EVALUATION OF MECHANICAL CHARACTERISTICS OF HIGH STRENGTH HYBRID FIBER REINFORCED SCC

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Abstract

A special kind of concrete called high-performance hybrid fibre reinforced self compacting concrete (HSHFRSCC) which inturn capable of withstanding loads which normal strength concrete (NSC) cannot. It can also speed up construction because of early strength and better performance. The current study attempts to develop M_{55} grade of HSHFRSCC mixes in accordance with IS 10262:2019. Many tests for HSHFRSCC mixtures were conducted, using silica fumes and GGBS as fillers and marginal materials as binders. The maximum size of coarse aggregates was fixed at 12.5 mm, while the water content, fine to coarse aggregate ratio, and super plasticizer dose were all maintained constant.The percentages of Silica fumes and GGBS (0% to 30%) replaced by weight of cement are varied throughout the process. When using GGBS and Silica fumes in place of cement, the water content is also maintained constant by adjusting the water to cement ratio correspondingly. This study aims to develop hybrid fibre-reinforced composition by inducting steel and polypropylene fibers (0%-2%) by weight of cement in the mix. The test result demonstrates that HSHFRSCC mixes can be created using IS 10262:2019 for the specified grade of concrete, and that these mixes satisfied the requirements for both fresh and hardened qualities. Also, the statistics show that adding hybrid fibre and substituting the GGBS and Silica fumes is more efficient. Sample L5 had the highest value for both compressive and tensile strength, and it also had the highest value for flexural strength.

Keywords: GGBS, Silica Fume, Steel Fibres, Polypropylene fibre, Superplasticizer, Workability, Mechanical Properties.

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1. Introduction

Civil engineers and researchers are interested in developing new materials that are flexible yet sturdy enough to withstand applied loads as well as to meet the specific requirements of various systems in the present day. A lot of structures are built with dense reinforcement, which makes it difficult to install concrete in these situations. Thus, the necessity for self-compacting concrete (SCC), In Japan, this was produced in the late 1980s by Professor Hajme Okamura and is mostly employed for extremely crowded systems, arises. It addresses the drawbacks of conventional concrete and also avoids the associated trouble Concrete that is both self-compacting and can be moulded into any shape framework is known as self compacting concrete (SCC). It's competent of entirely fill any shape of formwork using only its own weight or gravity, with no external vibration or compaction. Due to its low viscosity and excellent workability, SCC is a type of concrete that can cover any kind of formwork and achieve the desired compaction without the need for extra shaking. This is possible because of its own gravity and rheological nature. The key feature of SCC is the unique fluidity of the blend in relation to stability, the latter being a gauge of its resistance to material segregation, either dynamic (during transit) and static. (after placement). This innovative concrete aims to enhance particular elements of customary practice [25]. In comparison to normal concrete, SCC contains much more binder, superplasticizer, and/or viscosity changing admixtures (VMA). Rice husk ash, fly-ash, GGBFS, silica-fume, metakaolin, and other SCMs are linked with the increased binder content[3]. The addition of SCMs to cement or concrete mixtures offers numerous advantages to fresh and hardened concrete, including increased workability and final strength values. It also lowers building costs[4]. SCC with high-volume SCMs is characterised by the substitution of a significant quantity of SCMs (generally more than 40-50%) for cement in SCC mixtures The primary goal of this study is to identify the appropriate mix ratio for higher strength SCC (HSSCC) with cement substituted by mineral admixes such as Silica Fume (SF), and GGBS. Lowering the water cement ratio and adding chemical and mineral admixtures to enhance workability and avoid segregation can increase strength. High Strength Self Compacting Concrete's workability characteristics, mechanical characteristics, were studied.

