash. This allows large aggregate to move more freely and reduces the amount of air entrapment. Use aggregate that is more uniform in shape. Irregular shaped pieces of aggregate tend to make the concrete less fluid.

9. What is concrete air content?

Ans: Concrete having a total air void content of about 6.5% seems optimal. A mix having 6.5% total air voids will have approximately 1.5% entrapped air voids and 5.0% entrained air voids.

10. How do you remove entrapped air from concrete?

Techniques used during vibration can eliminate most surface voids. Vibrating both the outside and inside of your mould will draw most air and water bubbles away from the surface of the concrete. Hammering the mould can eliminate any residual voids.

Experiment No: 11

MARSH CONE TEST
As per IS 9103:1999

Objective
To find the rheological properties of cements and mortars.

Apparatus
Marsh Cone (Conical brass vessel), Stop watch, Mortar mixer, Balance, Weights and Trays.

Theory

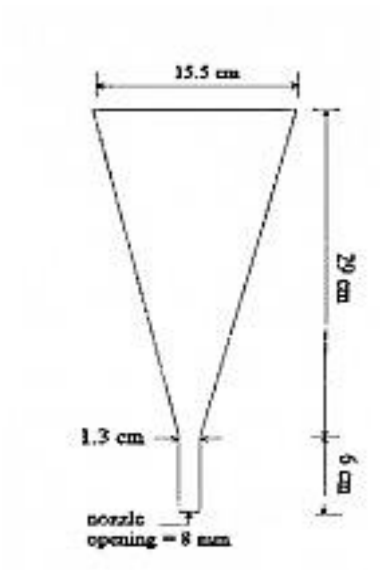
Marsh cone test is a test for finding the optimum dosage of plasticizers and superplasticizers for different types of cement. You know that the amount of plasticizers added to concrete ranges from 0.1 to 0.5 % of the total weight of cement. You have three tests to determine the optimum dosage content. They are

1. Marsh cone test
2. Mini-slump test
3. Flow table test

Marsh cone test is an easy test to study fluidity property of cement and mortar.
Apparatus needed for marsh cone test

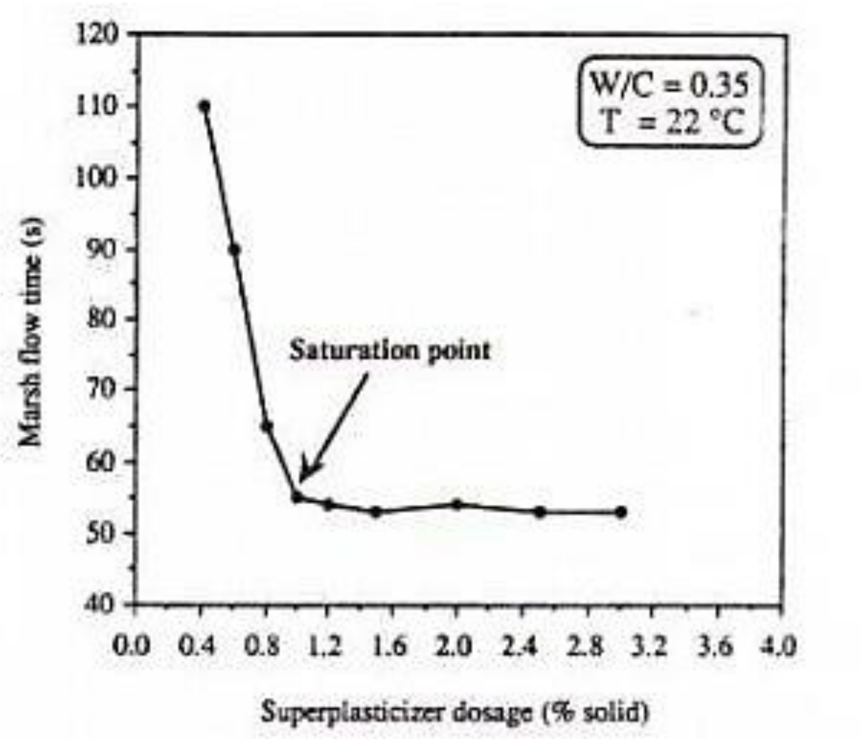
1. A conical brass vessel held on a wooden stand with a diameter of 5 or 8mm at its bottom.
2. Stopwatch
3. Mortar mixer to mix the cement paste with the desired water-cement ratio.

