COMPARATIVE STUDY TO EVALUATE THE EFFECT OF CLAMPING REINFORCEMENT ON IN-PLANE SHEAR STRENGTH OF DIFFERENT TYPES OF CONCRETE USING PUSH-OFF SPECIMENS

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Abstract

This paper illustrates the comparative study of direct shear transfer capacity in Normal Strength Concrete (NSC), Self-Compacting Concrete (SCC), High Strength Concrete (HSC) and Geo Polymer Concrete (GPC) using push-off specimens. Size of the mould used for the study was 150 × 150 × 260mm with two notches of 10mm thick placed perpendicular to axis of loading of specimen at 100mm apart opposite to each other. The line which joins the notch tips is known as shear plane for the study. Shear reinforcement across the shear plane was varied with number of bars (Zero, one, two and three respectively). A linear regression analysis was carried out and equation was developed toestimate the shear stresses and the theoretical results were compared with that of experimental data.

Keywords: *In-plane shear strength, Push-off specimen, NSC, SCC, HSC, GPC*

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1. INTRODUCTION

Concrete is widely used material in construction industry [5]. Failure of concrete is sudden and brittle which is catastrophic in nature [2]. Failure of concrete member by bending is different when compared with that of failure by shear, which is considered to be unsafe mode of failure.Although we can calculate the safety of structural members with respect to bending failures with a fair degree of certainty, the same cannot be said in regard to shear failures. Hence investigation on shear strength is needed to be carried out. In-plane shear strength is important in design of shear keys, corbels, brackets, flyover units [3].There are few methods to evaluate shear strength of concrete and push-off test is one of them. Since push-off test is easy and simple it was carried out in the present investigation.

This paper deals with comparative study of effect of clamping reinforcement on in-plane shear strength on different types of concrete using push-off specimens. Changesin type of concreteaccounts for change in mechanical and fracture properties. A linear regression analysis was carried out based on experimental values of shear stress of NSC, SCC, HSC and GPC, an equation was developed by taking percentage of shear reinforcement and compressive strength as variables, experimental values and theoretical values were compared. It was observed that predicted equation gave similar results as that of experimental results with co-efficient of correlation of 0.94.

2. SCOPE OF EXPERIMENTAL INVESTIGATION

- To obtain mix proportion for M_{30}grade NSC and M_{30}grade GPC.
- To observe variation of shear stress values with variation of shear reinforcement across the shear plane.
- To carry out the linear regression analysis based on the experimental data of NSC and GPC and literature data of HSCand SCC [4].
- To compare the theoretical values obtained from predicted equation and experimental values.

2.1 Materials Testing

The following materials were used
Cement:53 grade OPC with specific gravity of 3.17 and fineness of 9% as per IS 4031 (part 1): 1988.**Fly ash:** Class F (ASTM) with specific gravity of 2.09 conforming to IS 3812 (part 1): 2003 obtained from Raichur thermal power station, Karnataka.**Ground granulated blast furnace slag (GGBS):** GGBS conforming to IS 12089: 1987, for present study 10% of mass of binders was replaced by GGBS.**Coarse aggregates:** Crushed angular Coarse aggregates were used with 20mm downsize for NSC and 12.5mm downsize for GPC with specific gravity of 2.627.**Fine aggregates:** Manufactured sand passing through 4.75mm sieve was used as fine aggregates. **Alkaline liquids:** Sodium silicate gel (Na_2SiO_3) and Sodium hydroxide (NaOH) solutions with 8 molar concentration were used for the study.

2.2 Mix Proportions

NSC: Mix design for NSC was done based on Indian code IS: 10262:2009. Mix proportions for M_{30} grade NSC are as shown in table 1.

GPC: In our present study the GPC mix design was followed based on previous literature as proposed by R. Subhaja[6]. Mix proportions for M_{30} grade GPC are as shown in table 2.

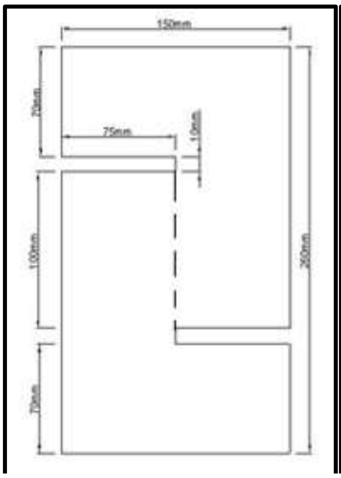
Table 1: Mix Proportions for M_{30} grade concrete NSC

Materials	Quantities
Cement	348.33 kg/m^3
Coarse aggregates	681.66 kg/m^3
Fine aggregates	1146.8 kg/m^3
Water	191.58 kg/m^3
Water cement ratio	0.55