Conduction calorimetry, $Ca(OH)_2$ monitoring, and subsequent reactions by $Ca(OH)_2$ and non-evaporable moisture content were all investigated during the portland cement-silica fume blends quickly hydrate. Tricalcium silicate (C_3S) and tricalcium aluminate (C_3A) were both hydrated more quickly in the first several hours when silica fume was present. The pozzolanic interaction with calcium hydroxide during cement hydration may improve the process overall while reducing the amount of calcium hydroxide[7]. Mineral admixtures enhanced the SCC's fresh properties. The slump flow time of the concretes including some of the mineral admixtures was quicker than that of the Portland cement-only control mixture. (PC). Contrary to SF, FA and GGBFS reduced the viscosity of binary mineral admixture-containing solutions. By combining these elements in ternary and quaternary blends, as opposed to combinations comprising just PC and SF, the rheology of both concretes was improved When the cementitious material concentration rose, the electrical resistance of the concrete mixes increased with the addition of mineral admixtures. According to, silica fume impacts the level of alignment of the Calcium Hydroxide (CH) crystals as well as the thickness of the transition phase in mortars]. This might be explained by the use of silica fume, which considerably lowers pore size, or by the pozzolanic reaction of the larger pores occurring concurrently with cement hydration, which causes the larger pores to shrink into smaller ones. The connection between porosity and strength in porous concrete using silica fume, porous concrete's internal porosity has a significant influence on its strength in a variety of porous media

When utilizing the new kind of SP, there was less of a decline in the contact between freshly mixed mortar and coarse aggregate particles. A correlation between a rise in the w/c ratio and a fall in the interaction between new mortar and coarse aggregate particles was found using the new kind of SP. It had an impact on the way the new kind of SP worked. They concluded that more study was required to fully understand the mechanism for reducing the interaction. In comparison to naphthalene sulphonate-based SP, polycarboxylate-based SP demonstrated higher workability and compressive strength in concrete mixtures.

It was found that employing nanosilica and combining microsilica and nanosilica in M_{40} and M_{50} SCC mixes, improved concrete mixtures could be formed SCC strengthening by utilizing GGBS to improve concrete's cost effectiveness. Concrete is utilized to create long-lasting structures when GGBS is used in combination with regular Portland cement and other components In the SCC mix, the amount of ground granulated blast furnace slag varies between 20% and 40%. To assess the SCC mix's qualities, many experiments are performed. It has been shown that using GGBS as a filler lowers the overall void content of SCC. At 30% GGBS addition, they computed a 1.74 percent improvement in compressive strength and the potential uses of industrial leftovers was assesed Self-compacting concrete is produced using silica and GGBS gases. The properties of GGBS and SF-based SCC concrete compositions were examined. It was advised to employ mineral admixtures like GGBS and SF. by adding the mix design, as an alternative to cement in the preparation of SCC. The results showed that the GGBS-based SCC mixes worked well. When calculating a material's tensile qualities, consider its compressive, split-tensile, and flexural strength. compared to SCC mix, which is situated in San Francisco. Self-compacting concrete is produced using silica and GGBS fumes. It was found out how well different mineral admixtures worked while producing SCC. This study looked at the viability of using GGBS as a mineral addition at SCC in a variety of cement replacement percentages. The investigation found that adding up to 50% GGBS as a mineral addition had no influence on self-compactability. It was shown that when the GGBS concentration in SCC rises, workability decreases. When GGBS is used in lieu of cement, self-compaction is preserved up to 40%. As the GGBS level rises, it is shown that SCC's toughened properties weaken. The findings of the hybrid fibre integration in SCC give extremely important economic and technological advantages. The use of two different kinds of steel fibers was combined with research on flow and mechanical properties. To maintain high levels of flow ability while employing SCC with fibre reinforcement, the amount of paste in the mixture must be increased to allow optimum fibre dispersion. Increasing the cement concentration, adding more fine aggregate, or using pozzolanic admixtures are other potential answers to this issue, all of which will be researched as the experimental studies continue

The researchers investigated the strength and permeability properties of SCC incorporating fly ash and hooked steel fibres. The impact of steel fibres (0.5, 1.0, and 1.5 percent by volume) on rheological (slump flow/V-funnel/L and U-box), mechanical strength, and permeation characteristics were studied in SCC specimens (porosity, rapid chloride permeability, and ultrasonic pulse velocity). The workability of SCC with volume fractions of 0.5 and 1.0 percent hooked steel fibres was found to be within the EFNARC range. But that the workability of SCC with volume fractions of 1.5 percent and higher is somewhat reduced. This results in a reduction in rheological qualities as compared to ACI 237 R and EFNARC. The features of hybrid fibre reinforced self compacting concrete (HyFRSCC) including class F fly ash (FA), (CNS)colloidal-nano-silica, crimped steel fibres (CSF), and polypropylene fibres (PPF) were examined The optimal suggested combination was revealed to be 10% FA, 0.4% CNS, 1.25 percent CSF, and 0.167 percent PPF. Superplasticizers and viscosity-modifying admixtures (VMAs) are used to make self-compacting concretes (SCC). They enhance the plastic viscosity while decreasing the yeild. This will result in a very steep but gradual slump. These mixtures will settle without compression but will not separate. It should be noted that the admixtures alone are insufficient to produce SCC in the absence of an adequately higher powder mass and appropriate aggregate grading. If the aggregate grading is excellent, it is often feasible to produce SCC without a VMA using a superplasticiser.