Flow time of Cement/Mortar through marsh cone is indicator of viscosity which depends upon cement super plasticizer compatibility. It is widely used to study cement super plasticizer compatibility and to determine optimum super plasticizer dosage of a specific cement super plasticizer combination. This test can be done for different water cement ratios, temperatures and admixtures. The saturation dosage of super plasticizer can be defined as that point beyond which there is no significant decrease in the flow time. Saturation point can be taken as the maximum super plasticizer content to be used in concrete.



Procedure

1. First, you need to prepare a cement paste of 1L with a desired water-cement ratio by adding 2kg of cement to them.
2. While preparing the cement paste, the mixing should take place in the mortar mixer. The mortar mixer is used to avoid the formation of lump at the bottom of the vessel.
3. You can take water cement ration ranging from 0.3 to 0.5.
4. 70 percent of water is added at the beginning of mixing in the first step and the remaining water is added in the second step with superplasticizers. The dosage of superplasticizer will be 0.1 percentage of the weigh of cement.
5. Take 1L slurry and pour into marsh cone by closing the aperture with a finger.
6. Start the stop and remove the finger. Note the time taken in seconds for complete flow out of cement paste. This time in seconds is called marsh cone time.
7. Repeat the above steps with different amount of plasticizer with the desired water-cement ratio. The Saturation point is the dose at which marsh cone time is lowest. This dose is the optimum dose of superplasticizer of plasticizer for that brand or type of cement.
You can do this experiment with different type of cement and find out the right amount of plasticizer for your brand of cement.
From the above the procedure you can plot a graph between marsh cone time in the x-axis and superplasticizer dosage percentage on the y-axis as given below. The longer the flow time, the lower is the fluidity.
The dose at which the Marsh cone time is lowest is called the saturation point. The dose is the optimum dose for that brand of cement and admixture (plasticizer or superplasticizer) for that w/c ratio.



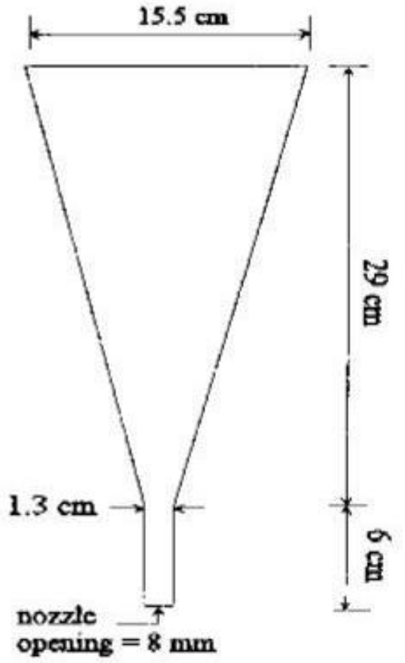
Observations

1. Observations for 0 minutes, 15 minutes and 60 minutes retention period are taken. 2. For first test, water cement ratio is kept as 0.55 and chemcial admixture dose of 0.2% is administered. Temperature is noted down
2. Mix the measured quantity of Cement, water and chemical admixture thoroughly in a mechanical mixer for two minutes. While mixing, first put the water in mixing bowl and then add 2 kg of cement to this water. Stir for 1 minute and then add chemical admixture dose and stirring operation is continued for next one minutes. Thus, slurry is formed.
3. Pour one liter slurry into marsh cone duly closing the aperture with a finger.

