EXPERIMENTAL INVESTIGATIONS AND COMPARATIVE STUDY ON EFFECT OF FIBERS ON IN-PLANE SHEAR STRENGTH OF DIFFERENT CONCRETES USINGPUSH-OFF SPECIMENS

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Abstract

This paper focuses on the experimental investigation and comparative study on effect of fibers on In-plane shear strength of Normal Strength Concrete (NSC), Geo-Polymer Concrete (GPC), Self Compacting Concrete (SCC) and High Strength Concrete (HSC) using push-off specimen. Size of push-off specimen chosen was 150mm×150mm×260mm. Two notches each of dimension 150mm×10mm×75mm were cut on the specimen which are perpendicular to the loading axis and having 100mm spacing between them. The end blocks of the push-off specimens were strengthened by adopting cage reinforcement. The steel fibers are added at 0.5%, 1.0% and 1.5% by volume of push-off specimens. It was observed from the experimental investigation that shear stress and crack resistance of fibre reinforced HSC were higher than the other concretes. An attempt was made to predict the shear stress by developing a mathematical model using the experimental and literature data.

Keywords- *Shear stress, NSC, GPC, SCC, HSC, Steel Fibers, Push-Off Specimen, In-Plane Shear Strength.*

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1. INTRODUCTION

Concrete is highly adoptable and most extensively used material for construction. The failure of concrete memberwas mainly affected by flexure and shear. Shear failure is troublesome mode of failure due to its rapid progression. Now-a-days the architectural design leads to different shapes of structures where shear forces plays a crucial role. Shear force produces sliding failure on concrete along the plane vertical to the direction of force. Geo polymers are new form of binder used in concrete composites which are produced by the chemical reaction of alumino silicate material with alkaline solutions [1].

Fibers, chemicals, mineral admixtures were added into the concrete to enhance the strength, workability, performance and durability of concrete. The shear behavior and mechanical properties of GPC, SCC and HSC are considerably different from that of NSC.

In-plane shear strength is the stress developed at maximum load or rupture in which plane of fracture is centrally located along longitudinal axis of the specimen. One of the simplest techniques to study the mechanism of shear transfer using push-off specimen is called as push-off test. To know the shear behavior of structural elements with reinforced concrete, it is necessary to consider the pure shear condition. Push off specimen is made of two L shaped blocks thatare connected through a ligament along which a shear force is applied.

2. SCOPE OF PRESENT INVESTIGATION

- To observe variation of shear stress values with variation of percentage of fibers in different concretes.
- To carry out the linear regression analysis based on the experimental data of NSC, GPC and literature data of SCC and HSC [4].
- To compare the experimental values obtained with predicted values from regression.

3. MATERIALS USED

Cement- ordinary Portland cement with specific gravity 3.15 conforming to IS 12269-1987 was used for NSC.

Fly Ash- Class F Fly Ash from Raichur thermal power plant was used for GPC. And about 10% by mass of binders was replaced with GGBS.

Fine aggregates- Fine aggregates (M-sand) used were conforming to IS 383-1970. Specific gravity, Fineness modulus and bulk density of fine aggregates are 2.38,3.05 and 1691 kg/m^3 respectively.

Coarse aggregates- Crushed angular aggregates 12.5mm downsize for GPC and 20mm downsize for NSC conforming to IS 383-1970 with Specific gravity and bulk density of fine aggregates are 2.63 and 1498 kg/m^3 respectively were used.

Alkaline solution- Sodium hydroxide in the form of flakes or pellets and Sodium Silicate are used as alkaline activators to give a good binding solution for the geo polymeric mix (GPC). Sodium hydroxide solution with 8 molar concentrations was used. Sodium Hydroxide and Sodium Silicate solution was prepared before 24 hours prior to casting.

Steel fibers- In the present study crimped steel fibers of aspect ratio (a/d) 50 were used.

Water- Potable drinking water obtained from MSRIT (Bangalore) laboratory was used for present study.