The kind of SP and VMA was crucial to the survival of the air-entrained HPSCC. The amount of air in freshly produced HPSCC is significantly influenced by the kind of SP. The VMA type has a large influence on the air content in HPSCC. Due to the specifications for the size of HPSCC air holes, the kind of SP and VMA was crucial. Moreover, the porosity of HPSCC varied according on the kind of VMA.

Because of HPSCC's strength and ability to penetrate water, the kind of SP and VMA was crucial. The ingredients used in this study are listed in Table 2.1. In this study, GGBS and micro-silica were the two main materials chosen as a target to substitute some of the cement. To improve flexibility, polypropylene and steel strands with crimped tips were used. Chemical admixtures like the viscosity altering agent and the super plasticizer were used to make the design with the least amount of slump flow. These admixtures make new SCC more flexible so that it can pass the property tests for fresh concrete.

2. Materials and Experimental Methods

For the concrete compositions, ordinary Portland cement that complied with IS 12269[23] was utilized. For the high strength concrete combinations, Aastra chemical, Chennai, India supplied GGBS and silica fume. The characteristics are displayed in Table 2.1. River sand, which has a specific gravity of 2.67 and a fineness modulus of 2.74, was used which confirms to zone II and have 1% water absorption, while the coarse aggregate (12.5mm), which has a specific gravity of 2.72 and water absorption of 0.5%, its bulk density of 1693 kg/m^3. To achieve the requisite workability, a super-plasticizer (Polycarboxylate ether) and Viscosity modifying agent (VMA) was utilized the properties are provides in Table 2.2.

Table: 2.1 Physical and Chemical Properties of Cement, GGBS and Silica fume

Sl. No.	Properties	Test value
1.	Fineness (m^2/kg)	295
2.	Specific gravity	3.12

3.	Soundness (mm)	1.2	
4.	Consistency	31(%)	
5.	Initial & Final-setting (min)	163/238	
6.	Compressive-strength (28 Days)	59	
GGBS			
7.	Fineness (m^2/kg)	390min	
8.	Specific-gravity	2.85	
9.	Cumulative Particle size (45 micron %)	97.12	
10.	Sulphide sulphur	0.60	
11.	Magnesia	7.63	
12.	Sulphate	0.38	
13.	Chloride	0.009	
14.	Chemical references a. $CaO + SiO_2 + MgO$ b. $(MgO + CaO)/SiO_2$ c. CaO/SiO_2	 76.01 1.32 1.07	
15.	Moisture	0.10	
16.	LoI (%)	0.26	
17.	Components	Concentrations (%)	
		Cement	Micro Silica
18.	$Si O_2$	28.68	97.58
19.	$Al_2 O_3$	8.56	0.043
20.	$Fe_2 O_3$	3.79	0.040
21.	Mg O	1.89	0
22.	SO_3	2.62	2.34
23.	Ca O	53.32	0.001
24.	$Na_2 O$	0.30	0.001
25.	$K_2 O$	0.82	0.001
26.	$Ti O_2$	-	0.001
27.	LoI	-	0.015

Table: 2.2 Properties of Super-Plasticizer

Sl. No.	Particulars	Remarks
1.	Appearance and colour	Colorless to light lazy liquid
2.	Product type	Polycarboxylic
3.	Specific Gravity	1.10
4.	Total solids (%)	45

In the current experimental investigation, circular crimped steel fibers along with polypropylene (Recron 3S) that was readily accessible locally was chosen. The characteristics of the fibers utilized are given in Table 2.3

Table: 2.3 Recron-3s's and Crimped Steel Fibre Qualities

Sl. No.	Qualities	Results
Polypropylene		
1.	Strength (tensile) kg/cm^2	4000 to 6000

2.	Cut-Length (mm)	6 to 12
3.	Point of melting (^{0} C)	> 250
4.	Color	White
5.	Shape	specialized for enhanced cement aggregate holding
Crimped Steel Fiber		
6.	Fibre Length (mm)	35
7.	Dia in (mm)	1.0
8.	Aspect-ratio	35 to 50
9.	Strength(Tensile)	800 to 900 MPa
10.	Type	Crimped

The usual ranges by mass and volume of the ingredients listed are as per IS: 10262-2019[24] standards were considered while creating the combination.