4. Start the stop watch and simultaneously remove the finger. Note the time taken for emptying the Marsh Cone. This time is called the "Marsh Cone Time"
5. Repeat the test for 15 minutes and 60 minutes retention period for same mix and duly noting Marsh Cone time. The mixture of cement and admixture should be kept stirred throughout the test.
6. Repeat the test for different plasticizer dosage i.e. 0.2% to 2.0% (AS per IS 456: 2000)
7. Different w/c ratio i.e. 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55 the whole procedure is repeated and for each combination of cement, water and plasticizer, saturation point is obtained. So recommendations can be made using this test on the dosage of SP for that particular cement.

Admixture type:

Marsh Cone Test						Saturation Point		
S.No.	W/C ratio	Cement (kg)	Water (L/kg)	Chemical admixture/Cement Ratio	Chemical Admixture (mg/ml)	Marsh Cone flow time (sec) After 0 min retention	Marsh Cone flow time (sec) After 0 min retention	Marsh Cone flow time (sec) After 0 min retention
1								
2								
3								

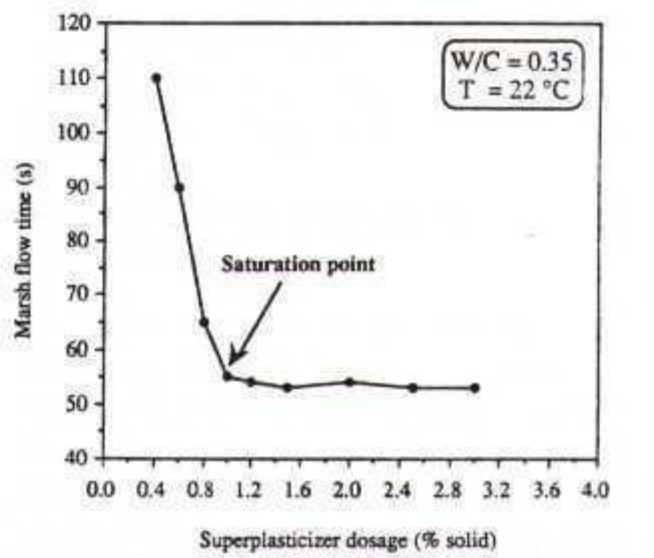


Application

1. Analytical method for determining the saturation point of superplasticizers in cement pastes
2. Test for Plasticizers and SuperPlasticizers

Procedure

1. Take 2kgs of the given cement and 1litre of water (w/c=0.5) for normal concrete. For high strength concrete take w/c ratio as 0.32 to 0.35.
2. Mix them thoroughly in a mechanical mixer (Hobart mixer) for 2minutes. Hand mixing does not give consistent results because of unavoidable lump formation which blocks the aperture. If hand mixing is done , the slurry should be sieved through 1.18 sieve to exclude lumps
3. Take one llitre of slurry and pour it into marsh cone duly closing the aperture with a finger.
4. Start a stop watch and simultaneously remove the finger. Find out the time taken in seconds for complete flow out of the slurry.
5. This time in seconds is called Marsh Cone Time.
6. Repeat the test with different dosages(in steps of 0.2%) of plasticizer or super plasticizer and plot a graph connecting Marsh cone time in seconds(Y-axis) and dosage of plasticizer or super plasticizer(X-axis).



Observations:

Saturation dosage of super plasticizer=

Saturation dosage of super plasticizer=

Inference

Viva Questions

What do you mean by compatibility of admixtures with cement?

Admixtures in concrete confer some beneficial effects such as air entrainment, water reduction, plasticity, etc. on the cement paste. Also setting time acceleration / retardation can be achieved by the use of admixtures. Addition of some particular admixture may develop undesirable interaction between varying ingredients of concrete. Many times addition of admixture beyond certain limit may show incompatibility. The term "incompatibility" has been applied to various types of abnormal performance characteristics of concrete in both plastic and hardened stages, including setting and strength gain issues, excessive slump losses and increased water demand. Marsh cone test is used to formulate the optimum dose of particular admixture to the cement thereby avoiding cement-admixture incompatibility. For high Strength concrete and high performance concrete, depending on location i.e. distance of site from the plant, the retention time of the concrete plays important role. Because of retention time, the workability of concrete mix is increased as well as other properties like flowability, setting time of concrete is enhanced.

