Performance of hybrid glass/steel fibre self-compacting concrete beams under static flexural loading

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Abstract. In this paper, it is proposed to study the static flexural performance of hybrid (glass and steel) fiber reinforced M30 grade self-compacting concrete (SCC) beams made with glass fiber reinforcement polymer (GFRP) re-bars. Nan Su mix design approach is adopted to develop the M30 grade plain SCC (PSCC) mixes. Glass fibre SCC (GFRSCC), steel fibre SCC (GFRSCC) and hybrid fibre SCC (HFRSCC) mixes are prepared using the optimum dosages of glass (0.05%) and steel fibres (1%) by volume fraction. HFRSCC reinforced beams of size 1200 *200*150 mm will be casted with steel and GFRB rebars and tested to study the flexural properties such as ultimate flexural strength, load at first crack, deflection at the center, crack width and crack patterns. For the above fibred beams, load-deflection relations will be established. The HFRSCC beam made with GFRP rebars have the load carrying capacity 37.03% more than HFRSCC beam made with steel rebars. The deflection for the HFRSCC beam made with GFRP rebars is 61.52% more than beam made with steel rebar HFRSCC beam made with GFRP rebars increases the load at first crack, ultimate flexural strength, and deflection at the centre at failure and the crack width for same HFRSCC beam made with steel rebars

Keywords. SCC, Glass fibre, Steel fibre, flexural strength, GFRB rebars, hybrid fibre

1 Introduction

The two fundamental elements that give concrete constructions their strength are steel and concrete [1]. The two materials will be combined to create the structural element, with the concrete taking the compressive forces and the steel withstanding the ensuing tensile and

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shear forces[2]. When steel bars in reinforced concrete constructions encounter moisture, it compromises their performance and longevity and leads to cracks. To lessen these effects, hybrid reinforcement is introduced to the situation[3]. Fibre reinforced polymer (FRP) materials combined with steel are referred to as hybrid reinforcement[4]. This combination could produce a corrosion prevention strategy for reinforcement that is more practical from a financial and commercial standpoint[5].

2 Objectives

1. To develop M30 Grade plain self-compacting concrete (SCC) mix using Nan Su mix design principles.
2. To determine the hybrid dosage of steel and glass fiber for hybrid fibre reinforced concrete mix of M30 grade
3. To evaluate the flexural properties such as ultimate flexural strength, load at first crack, deflection at the center and at the load applied, of under reinforced plain concrete beam made with steel rebars
4. To assess the flexural properties such as ultimate flexural strength, load at first crack, deflection at the center of under-reinforced hybrid-fibre reinforced concrete beam made with GFRP rebars

3 Materials

a) Steel fibres

Crimped steel fibres of aspect ratio 30 (length: 12mm Dia 0.4mm) is used.

Figure1. Steel fibre

b) Glass fibre

Glass fibres of aspect ratio 857 (length 12mm) is used for the study.

Figure 2. Glass fibres

c) Steel rebars

The 12mm Fe 450 grade HYSD rebars are used to strengthen the beam.

Figure 3. 12mm HYSD steel bars

d) Glass Fiber Reinforced Polymer (GFRP) rebars

GFRP, or glass fibre reinforced polymer rebar used is of 2 m length and 12mm diameter.

Figure 4. GFRP rebars of 12mm diameter

e) Fly Ash

In this experiment, fly ash from the Vijayawada Thermal Power Station in Andhra Pradesh, India, was employed. This is supported by IS: 3812 - 1981 grade I, which specifies "Specifications for Fly Ash for Use as Pozzolana and Admixture." It underwent testing in accordance with IS: 1727-1967 [Methods of test for pozzolana materials][6].

f) Mix Design

The proportioning of the SCC mix was initially carried out using the Nan-Su mix design principles. In the current experimental study, ordinary self-compacting concrete (SCC) in the M30 grade was mixed with varied ratios of fine aggregate to total aggregate (s/a ratio) ranging from 0.5 to 0.57 and packing factors (PF) ranging from 1.10 to 1.18. Based on combinations of the packing factor and s/a ratio, the mix design is further changed. According to Nan Su, the variables that affect the mix proportion are the packing factor, the fine aggregate/total aggregate ratio, and the powder content. According to the presumptions provided in the Nan Su mix design guidelines, the cement content, fly ash content, and fine aggregate/total aggregate ratio were calculated. Fly ash is employed as a mineral additive in the current inquiry and was created using the efficiency concept[7].

