Gokaraju Rangaraju Institute of Engineering and Technology

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Department of Civil Engineering

YEAR 2016

Year	Number of Journal Publications			Number of Conference Proceedings	
	SCI	SCOPUS	UGC	SCOPUS	UGC
2016	0	1	0	0	0

JOURNAL PUBLICATIONS:

SCI JOURNALS:

NIL

SCOPUS JOURNALS:

1. Ravi Dakshina Murthy Nemani, M. V. S. Rao, **Veera Venkata Satya Naranyana Grandhe**" (2016), " Studies on Punching Shear Resistance of Two Way Slab Specimens with Partial Replacement of Cement by GGBS with Different Edge Conditions", J. Inst. Eng. India Ser. A (September 2016) 97(3):307–312, DOI 10.1007/s40030-016-0175-x

CONFERENCE PROCEEDINGS:

-Nil-

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ORIGINAL CONTRIBUTION

Studies on Punching Shear Resistance of Two Way Slab Specimens with Partial Replacement of Cement by GGBS with Different Edge Conditions

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Abstract The present work is an effort to quantify the punching shear load resistance effect on two way simply supported slab specimens with replacement of cement by Ground Granulated Blast Furnace Slag (GGBS) with different edge conditions at various replacement levels and evaluate its efficiency. GGBS replacement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, cost savings, environmental and socio-economic benefits. The two way slab specimens were subjected to punching shear load by in house fabricated apparatus. The slab specimens were cast using M30 grade concrete with HYSD bars. The cement was partially replaced with GGBS at different percentages i.e., 0 to 30 % at regular intervals of 10 %. The test results indicate that the two way slab specimens with partial replacement of cement by GGBS exhibit high resistance against punching shear when compared with conventional concretes slab specimens.

Keywords GGBS · Punching shear · Edge conditions

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Inroduction

Today constructional activities and rapid urbanization were increased, so usage of concrete is going on increasing rapidly. Cement is major constituent material of the concrete, which produced by natural raw material like lime and silica. On one hand the natural raw materials were depleted in higher rate and on the other hand the global emissions were increased which effect the green house and leads many environmental hazards. This situation may occurs when there will be no lime on earth for production of cement. This situation leads to think all people working in construction industry to do research work on cement replacing material like GGBS, fly ash etc., and use of it. Industrial wastes like GGBS shows chemical properties similar to cement. Use of GGBS as cement replacement will simultaneously reduce the cost of concrete and help to reduce rate of cement consumption. This study report shows that the punching shear load capacities with GGBS concrete improved and give assurance to encourage people working in the construction industry for the beneficial use of it. This research work focuses on punching shear strength characteristics analysis of M30 grade concrete with replacement of cement by GGBS with a regular interval 10 % and compare with conventional cement concrete.

Major raw material of RCC is reinforcement in addition to cement concrete, which contributes to the tensile strength of concrete, while manufacturing of steel lot of waste were produced as slag. The disposal of slag is a problem of concern [1], which has been concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period. Meanwhile the acceptance of mineral admixtures like GGBS in construction became popular due to various reasons and advantages i.e., improvement in workability, durability, toughness and flexural strength at lateral stages. Not much work has been reported on punching shear load effect for pozzolanic (GGBS) concretes. This paper presents detailed investigation carried out on blended cement concrete slab specimens under punching shear. The results were compared between controlled/conventional slab specimens and blended concrete specimens. Concrete specimens with GGBS replacement has shown significant improvement over conventional concretes.