What is the purpose of marsh cone test?

Marsh cone test is reliable and simple method to study the rheological properties of cements and mortars. Flow time of cement/mortar through marsh cone is indicator of viscosity, which depends upon cement superplasticizer compatibility. It is well known that workability of high performance concrete (HPC) is dependent on slump value of concrete mixture. Moreover, slump retention is the most sensitive compared to a well-known slump value because it represents the durability of concrete mixture for its applications in the field of civil engineering.

What is the importance of the marsh cone test?

In concrete mix design the superplasticizer dosage are fixed based on the composition of the paste (cement, water and chemical admixtures) with the maximum fluidity for a given water/cement ratio and a given chemical admixture/cement ratio. The characteristics of the fresh paste mostly govern the properties of the fresh concrete and this procedure will yield a concrete with the desired workability for a given aggregate content. The only variable in this process is the superplasticizer/cement ratio. Admixture manufacturers try to overcome compatibility problem by formulating project-specific chemicals. Obviously, this is only a short term solution. For a more comprehensive approach, the optimum dosage of chemical admixture is decided for each batch of cement and each admixture. To formulate this objective, a test known as "Marsh Cone Test" is performed. In this test, for particular w/c ratio, cement and admixture dosage, a optimum dose of that chemical admixture is found out. At optimum dose of admixture, cement-admixture paste is the most compatible to each other.
Cement superplasticizer interaction in concrete is a complex blend of chemical and physical mechanisms that are interdependent. The complicated nature of the problem prevents the development of simple solutions to address the field related issues of application of chemical admixtures. One such solution is to perform Marsh Cone Test on Cement Admixture sample.

Is marsh cone test a workability or quality control test?

The Marsh cone test is a workability test used for specification and quality control of cement pastes. Marsh cone test standard varies from one country to another, but its principle is usually the same. The time needed for a certain amount of material to flow out of the cone is recorded. This measured flow time is linked with the fluidity of the tested material. The longer the flow time, the lower is the fluidity. The Marsh cone test is a simple approach to get some data about cement pastes behaviour. It is used in cement based materials mix design in order to define the saturation point, i.e. the dosage beyond which the flow time does not decrease appreciably.

What do you mean optimum dosage of superplasticizer?
Mostly optimum admixture dose expressed as percentage of cement in concrete mix decreases with increase in retention time. As w/c ratio decreases, the optimum dose of admixture expressed as percentage of cement in concrete mix increases.
The addition of superplasticizers with mineral admixtures like fly ash, alccofine etc. to concrete imparts a high strength and workability to it, even at very small water cement ratios. But to get the maximum benefit from this amalgamation of concrete and admixtures, the incompatibility issues between these two need to be studied. It has been found that Polycarboxylate Ether (PCE) based superplasticizers show greater compatibility and economical dosage as compared to Sulphonated Napthalene Formaldehyde (SNF) based superplasticizers.

What are various types of superplasticizers?
Superplasticizers can be classified into following four groups:
a) Sulfonated melamine–formaldehyde condensates (SMF)
b) Sulfonated naphthalene-formaldehyde condensates (SNF)
c) Modified lignosulfonates (MLS)
d) Polycarboxylate Derivatives (PCE based)

Explain the Dispersion–Fluidification property of superplasticizers.
Superplasticizers are the dispersants, having a polar hydrophilic group attached to a non-polar hydrophobic organic chain with some polar groups, which prevent the flocculation of fine particles of cement. The polar groups in the chain get adsorbed on the surface of the cement grains, and the hydrophobic end with the polar hydrophilic groups at the tip point outwards from the cement grain. The hydrophilic tip is able to reduce the surface tension of water, and the adsorbed polymer keeps the cement particles apart due to electrostatic repulsions. Thus the fluidic property of the concrete increases and the concrete is workable even at lower water–cement ratios. [The Concrete Portal (2013)]