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Table 1: Mix quantities of PSCC and HFRSCC

Designation	Cement kg	CA Kg	FA kg	Fly Ash kg	Water kg	SP % bwcf	VMA % bwcf	Glass Fibres % Volume of concrete	Steel fibres % Volume of concrete
PSCC	333.1	795.8	863.5	145	189	1.0	0.05	_	_
HFRSCC	333.1	795.8	863.5	145	189	1.2	0.06	0.024 (0.60 kg)	0.4 (31.50 kg)

bwcf – by weight of cement and fly ash

Table 2: Mix proportion of GRSCC, SFRSCC and HFRSCC

Designation	Mix Proportion
GFRSCC	PSCC + 0.60 kg/m^3 of Glass Fibre
SFRSCC	PSCC + 31.50 kg/m^3 of Steel Fibre
HFRSCC	SCCP + 0.60 kg/m^3 of Glass Fibre + 31.50 kg/m^3 of Steel Fibre

Figure 5. Beam Reinforcement and casted beams

Figure 6. Beam Setup

Figure 7. Beam testing

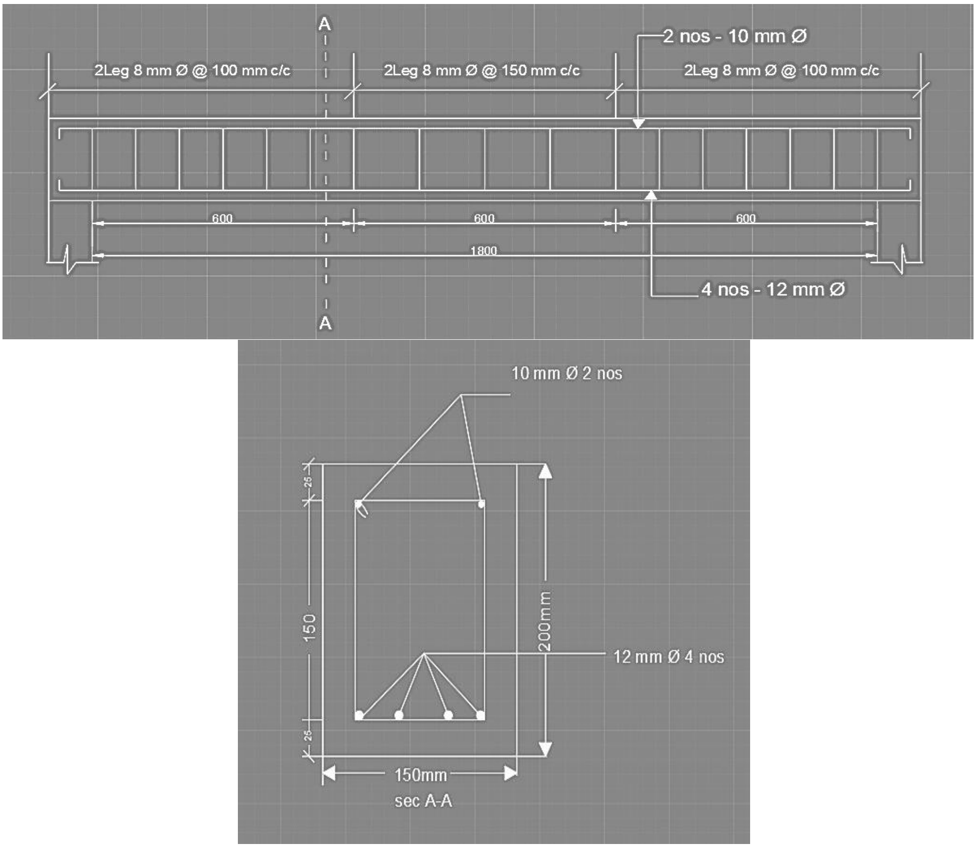

Figure 8. Beam details

The below results are the flexural characteristics of the steel and GFRP of self-compacting concrete. Load deflection curve of M30 grade hybrid fibre reinforced SCC beam made with steel and GFRP rebars