4. MIX PROPORTIONS

NSC M_{30} mix was obtained as per IS 10262-2009. GPC mix was obtained from B V Rangan literatures [4]. The final mix proportions are presented in Table 1

Table 1: Final Mix proportions of NSC and GPC

Materials	NSC	GPC
Cement (kg/m^3)	348.33	-
Fly ash + GGBS (kg/m^3)	-	382.14 + 42.46
Fine aggregates (kg/m^3)	681.66	554
Caorse aggregates (kg/m^3)	1146.8	1293.6
NaOH solids (kg/m^3)	-	36
Na_2SiO_3 (kg/m^3)	-	91

5. EXPERIMENTAL INVESTIGATOIN

The push-off specimens were prepared with the design of steel fibers varied at 0.5%, 1.0% and 1.5% by volume of push-off specimen. Adding of steel fibers is to know thefiber effect on shear strength and crack width pattern with different dosages in NSC and GPC specimens and compared with literature results of SCC and HSCspecimensprepared with same dosages of steel fibers[4]. The end blocks of the specimens were strengthened with cage reinforcement. The schematic diagram of push-off test specimen is as shown in **Figure 1**.

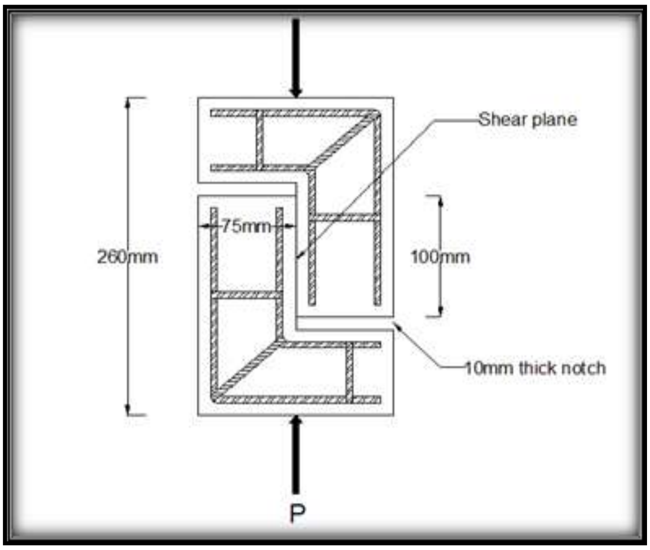

Fig 1: Schematic diagram of push off test specimen

Casting of Push off Specimens

The required quantities of ingredients per cubic meter of concreteare batched**(Table 1)** and mixed in a pan mixer. Then the concrete is poured into push-off moulds**(Figure 2)**.Steel fibers were weighed exactly 0.5%, 1.0% and 1.5% by volume of concrete and thoroughly mixed in the concrete until there was uniform distribution of all the ingredients and consistency without any lumps formation.The NSC push-off specimens casted were covered with wet jute bags andall the de-molded NSC specimens were immersed in water for a period of 28 days.

GPC push-off specimens were casted by dry mixing the solid constituents**(Table 1)**. The alkaline solution which is prepared 24 hours before with required water added to the solids. The wet mixing usually continued for another four minutes. GPC push-off specimens were de-molded **(Figure 3)**after 24 hours and then transferred to the steam curing chamber at 60^0C for about 24 hours and then allowed to cool. Until the day of testing GPC specimens are kept at room temperature.

Fig 2: Push-off specimen Mould **Fig 3:** Push-off specimens

6. TEST ARRANGEMENTS

Figure 4 illustrates that all the push off specimens were tested using compression testing machine. The load was applied through steel plate of rectangular size of 150mm×10mm above and below the push-off specimen so that the load is passed along the shear plane. Filar (hand) microscope (**Figure 5**) is used to measure the crack width along the shear plane after the failure of specimen.

Fig 4: In-plane shear strength test arrangement under CTM

Fig 5: Crack Width by Filar Microscope

Fig 6: Failure pattern in NSC **Fig 7:** Failure pattern in GPC

7. TEST RESULTS

Shear stress results of NSC and GPC are given **Table 2**along with the literaturedata of SCC and HSC. All the specimens failed in shear plane**.** Since the shear stress values are taken at ultimate load it was assumed that for a fully cracked section there was no contribution from concrete but with contribution only from steel fibers.