Explain the origins of incompatibility of superplasticizers and cement.
Some of the causes of incompatibility problems like early stiffening, retardation etc. are listed below. Incompatibility of cement and admixtures can be either due to cement or admixtures or both. Chemical composition of cement can predict some extent of incompatibility. If SO_4/C_3A ratio is too low uncontrolled C_3A hydration occurs which result in early stiffening (flash set). On the contrary when SO_4/C_3A ratio is too high calcium sulphates are converted to gypsum (false set). Temperature is another factor affecting compatibility. Hot weather conditions lead to increased admixture adsorption thereby leads to fluidity whereas low temperature results in low fluidity. Higher alkali cements react faster and leads to higher rate of stiffening and higher slump loss. Timing of admixture addition is also a factor of compatibility. When admixture addition is delayed after the addition of 70% mixing water majority of the cementitious materials will be hydrated and adsorption of admixture is taking place by unhydrated cementitious materials. So more admixtures are available in the paste which results in increased workability and retarded set. Presence of lignin based admixtures affect the SO4/C3A ratio. It reduces the solubility of sulphates. Trials can be performed to evaluate the compatibility by applying different brands of admixtures and cements. Incompatibility can be reduced by adding retarding agent or pozzolanic material. Saturation point can be taken as the maximum admixture content to be used in concrete because there after no significant change will occur in flow time. Fineness of cement also plays a role in the variation of admixture dosage. As fineness increases surface area increases and resulting in more adsorption of admixture. Fineness is directly proportional to saturation dosage. As fineness increases saturation dosage also increases. Consistency, setting time etc.also depends on fineness. As fineness increses, setting time also increases.

Experiment No.:12

REBAR LOCATOR TEST

Objective

To locate the Reinforcement details in existing RC structures using Profometer

Apparatus

Profometer, Marker, Ruler.

Theory

Profometer test can be defined as the non- destructive test conducted on the concrete structures to determine the size and location of the reinforcements and concrete cover rapidly and efficiently. This test is also known as Rebar locator test. The Rebar locator is a light weighted and portable instrument. It combines the measurement of concrete cover and the diameter of the bars in one direction. The basic working principle of the rebar detector is the application of magnetic field so that the embedded steel will be detected.

Applications:

1. Determination of the thickness of concrete cover.
2. Determination of the location of steel rebar.
3. Determination of the diameters of reinforcement bars.

Principle of Profometer Test

The instrument is based upon measurement of change of an electromagnetic field which is caused by steel bars embedded in the concrete.

Calibration of Profometer Equipment

Profometer device needs to be calibrated before starting the operations and at the end of the test in order to ensure satisfactory working and to get accurate results. To achieve this purpose, test block provided with the instrument should be used. To check the calibration accuracy, the size and cover of the reinforcement of the test block is measured at different locations by using profometer equipment. Then compare the recorded data with the standard values prescribed on the test block. The recorded data and the standard values should match.

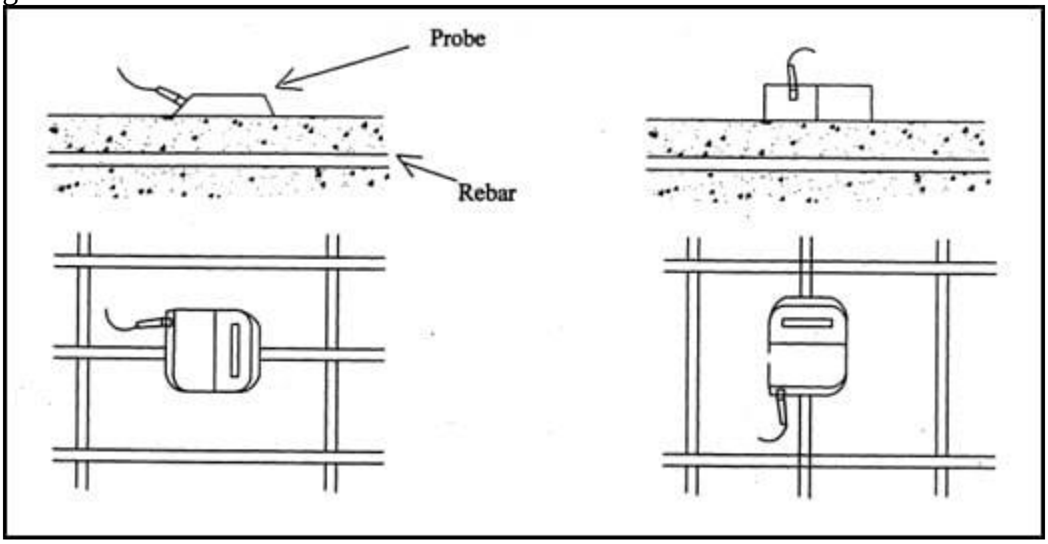
There are certain preparations that are required to be done before the testing operation begin. For instance, it is essential to conduct proper assessment of the structure before the test.