Some of the researchers have [2], discussed the usage of GGBS with various percentages replacement of cement with GGBS in flexural strength and compared with conventional concretes. It has been [3] reported the durability studies over the compressive strength and weight reduction with mineral admixtures in concrete with Fly ash and GGBS and compared with the conventional concretes and reported that mechanical properties and durability of Fly ash blended cements were increased when compared with normal concretes. The researchers have [4] reported that the triple blend cement exploits the beneficial characteristics of both Pozzolanic materials in producing a better concrete. Some of the investigators have [5] reported that the strength of concrete is inversely proportional to the percentage of replacement of cement with ground granulated blast furnace slag. An experimental investigation was conducted on two way slab specimen sand reported on the response of restrained SIFCON two way slab specimens under punching load and developed a regression model to predict the punching shear load of SIFCON slabs [6]. They concluded that SIFCON slabs with 12 % fibre volume exhibit excellent performance in punching shear strength and energy absorption characteristics when compared with normal concretes. One of the researchers have [7] reported that the behavior of HPC slabs over conventional concrete slabs and concluded that punching shear load was increased. The investigators have [8] evaluated the structural performance of slab-column connections on the basis of failure mode, load–displacement curve and punching shear strength. It has been [9] reported earlier that the punching shear capacity of two way slabs with CFRP can increase over reference specimen and developed 3D CAMUI to simulate the experimental slabs [10]. Some of the investigators have proposed the failure criterion, and reported the punching shear strength is a function of the opening of a critical shear crack in the slab. The researchers have [11] studied the punching shear resistance of concrete slabs using mode–II fracture energy and reported that the punching shear strength of concrete is strongly influenced by the thickness of slab.

Experimental Investigation

The two way slab specimens of size 1100 × 1100 × 65 mm (overall) were cast with M30 grade concrete with 6 mmϕ HYSD steel. The concrete mix was designed as per the IS: 10262-1982. In the designed concrete mix, cement was partially replaced with GGBS up to 30 % at regular intervals of 10 %. The details of ingredients of mix were tabulated in Table 1. The mix proportions for M30 grade concrete (design mix) were 1: 1.51: 2.61: 0.42 (w/c ratio). The test results of raw materials were tabulate in Table 2. The compressive strength of M30 grade concrete were tabulated in Table 3. For casting of two way slab specimens, the moulds were made with steel channels of required size. The ends of channels were connected by using nut and bolt system. The gaps were sealed with suitable material to prevent any leakages while casting the slab specimens. Initially these moulds were coated with waste oil to all inside surfaces to remove casted slab specimens easily from the moulds and these moulds were kept on a flat leveled ground to get uniform levelled slab specimens after casting. The slab specimens were

Table 1 Ingredients of M30 grade concrete

% of replacement of fly ash	Cement, Kg	GGBS, Kg	Sand, Kg	Coarse aggregate, Kg	Water, l
0	400	–	604	1040	168
10	360	40	604	1040	168
20	320	80	604	1040	168
30	280	120	604	1040	168

Table 2 Details of experimental programme

Sl. no.	Property of material	Value
1.	Specific gravity of OPC 53 grade cement	3.12
2.	Specific gravity of coarse aggregate	2.83
3.	Specific gravity of fine aggregate	2.46
4.	Fineness modulus of coarse aggregate	7.2
5.	Fineness modulus of fine aggregate	2.73

Table 3 Compressive strength of M30 grade concrete

% of GGBS replacement	Compressive load, kN	Compressive strength $\left(\frac{N}{mm^2}\right)$
0	875	38.88
10	942	41.87
20	990	44
30	1005	44.67
40	835	37.11

Table 4 Nomenclature of slabs

Sl no.	Slab designation	Explanation
1.	S 0	Simply supported slab with 0 % replacement of cement
2.	S G 10	Simply supported slab with 10 % replacement of cement with GGBS
3.	S G 20	Simply supported slab with 20 % replacement of cement with GGBS
4.	S G 30	Simply supported slab with 30 % replacement of cement with GGBS
5.	F 0	Fixed with 0 % replacement of cement
6.	F G 10	Fixed slab with 10 % replacement of cement with GGBS
7.	F G 20	Fixed supported slab with 20 % replacement of cement with GGBS
8.	F G 30	Fixed supported slab with 30 % replacement of cement with GGBS

casted in above said sections with M30 grade concrete. The slab specimens removed from the moulds and plastered with cement mortar to get uniform surfaces. These two way slab specimens were cured for 28 days after removing the side form work. The top and bottom surfaces of slab specimens were coated with white washing before testing the slab specimens for clear crack visibility. The nomenclature of slabs was shown in Table 4.