Table 3. Flexural characteristics

Rebars used	M30 Hybrid fibre reinforced scc beam			
	Load at first crack occurrence (kN)	Load at failure (kN)	Mid-deflection (mm)	Width of crack at failure (mm)
Steel	24	54	6.81	0.98
GFRP	44	74	11.10	0.80

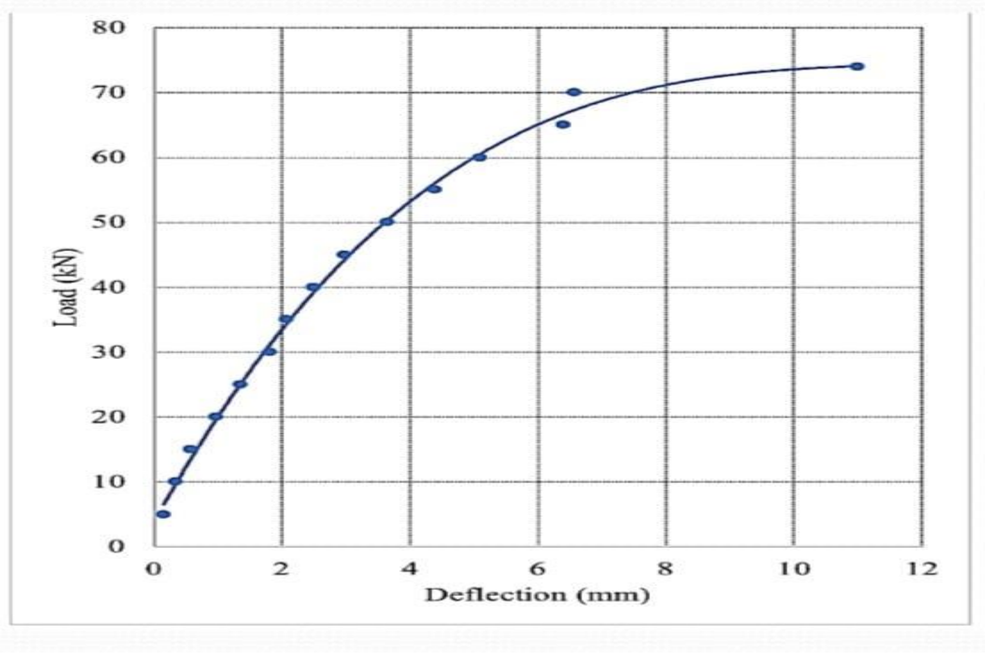

Figure 9. Load deflection curve of M30 grade hybrid fibre reinforced SCC beam made with GFRP rebars