In the investigation, the following measurements were used: powder volume: 564 kg/m^3, over all 30% of cement is replace by silica fume and GGBS, further Silica fume were varied from (0,5,7.5 and 10%) and GGBS were varied from (0,25,22.5 and 20%) of paste volume: 491 kg/m^3, water volume: 162 kg/m^3, coarse and fine aggregate volume: ≈848 kg/m^3 and 937.5 kg/m^3, and water powder ratio by volume: 0.85. Without producing any segregation in the mixes, the appropriate quantity of admixture (1.6%) was applied. further steel and polypropylene fibers were inducted in the range of (0-2%) with 0.5% variation.

Table 2.4 contains the mixing ratios that were discovered.

Fresh and Hardened Tests on Concrete

The workability characteristics, like segregation, flow, and passing capacities, are measured.

To determine the properties of the new concrete, tests such as the Slump Cone Test, T50 Time Test, V(funnel), L and U Box, Flow test were conducted. The results are shown in Table 3.1. The diameter of the flow of concrete ranges from 649 to 709 cm for a w/c ratio of 0.33 and T_{50} (s) varies from 0.34 to 5.4sec

Table: 2.4 Information About the Mix's Proportions

Sl. No.	Mix Name	Ingredients (kg/m^3)					SP %	SP kg/m^3	VMA %	VMA kg/m^3	Fiber in % (PP+SF)	(w/c)	w/c kg/m^3
		C	SF	GGBS	FA	CA							
1.	M	491	0	0	937.5	847.64	1.3	4.91	0.3	1.47	0	0.33	162.03
2.	TA1	343.7	24.55	122.75	937.5	847.64	1.3	4.91	0.3	1.47	0	0.33	113.5
3.	TA2	343.7	24.55	122.75	937.5	847.64	1.3	4.91	0.3	1.47	0.5	0.33	113.5
4.	TA3	343.7	24.55	122.75	937.5	847.64	1.3	4.91	0.3	1.47	1	0.33	113.5
5.	TA4	343.7	24.55	122.75	937.5	847.64	1.3	4.91	0.3	1.47	1.5	0.33	113.5
6.	TA5	343.7	24.55	122.75	937.5	847.64	1.3	4.91	0.3	1.47	2	0.33	113.5
7.	VB1	343.	36.8	110.	937.	847.	1.	4.91	0.3	1.47	0	0.3	113.

		7	3	5	5	64	3					3	5
8.	VB2	343.7	36.83	110.5	937.5	847.64	1.3	4.91	0.3	1.47	0.5	0.33	113.5
9.	VB3	343.7	36.83	110.5	937.5	847.64	1.3	4.91	0.3	1.47	1	0.33	113.5
10.	VB4	343.7	36.83	110.5	937.5	847.64	1.3	4.91	0.3	1.47	1.5	0.33	113.5
11.	VB5	343.7	36.83	110.5	937.5	847.64	1.3	4.91	0.3	1.47	2	0.33	113.5
12.	LC1	343.7	49.1	98.2	937.5	847.64	1.3	4.91	0.3	1.47	0.5	0.33	113.5
13.	LC2	343.7	49.1	98.2	937.5	847.64	1.3	4.91	0.3	1.47	0.5	0.33	113.5
14.	LC3	343.7	49.1	98.2	937.5	847.64	1.3	4.91	0.3	1.47	1	0.33	113.5
15.	LC4	343.7	49.1	98.2	937.5	847.64	1.3	4.91	0.3	1.47	1.5	0.33	113.5
16.	LC5	343.7	49.1	98.2	937.5	847.64	1.3	4.91	0.3	1.47	2	0.33	113.5