Table 2: Mix Proportions for M_{30} grade concrete GPC

Materials	Quantities
Fly ash	382 kg/ m^3
GGBS	42 kg/ m^3
Coarse aggregate	1293.6 kg/ m^3
Fine aggregate	554.4 kg/ m^3
Sodium hydroxide solids	36 kg/ m^3
Sodium silicate solution	91 kg/ m^3

Specimen Geometry: Dimension of push-off specimen used in study was 150 × 150 × 260mm with shear plane height of 100mm as shown in figure 1. Two notches were cut of width 10mm at 100mm apart under the loading axis of specimen. Reinforcement arrangement in push-of specimen is shown in figure 2.The mould used to cast push-off specimen and end-block reinforcement is as shown in figure 3 and figure 4 respectively. Clamping reinforcement was done by varying number of bars (Zero, one, two and three respectively)across shear plane as shown in figure 5.



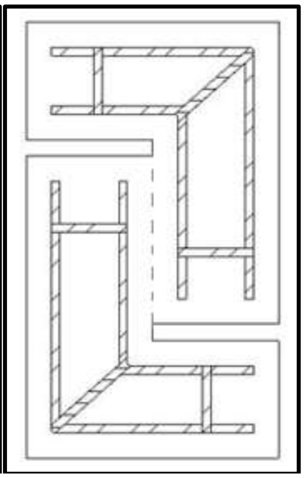


Fig 1: Push-off test specimen**Fig 2:** Reinforcement Arrangementin push-off specimen

Fig 3: Mould for casting **Fig 4:** End-block reinforcement push-off specimenforpush-off

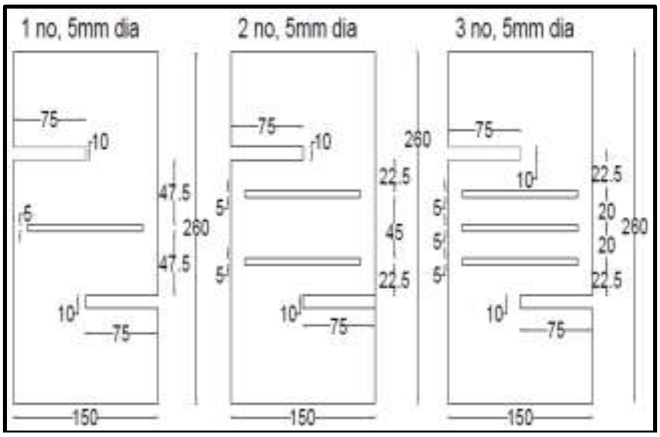


Fig 5: Variation of clamping reinforcement across the shear plane

3. CASTING AND TEST PROCEDURE

NSC: Required quantities as per table 1 are mixed in pan mixer to get a uniform mix, then the concrete is poured into mould. Push-off specimens are demoulded after 24 hours of casting and were placed for water curing for 28 days.

GPC: Sodium hydroxide solution is prepared 24 hours prior to casting. On casting day materials as per table 2 were mixed in pan mixer and the concrete is poured into mould. The specimens are demoulded after 24 hours and placed in steam curing chamber for 24 hours, after steam curing the specimens are placed at room temperature for 28 days.

Testing: Push-off specimens were tested in compression testing machine of 2000kN capacity. Test setup is as shown in figure 6.

Fig 6: Compression testing machine

3.1 Shear Stress Results

The V_u values were taken at ultimate load hence the shear stress was calculated based on the assumption that there waszero contribution from concrete and hence for a fully cracked section the contribution was only from steel reinforcement. The percentage shear reinforcement (ρ) was obtained as a ratio between the shear reinforcement and the gross area of shear plane of concrete.

Shear stress results of NSC and GPC are given in the table 3. Shear stress results of SCC and HSC were obtained from previous literature [4] and are given in table 4.

Table 3: Shear stress values for NSC and GPC

Specimen	**Shear reinforcement**	**ρ%**	**A_{st} (mm^2)**	**V_u (kN)**	**τ_u (MPa)**
NSC/0B	0	0	0	75.21	5.01
NSC/1B	#1,5mm ϕ	0.13	19.63	83.39	5.56
NSC/2B	#2,5mm ϕ	0.26	39.26	94.01	6.27
NSC/3B	#3,5mm ϕ	0.39	58.9	101.78	6.79
GPC/0B	0	0	0	83.4	5.56
GPC/1B	#1,5mm ϕ	0.13	19.63	91.04	6.06
GPC/2B	#2,5mm ϕ	0.26	39.26	103.4	6.89
GPC/3B	#3,5mm ϕ	0.39	58.9	109.67	7.31