Table 2: Test results of fiber reinforced push-off specimens

Sl No.	Specimen Designation	f'_{ck}	W_r	τ_u
1	NSC/SF/0	30.98	1.13	5.04
2	NSC/SF/0.5	34.36	0.35	5.99
3	NSC/SF/1	33.66	0.23	7.14
4	NSC/SF/1.5	35.23	0.15	7.19
5	GPC/SF/0	34.53	1.08	5.56
6	GPC/SF/0.5	38.45	0.29	6.98
7	GPC/SF/1	42.37	0.23	8.72
8	GPC/SF/1.5	46.3	0.14	11.22
9	SCC/SF/0	39.07	0.96	7.7
10	SCC/SF/0.5	33.93	0.97	8.72
11	SCC/SF/1	35.22	0.6	9.26
12	SCC/SF/1.5	35.57	0.53	9.59
13	HSC/SF/0	54.59	0.74	8.55
14	HSC/SF/0.5	62	0.42	13.98
15	HSC/SF/1	62.78	0.26	16.02
16	HSC/SF/1.5	61.2	0.26	15.85

An attempt was made to develop a regression equation of the type $\boldsymbol{\tau_u}$= **C + ax_1+bx_2+cx_3** where **a,b,c** are coefficients, **x_1,x_2,x_3**are independent variables (steel fiber(SF) content, compressive strength (f'_{ck})and crack width (Wr)) and $\boldsymbol{\tau_u}$ is the ultimate shear stress. The regression equation obtained is given below.

$$\tau_u = -6.644 + 3.432\times SF + 0.273\times f'_{ck} + 3.186\times W_{cr}$$

Using calculated shear stress values and experimental shear stress values Mean, SD and Coefficient of Variance (CV) were calculated as shown in **Table 3**.

It clearly observed from **Figure 8** that the shear stress values of HSC was greater than the GPC, SCC and NSC.

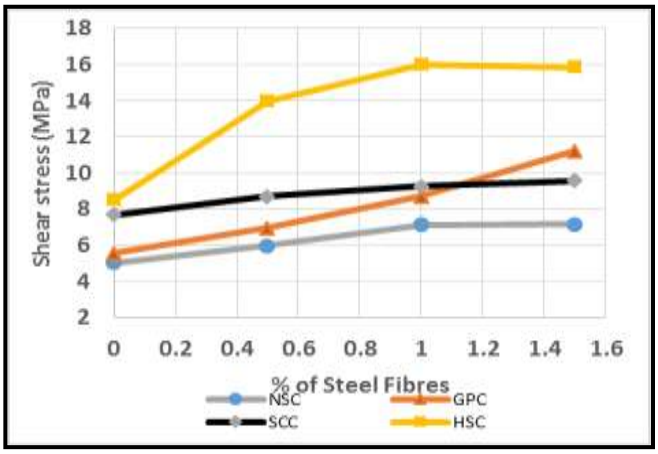

Fig 8: Variation of shear stress of different concrete with steel fibers

Table 3: Experimental / Calculated shear stress values using regression analysis

Sl No.	Specimen Designation	τ_u(EXP) MPa	τ_u(CAL) MPa	τ_u(EXP)/ τ_u(CAL)
1	NSC/SF/0	5.04	5.41	0.93
2	NSC/SF/0.5	5.99	5.57	1.07
3	NSC/SF/1	7.14	6.63	1.07
4	NSC/SF/1.5	7.19	8.59	0.84
5	GPC/SF/0	5.56	6.22	0.89
6	GPC/SF/0.5	6.98	6.49	1.07
7	GPC/SF/1	8.72	9.08	0.96
8	GPC/SF/1.5	11.22	11.59	0.97
9	SCC/SF/0	7.7	7.08	1.09
10	SCC/SF/0.5	8.72	7.42	1.17
11	SCC/SF/1	9.26	8.31	1.11
12	SCC/SF/1.5	9.59	9.9	0.96
13	HSC/SF/0	8.55	10.61	0.8
14	HSC/SF/0.5	13.98	13.34	1.04
15	HSC/SF/1	16.02	14.75	1.08
16	HSC/SF/1.5	15.85	16.04	0.99
			MEAN	1.00
			SD	0.06
			CV(%)	6

8. CONCLUSION

- It was observed that the specimen with steel fibers shows better compressive strength than the specimen without steel fibers. Also we can observe from the results obtained that the compressive strength of GPC was more than the NSC specimens
- The failure pattern was found to be trans-granular fracture in GPC and HSC and found to be surface granular fracture (passing over the surface of the aggregates) in case of NSC and SCC.
- From **Table 2,** HSC specimens show greater shear stress followed by SCC, GPC and NSC specimens.
- The predicted equation from regression analysis is used to estimate shear stress values and these values were compared with experimental values. **Figure 6** showed that COR (R^2) was found to be 0.926. From **Table 3** CV was 6%, it indicates consistency in the test results.

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