For this purpose, proper staging, ladder or a suspended platform may be provided. Before actual scanning, marking is done with chalk on the concrete surface by dividing it into panels of equal areas.

Determine Steel Bar Location

Path measuring device and spot probes are used together for path measurements and scanning of rebars. These are connected to profometer via cables and are moved on the concrete surface for scanning the rebars and measuring the spacing. As soon as the bar is located, it is displayed on the screen. Once the bar is located, it is marked on the concrete surface.

Measure Bar Diameter
Diameter probe is used for measuring the diameter of bars. It is also connected with profometer by a cable. After finding out the location of rebar, the diameter probe is placed on the bar parallel to the bar axis. Four readings are displayed and the mean value of these readings is taken as diameter of bar.



Determine Concrete Cover
Depth probe of the profometer is used to measure the cover. It is also connected with profometer by cable and is placed exactly on the bar. As soon as the depth probe is above rebar or nearest to it, it gives an audio signal through a short beep and visual display. Simultaneously, the measured concrete cover is stored in memory.

Precautions
There are various factors that affect Profometer results. These factors should be considered in the interpretation of observations obtained from this instrument:

1. Arrangement of reinforcement,
2. Variation in the iron content of cement and use of aggregate with magnetic properties,
3. Metal ties also affect the magnetic field.

Advantages and Limitations

1. This is a purely non-destructive test for the evaluation of concrete structures, particularly old structures.
2. The method is very fast and gives quite accurate results if the reinforcement is not heavily congested.
3. The equipment is very light and even one person can perform the test without any assistance.
4. Factors such as very closely spaced bars or bundled bars, binding wire, aggregate containing iron or magnetic properties would affect the accuracy of the measurements.
5. Concrete cover thickness may be underestimated when special cement, including high alumna or added pigments are used.
6. Rebars in excess 32mm distance may require recalibration.

Applications

1.Evaluate Strength of Concrete Structures

Profometer test can be used to evaluate the actual strength of concrete structures in which the number of reinforcing bars, their condition of corrosion, concrete cover, and grade of concrete are required.

In the case of old structures, when the detailed drawings are not available, it becomes very difficult to compute the strength of the structure which is required for the strengthening scheme of the structure.

Sometimes, the strength of concrete structures is to be checked to permit higher load and in the absence of reinforcement details, it becomes very difficult to make a decision.

2. Corrosion analysis

3. The method can be used both for quality control as well as quality assurance of new structures.

4. Locating rebars is a necessity when drilling, cutting coring as well as a preliminary operation required for most other non-destructive investigations.

Procedure

1. The concrete surface to be tested is first marked.
2. The instrument is then laid on the concrete surface generally surface of Beams, columns or slabs.
3. Then the instrument is duly moved from left to right and from bottom to up to get the position of the reinforcement bars.
4. After locating the reinforcement, the total cover of the rebar is determined using masonry drill.

The reinforcement bar is detected by magnetising it and inducing a circulating "eddy current" in it. After the end of the pulse, the eddy current dies away, creating a weaker magnetic field as an echo of the initial pulse. The strength of the induced filed is measured by a search head as it dies away and this signal is processed to give the depth measurement. The eddy current echo is determined by the depth of the bar, the size of bar and the orientation of the bar. This detection of location of reinforcement is required as a pre process for core cutting.