Table: 3.1 Workability Test results of HSHFRCSCC mix for w/c = 0.33

Sl. No.	Mix ID	Slump Flow (mm)	T_{50} (sec)	V-Funnel		L-Box h_2/h_1	U-Box h_2/h_1
				T_{10} (sec)	T_{50} (sec)		
1.	M	720	3.4	5.7	10.2	0.86	23
2.	TA1	674	3.5	5.8	10.4	0.87	24
3.	TA2	669	3.7	6.0	10.6	0.88	23
4.	TA3	664	3.9	6.2	10.7	0.89	22
5.	TA4	662	4.2	6.3	10.9	0.89	21
6.	TA5	660	4.1	6.5	11.1	0.90	20
7.	VB1	657	4.0	6.4	11.2	0.86	24
8.	VB2	659	4.2	6.6	11.4	0.87	23
9.	VB3	653	4.5	6.7	11.5	0.87	22
10.	VB4	651	4.6	6.9	11.8	0.88	21
11.	VB5	650	4.9	7.1	12.1	0.89	21
12.	LC1	658	4.2	7.2	11.9	0.87	24
13.	LC2	656	4.6	7.4	12.3	0.88	23
14.	LC3	655	4.9	7.5	12.5	0.89	22
15.	LC4	653	5.2	7.7	12.6	0.89	21
16.	LC5	649	5.4	7.9	12.8	0.90	20

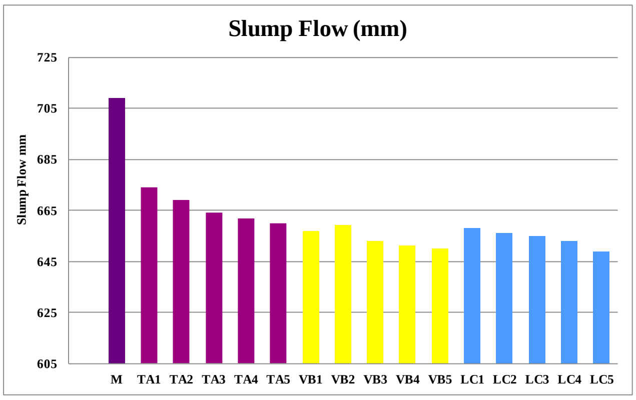

Fig: 1 Slump Flow Results of all Mixes

For all HSHFRSCC mix combinations, the test findings of workability properties such slump cones were determined. The Mix V5 and L5 have the lowest values of slump flow with 650 and 649 mm diameters, respectively, while T has the greatest value of slump flow with 709 mm diameter.

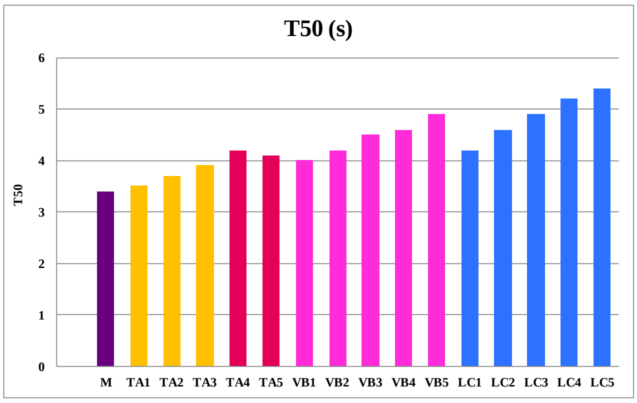

Fig: 2 T50 Results of all Mixes

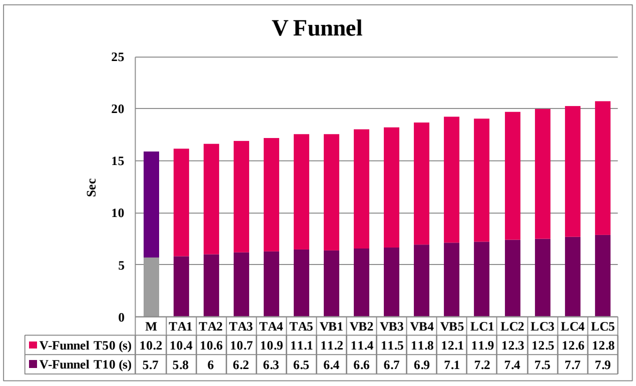

Fig: 3 V-Funnel Results of all Mixes

When the percentages of fibre and mineral admixtures rise, the value eventually declines.