Testing procedure

The two way slab specimens were subjected to punching shear load by a in house fabricated apparatus under a typical loading frame. The punching shear load was applied with help of a hydraulic jack of capacity along with 400 kN. The punching shear load was gradually applied to the slab specimens. The central deflections were recorded during loading continuously till the specimens reaches ultimate load (i.e., up to failure). The cracking pattern of each slab specimens were also observed and marked in ink for clear visibility.

The slab specimens of both categories i.e., simply supported and fixed were tested using typical loading frame for punching shear. The details of the loading arrangement are shown in Fig. 1a, b. A deflectometer with a least count 0.01 mm was placed at the center of bottom face of the slab specimen to record the deflections. The punching shear load was applied to simulate a column-footing arrangement. For this a plate of 200 × 200 × 12 mm iron plate resembles like a footing and 65 mmϕsolid steelrod resembles like Column over footing. An arrangement was made to apply load with help of a hydraulic jack of capacity 400 kN. The punching shear load was gradually applied on the slab specimens along the above arrangement. The total arrangement exhibits the

Fig. 1 **a** Test arrangement for punching shear load of SS slabs. **b** Test arrangement for punching shear load of fixed slabs

punching shear effect on the concrete slab specimens. The central deflections were recorded continuously till the specimen reaches ultimate load at failure (Figs. 2, 3).

Discussions of test results

The investigation results shows that, the load carrying capacity of SG_{20} two way simply supported category slab category specimens were increased 21 % under punching shear load when compared with S_0 category as shown in Table 5. In fixed slab category specimens the load carrying capacity were increased 17.5 % under punching shear load when compared with conventional concrete slab specimens as shown in Table 6. The experimental punching loads higher in simply supported slab case compared with ACI and IS methods. The experimental punching load is increased 16.67 % in S G_{30} category slab specimen when compared with S_0 category. This may be due to the

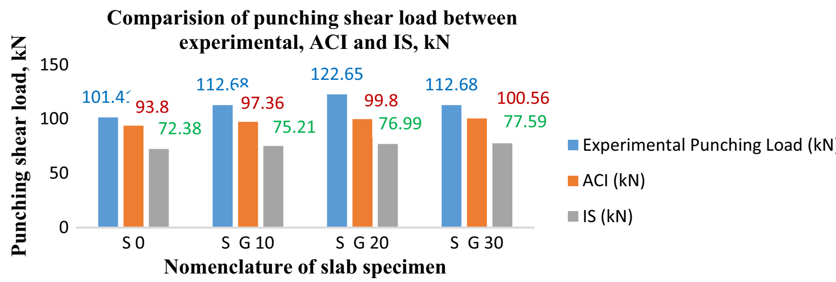

Fig. 2 Comparison of ultimate punching shear of SS slabs

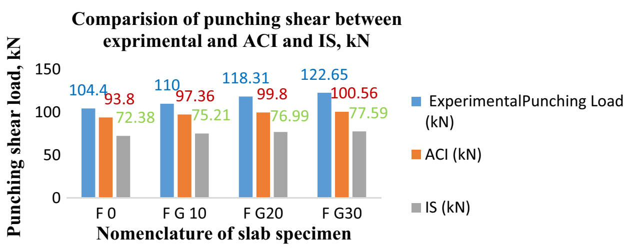

Fig. 3 Comparison of ultimate punching shear of fixed slabs

Table 5 Ultimate punching shear loads of experimental, ACI and IS methods of SS slabs

Nomenclature of slab	Experimental punching Load, kN	ACI, kN	IS, kN
S 0	101.41	93.8	72.38
S G 10	112.68	97.36	75.21
S G 20	122.65	99.8	76.99
S G 30	112.68	100.56	77.59

Table 6 Ultimate punching shear loads of experimental, ACI and IS methods of fixed slabs

Nomenclature of slab	Experimental punching Load, kN	ACI, kN	IS, kN
F 0	104.4	93.8	72.38
F G 10	110	97.36	75.21
F G 20	118.31	99.8	76.99
F G 30	122.65	100.56	77.59

characteristic strength of concrete was increased when cement was replaced with GGBS, the strength of blended concretes were increased with age. Minerals admixtures have positive impact on pore refinement of concrete. The improving effects when GGBS are the most remarkable due to micro aggregates filling and pozzolanic effect of GGBS, Compacting hydration product C–S–H gel forms due to pozzolanic effect and fine particles bridge the gap between cement particles, which makes the paste denser. C–S–H gels with higher strength optimize the microstructure of concrete.