Profometer is a portable battery operated magnetic device that can measure the depth of reinforcement cover in concrete and detect the position of reinforcement bars, Fig-. The basic principle in this method is that the presence of steel affects the field of electromagnet. Fig- shows a typical circuitry diagram to locate rebars and cover includes the probe unit and display unit.

In the typical Profometer, the probe unit consists of a high permeable U-shaped magnetic core on which two coils are mounted. An alternating current is passed through one of these coils and the current induced in the other coil is measured. The induced current depends upon the mutual inductance of the coils and upon the nearness of the steel reinforcement.

Profometer is available in three models namely Model 'S', Model 'S+', and Model 'SCANLOG'. Model 'S' is standard equipment and is used for locating rebars, measuring concrete cover, storing and evaluation of data. It displays location of rebar and concrete cover on a LCD monitor with x/y meter scale and values obtained can be printed and down load to PC also.

Model 'S+' is similar but this software can print cyber scan data without PC. Model 'SCANLOG' is similar to S+ but it also includes integrated software for grey-scale display of concrete cover and can give direct print out without PC. Using any of above model rebars can be scanned over a defined area by connecting the mobile probe first and following procedure is as follows :

a) Select defined area from 'Basic Steps' with scan area option
b) Set bar diameter of first layer
c) Select option 'Scanning Bar' from menu.
d) Press 'start' to locate the rebars over selected area.
e) The starting position of a mobile probe can be defined with the cursor and the cursor is moved with arrow keys to locate the rebars. The cursor position is then transferred to the measuring area. In similar way, other rebars in first layer is marked Fig-. The rebars in second layer is also marked by moving probe in other direction as shown in Fig. Cover is also simultaneously measured.
f) Store the diagram showing the position of rebars in first and second layer and concrete cover. Cyber scan print out can be obtained on a printer.

In the similar manner diameter of bar can also be determined. A typical arrangement for measurement of bar diameter by using diameter prob. There are various factors, which affect the Profometer results. These factors are: arrangement of reinforcement, variation in the iron content of cement and use of aggregate with magnetic properties, metal ties also affects the magnetic field. These factors should be considered in interpretation of observations obtained from this instrument.

Reliability and Limitations

With this instrument a cover to reinforcement can be measured up to 100 mm with an accuracy of $\pm$ 15% and a bar diameter with an accuracy of less than 2 to 3 mm. Proper calibration of these instruments is very essential. The factors which affect the accuracy are – very closely spaced bars or bundled bars, binding wire, aggregate containing iron or magnetic properties.

1. Reinforcement less than 10mm diameter, high tensile steel or deformed bars. In these cases the indicated cover is likely to be higher than true value.
2. Cover measured lower than the true value when special cement, including high alumna or added pigments is used.
3. Rebars in excess 32mm distance may require a recalibration.

Observations

Result

Viva Questions

What is Profometer?
Profometer test is a non-destructive testing technique used to detect location and size of reinforcements and concrete cover quickly and accurately. A small, portable, and handy instrument which is known as profometer or rebar locator, is used in this test.

What is rebar locator and how it is used?
Rebar locators are used to find the position of steel reinforcement bars in concrete structures and to measure their concrete cover. Certain type of reinforcement such as glass fibre rebar, post-tension or pretension strand will require a Ground Penetrating Radar systems to locate correctly.

What is principle of rebar locator test?
This test is also commonly known as the rebar locator test. It combines the measurement of concrete cover and the diameter of the bars in one direction itself. The basic working principle of the rebar detector is the application of the magnetic field so that the embedded steel will be detected.

Notes

Experiment No: 13

ASSESSING CORROSION LEVELS USING PROFOMETER

Objective

To assess the levels of corrosion using profometer test in existing RC structures.