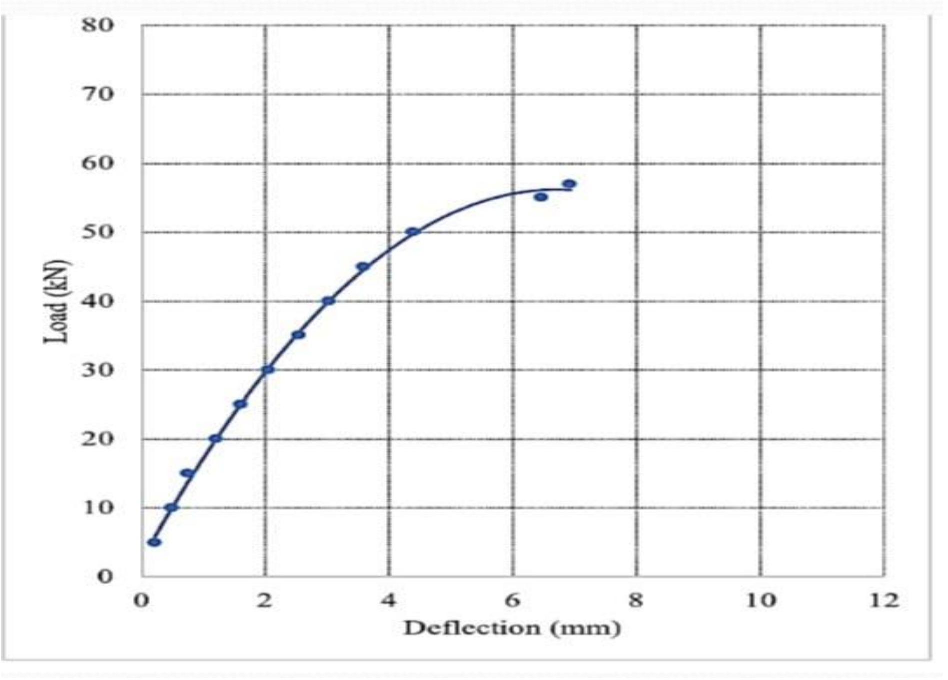

Figure 10. Load deflection curve of M30 grade hybrid fibre reinforced SCC beam made with steel rebars

Table 4. Load – deflection relations

HFRSCC - Steel Rebars		HFRSCC - GFRPB Rebars	
Load (kN)	Deflection (kN)	Load (kN)	Deflection (kN)
5	0.22	5	0.15
10	0.52	10	0.34
15	0.78	15	0.58
20	1.26	20	0.97
25	1.68	25	1.35
30	2.16	30	1.81
35	2.67	35	2.07
40	3.19	40	2.49
45	3.78	45	2.98
50	4.62	50	3.65
54	6.81	55	4.39
		60	5.10
		65	5.40
		70	5.57
		74	5.58

Table 5. Experimental results for workability of concrete

Fresh concrete properties						
Designation	Slump test		V funnel test		L Box test	
	Slump (mm)	T50 time (sec)	Time for discharge (sec)	T5 min (sec)	Test H2/H1	Remarks
SCCP	672	2.69	3.91	8.33	0.95	Conforms to EFNARC guidelines
HFRSCC	645	5.64	6.82	10.64	0.86	

4 Findings

1. M30 Grade plain self-compacting concrete (SCC) mix is developed using Nan Su mix design criteria.
2. Aspect Ratios of the Steel fibre is 30 (length: 12mm and Dia 0.4mm) and Glass fibres is 857 (length 12mm)
3. The hybrid dosage of steel and glass fiber for hybrid fibre reinforced concrete mix of M30 grade are decided as 31.50 kg/m^3 and 0.60 kg/m^3 respectively. These doses are arrived subjected to the fulfillment of EFNARC guidelines
4. Under reinforced beams are designed as follows: Hanger bars- 2 Nos. 10mm Dia.
    - Tension reinforcement- 4 Nos. 12mm Dia. (1) steel rebars (2) GFRP rebars
    - Total length of beam=2 m
    - Simply supported with overhang of 100mm
    - Stirrups near the centre – 2 legged 8mm Dia. @150mm c/c
    - Stirrups near the supports – 2 legged 8mm Dia. @100mm c/c
5. Casted hybrid-fibre reinforced concrete beam with steel rebars and with GFRP rebars

6. The deflections at center at failure in hybrid FRSCC beams with optimal PF and s/a ratios were more than that of conventional beams. The HFRSCC beam made with GFRP rebars have the load carrying capacity 28% more than HFRSCC beam made with steel rebars.
7. The deflection for the HFRSCC beam made with GFRP rebars is 19% less than beam made with steel rebars
8. HFRSCC beam made with GFRP rebars increases the load at first crack and ultimate flexural strength but deflection at the centre at failure and the crack width for HFRSCC beam made with GFRP rebars is lowered.

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