The presence of reactive silica in GGBS and the development of C_2S in the concrete which offers good

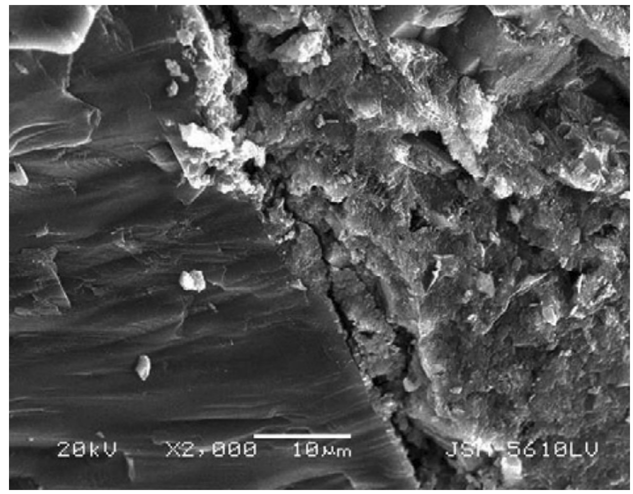

Fig. 4 Micro-morphology of ITZ at 28 days Micro-morphology of ITZ with (interfacial transition zone)

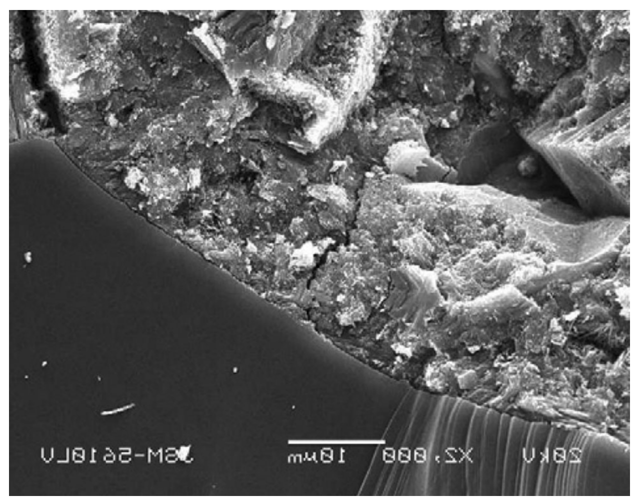

Fig. 5 Ground granulated blast furnace slag

compatibility and also resulting in strength gain. So as a consequence, increase in compressive strength will take place. The punching shear strength which depends on compressive strength will also increase as a result of the above said phenomenon.

With reference of above SEM photographs, the Fig. 4 shows more amorphous C–S–H gels mix with needlelike

Ettringite and C–S–H crystals, expansive destruction from hydration products result in looser structure and micro cracks. The Fig. 5 with addition of mineral admixtures like GGBS composition of ITZ (Interfacial Transition Zone) changes. Specifically, compacting hydration product C–S–H gel forms and content of $Ca(OH)_2$ decreases due to pozzolanic effect. Additionally, microstructure becomes denser and micro-cracks decrease, connection between paste and aggregate is enhanced due to this interlocking capacity will increased, friction between particles will decreased, so this effect offers increment in compressive strength of concrete. Once compressive strength increased the ultimate punching shear strength also increases.

From MIP (Micro-Morphology Interfacial Transition Zone), SEM (Scanned Electronic Microscopic) photographs shows the mechanical performance indicate that pore size distribution has obvious effect on compressive strength of concrete and macro-properties of concrete material are closely related to its microstructure. This also increase the compressive strength of concrete and later on durability aspects.

Ultimate Punching Shear Load Calculation as per ACI and is Methods (Model Calculation)

The calculation procedure of ultimate punching shear load as per ASI and IS methods has been shown below.