Table 4: Shear stress values for SCC and HSC

Specimen	**Shear reinforcement**	**ρ%**	**A_{st} (mm^2)**	**V_u (kN)**	**τ_u (MPa)**
SCC/0B	0	0	0	101.37	6.76
SCC/1B	#1,5mm ϕ	0.13	19.63	107.91	7.19
SCC/2B	#2,5mm ϕ	0.26	39.26	116.09	7.74
SCC/3B	#3,5mm ϕ	0.39	58.9	122.63	8.18
HSC/0B	0	0	0	128.35	8.56
HSC/1B	#1,5mm ϕ	0.13	19.63	145.11	9.67
HSC/2B	#2,5mm ϕ	0.26	39.26	153.69	10.25
HSC/3B	#3,5mm ϕ	0.39	58.9	184.76	12.32

The variation of shear stress of different types of concrete (NSC, HSC, SCC and GPC) with shear reinforcement across the shear plane are plotted below in figure 7.

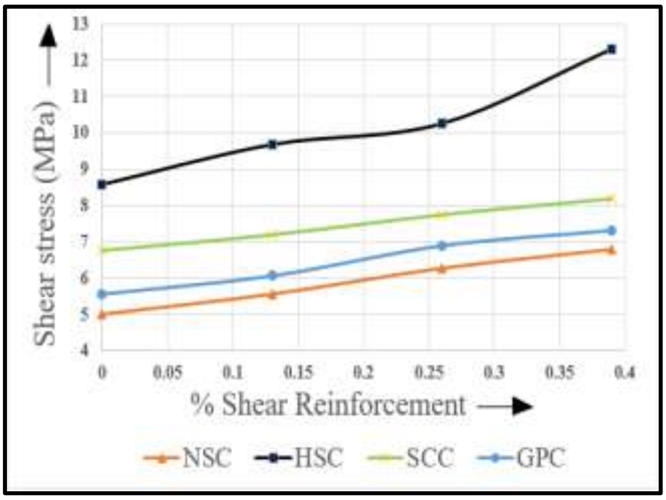


Fig 7: Variation of shear stress of different concrete with shear reinforcement

It was observed from figure 6 that shear transfer capacity results of HSC was better than GPC, SCC and NSC.

A linear regression analysis was carried out from experimental data and an equation was developed as shown in equation 1

$$\tau c = 0.6 + 5.47\rho + 0.12fck \ldots (1)$$

The ratio of shear stress of experimental values to calculated values are tabulated in table 5.

Table 5: Experimental / Calculated shear stress values for NSC, GPC, SCC and HSC

Specimen	**τ_u(MPa) (EXP)**	**τ_u(MPa) (CAL)**	**τ_u(EXP)/ τ_u(CAL)**
NSC/0B	5.01	5.27	0.94
NSC/1B	5.56	5,78	0.96
NSC/2B	6.27	6.56	0.95
NSC/3B	6.79	7.59	0.89
GPC/0B	5.56	4.83	1.15
GPC/1B	6.06	6.30	0.96
GPC/2B	6.89	6.82	1.01
GPC/3B	7.31	7.30	1.00
SCC/0B	6.76	6.40	1.05

SCC/1B	7.19	6.79	1.05
SCC/2B	7.74	7.76	0.99
SCC/3B	8.18	7.84	1.04
HSC/0B	8.56	8.78	0.97
HSC/1B	9.67	10.44	0.92
HSC/2B	10.25	10.08	1.01
HSC/3B	12.32	11.51	1.07
		MEAN	0.99
		SD	0.064
		CV	6.5%

4. CONCLUSION

- The ultimate load carrying capacity and ultimate shear stress values was better in specimens with clamped reinforcement than that which had no reinforcement across shear plane for both NSC and GPC.
- It was observed from results that as the number of bars increased across the shear plane the values of shear stress of push-off specimens increased.
- Cracks passed over the aggregates (Surface granular cracks) in case of NSC and SCC, however the cracks passed through the aggregates (Transgranular crack) in case of HSC and GPC.
- The predicted equation obtained from regression analysis to estimate shear stress values is summarized below:

$$\tau c = 0.6 + 5.47\rho + 0.12fck$$

Co-efficient of Variance (CV) obtained for calculated shear stress from the equation with respect to experimental shear stress was 6.5%. For better consistency of results CV should be less than 5%. Coefficient of correlation (R^2) calculated for shear stress which was obtained from predicted equation with respect to experimental data was 0.9434. The value of R^2 (co-efficient of correlation)nearer to 1 shows satisfactory relationship between variables.

ACKNOWLEDGEMENT

We acknowledge the support rendered by the Management of MSRIT, Principal, HOD, Faculty,Hiranyiah(Chief Engineer Bhagirath constructions), staff of Civil Dept, MSRIT affiliated to VTU, Belgaum.

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