Apparatus

Profometer

Theory

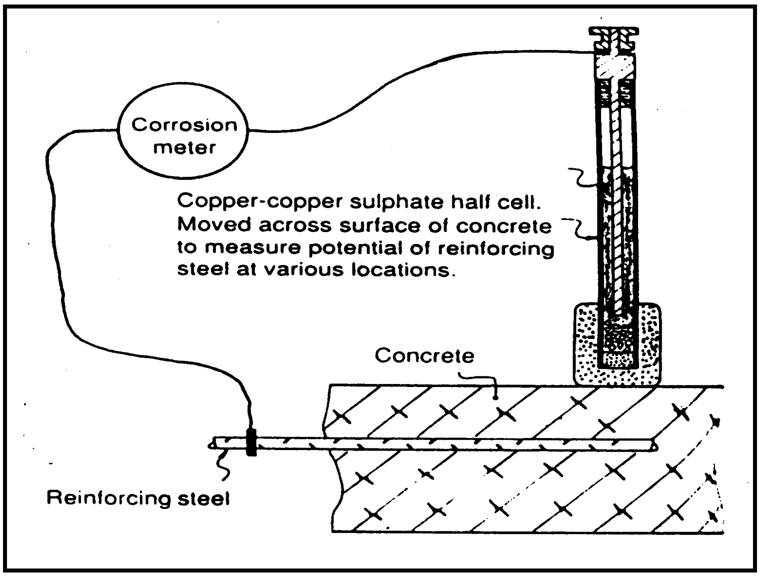
Profometer Corrosion is the most advanced instrument for corrosion analysis based on half-cell method which is used to identify active corrosion of rebars based on the electro chemical properties of reinforced concrete for assisted measurements with rod and wheel electrodes. In addition to the basic electrode (**rod or wheel**) that are based on a Copper/ Copper sulphate **half – cell,** the use of unique one- and four-wheel electrodes enable highest on-site productivity on large areas.

Corrosion Mapping

Reinforcement in concrete will not corrode if the protective iron oxide film formed by the high alkaline condition of the concrete pore fluid with a pH around 13 is maintained. This film gets destroyed by chlorides or by carbonation, if moisture and oxygen are present, resulting in corrosion. In the corrosion process anodic and cathodic areas are formed on the reinforcement, causing dissolution of the steel and the formation of expansive corrosion products at the anode.

Principle and Procedure

The instrument measures the potential and the electrical resistance between the reinforcement and the surface to evaluate the corrosion activity as well as the actual condition of the cover layer during testing. The electrical activity of the steel reinforcement and the concrete leads them to be considered as one half of weak battery cell with the steel acting as one electrode and the concrete as the electrolyte. The name half-cell surveying derives from the fact that the one half of the battery cell is considered to be the steel reinforcing bar and the surrounding concrete. The electrical potential of a point on the surface of steel reinforcing bar can be measured comparing its potential with that of copper – copper sulphate reference electrode on the surface. Practically this achieved by connecting a wire from one terminal of a voltmeter to the reinforcement and another wire to the copper sulphate reference electrode. Then readings taken are at grid of 1 x 1 m.



Half-cell Potential Test

The risk of corrosion is evaluated by means of the potential gradient obtained, the higher the gradient, the higher risk of corrosion. The test results can be interpreted based on the following table.

Half Cell Potential Corresponding to Percentage Chance of Corrosion Activity

Half-cell potential (mv) relative to Cu-Cu sulphate Ref. Electrode	% chance of corrosion activity
Less than -200	10%
Between -200 to -350	50% (uncertain)
Above -350	90%

Significance and Use

This method may be used to indicate the corrosion activity associated with steel embedded in concrete. This method can be applied to members regardless of their size or the depth of concrete cover. This method can be used at the any time during the life of concrete member.

Reliability and Limitation

The test does not corrosion rate or whether corrosion activity already started, but it indicates the probability of the corrosion activity depending upon the actual surrounding conditions. If this method used in combination with resistivity measurement, the accuracy is higher. If the concrete surface has dried to the extent that it is dielectric, then pre wetting of concrete is essential.

Observations

Result

Notes

Notes

Notes

Notes

Notes

Happy Learning!!

GRIET Hyderabad