As per **ACI 318-2005 code** the ultimate punching shear strength P_u is taken as the smallest value given by the following:

$$P_u = \left(0.166 + \frac{0.332}{B_c}\right)\sqrt{f_c}\,u\,d \quad (1)$$

$$P_u = \left(0.166 + \left(0.083\,\alpha\frac{d}{u}\right)\sqrt{f_c}\,u\right) \quad (2)$$

$$P_u = \left(0.332 + \sqrt{f_c}\,u\,d\right) \quad (3)$$

where,

P_u = ultimate punching shear strength, N

B_c = The ratio of long side to short side of the loaded area

F_c = specified compressive strength of concrete, N/mm^2$\alpha = 40$ for symmetric perimeter, mm taken at a distance of $\frac{d}{2}$ from the column or pedestal

d = effective depth of the slab, mm

As per **IS: 456-2000**, the expression for calculating the punching shear strength P_u by considering partial safety factor for the material as unity is given by

$$P_u = K_s \tau_{uc} u\, d \quad (4)$$

where,

P_u = ultimate punching shear strength, N

$K_s = (0.5 + \beta_0) \leq 1 \beta_0$ = the ratio of short side to long side of column

τ_{uc} = shear stress in concrete, N/mm^2

f_{ck} = characteristic compressive strength of concrete, N/mm^2

u = length of the perimeter (mm), taken at a distance of $\frac{d}{2}$ from the column or pedestal

d = effective depth at the critical section, mm

As per ACI 318-2005

1st equation:

$$P_u = \left(0.166 + \frac{0.332}{B_c}\right)\sqrt{f_c}\,u\,d$$

where,

$$B_c = \frac{1000}{1000} = 1$$

$$\therefore P_u = \left(0.166 + \frac{0.332}{1}\right)\sqrt{f_c}\,u\,d$$

$$P_u = (0.498)\sqrt{f_c}\,u\,d$$

2nd equation:

$$P_u = \left(0.166 + \left(0.083\,\alpha\frac{d}{u}\right)\right)\sqrt{f_c}\,u\,d$$

Effective depth $(d) = \left(65 - 15 - \frac{6}{2}\right) = 47\,\text{mm})$ $\alpha = 40$ for symmetric punching$u = \left(200 + \frac{47}{2} + \frac{47}{2}\right)4 = 988\,\text{mm})$ (The size of plate under punching rod = 200 × 200 mm)

$$P_u = \left(0.166 + \left(0.083(40)\frac{47}{988}\right)\right)\sqrt{f_c}\,u\,d$$

$$\therefore P_u = 0.324\sqrt{f_c}\,u\,d$$

3rd equation:

$$P_u = 0.332\sqrt{f_c}\,u\,d$$

So adopt the least or smallest value of the above three equations i.e., $P_u = 0.324\sqrt{f_c}\,u\,d$

Model calculation: as per **ACI 318-2005**

$f_{ck} = 38.88$ N/mm^2 (characteristic strength of M_{30} grade concrete obtained, is used in our slab casting)Ultimate punching shear strength = $P_u = 0.324\sqrt{f_c}\,u\,d = 0.324\sqrt{38.88}(988)(47) = 93,812.95\,\text{N}\,(93.813\,\text{kN})$

Model calculation: as per **IS: 456-2000**

Ultimate punching shear strength = $P_u = K_s \tau_{uc}\, u\, d$

where,

$$Ks = (0.5 + \beta_0) \leq 1$$

$$\beta_0 = \frac{1000}{1000} = 1$$

$\therefore K_s = (0.5 + 1) = 1.5 > 1 (\text{So } K_s = 1)$

$$\tau_{uc} = \text{shear stress} = 0.25\sqrt{f_{ck}} = 0.25\sqrt{38.88} = 1.558\,\text{N/mm}^2$$

u = 988 mm and d = 47 mm

$$P_u = \frac{1 \times 1.558 \times 988 \times 47}{10^3} = 72,386.56\,(72.386)\,\text{kN}$$

Conclusion

- When cement was replaced with 20 % of GGBS, then the punching shear load capacity increases to 21 % when compared with normal concrete for simply supported slab edge condition as shown in Fig. 2.
- The cement can be replaced with GGBS of 30 % the punching shear load capacity increases to 17.5 % when compared with normal concrete for fixed edge condition as shown in Fig. 3.
- The experimental punching shear load carrying capacity was increased compared with ACI, IS methods.

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