The inclusion of fibre and mineral admixtures, which affect the concrete's workability qualities, is what causes the reduction in flow. The flowing ability of the HSHFRSCC mix is decreased by removing cement and replacing it with silica fume and GGBS.

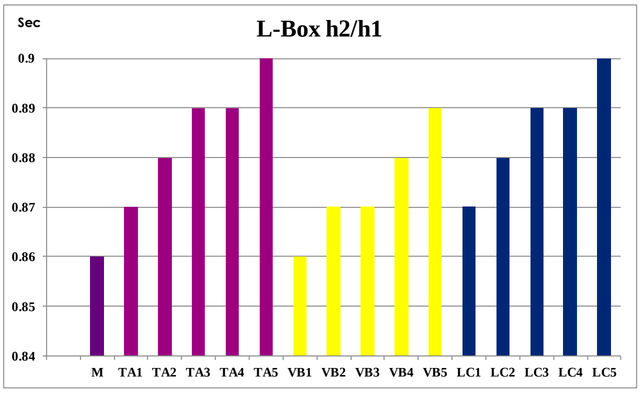

Fig: 4 L-Box Results of all Mixes

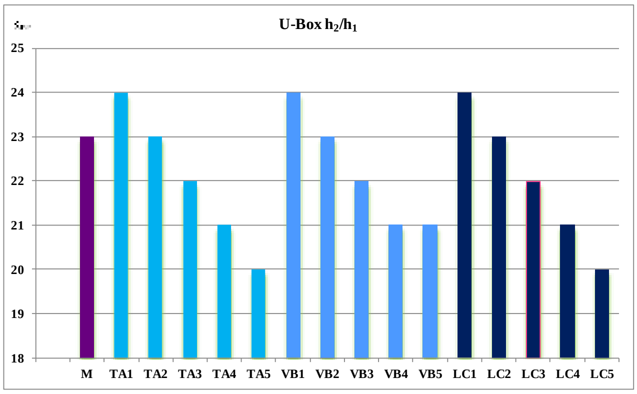

Fig: 5 U-Box Results of all Mixes

No segregation was found in any of the HSHFRSCC series, and it was decided that they all complied with the fresh state criteria based on actual outcomes.

The HSHFRSCC series' fresh characteristics were assessed in accordance along with the recommended limit values. Findings from the L-box test ranged between 0.86 and 0.9, as can be shown in Fig. 4.

As a result, all series have attained the capability of unobstructed passage through thick reinforcements.

The V funnel values from the control, and all the mixes of all series were evaluated and from Fig. 3 it is observed that as the percentage of fiber inducted increases the values also increased.

Slump flow and V (funnel) tests are used by EFNARC to assess the filling capacity of self-compacting concrete, while L box tests are used to assess the passage capacity of concrete.

Slump, V(funnel), U, and Lbox test outcomes do not generally correlate since these tests are meant to identify various concrete qualities.

The goal of the project is to create HSSCC series with comparable workability qualities.

Table 3.2 displays the variance in compressive strength data according to the HSHFRSCC series.

Table: 3.2 Compressive Strength Test Results of HSHFRSCC mix for w/c = 0.33

Sl. No.	Mix ID	Compressive Strength of Mixes (MPa) Age in days			
		3	7	28	90

1.	M	32.58	41.19	63.94	67.12
2.	TA1	31.62	40.72	63.86	67.38
3.	TA2	32.44	41.66	64.24	68.07
4.	TA3	32.78	42.35	64.75	69.87
5.	TA4	33.97	42.87	65.12	70.61
6.	TA5	34.45	43.12	65.97	71.81
7.	VB1	32.88	41.75	64.12	68.12
8.	VB2	33.83	42.15	64.45	68.39
9.	VB3	34.21	42.68	64.94	69.27
10.	VB4	33.85	43.79	65.36	70.68
11.	VB5	34.81	44.87	65.42	72.07
12.	LC1	32.80	42.03	64.74	69.75
13.	LC2	32.91	42.87	65.12	70.87
14.	LC3	33.97	43.19	65.38	71.77
15.	LC4	34.42	43.76	65.61	71.89
16.	LC5	35.72	44.12	65.87	72.20

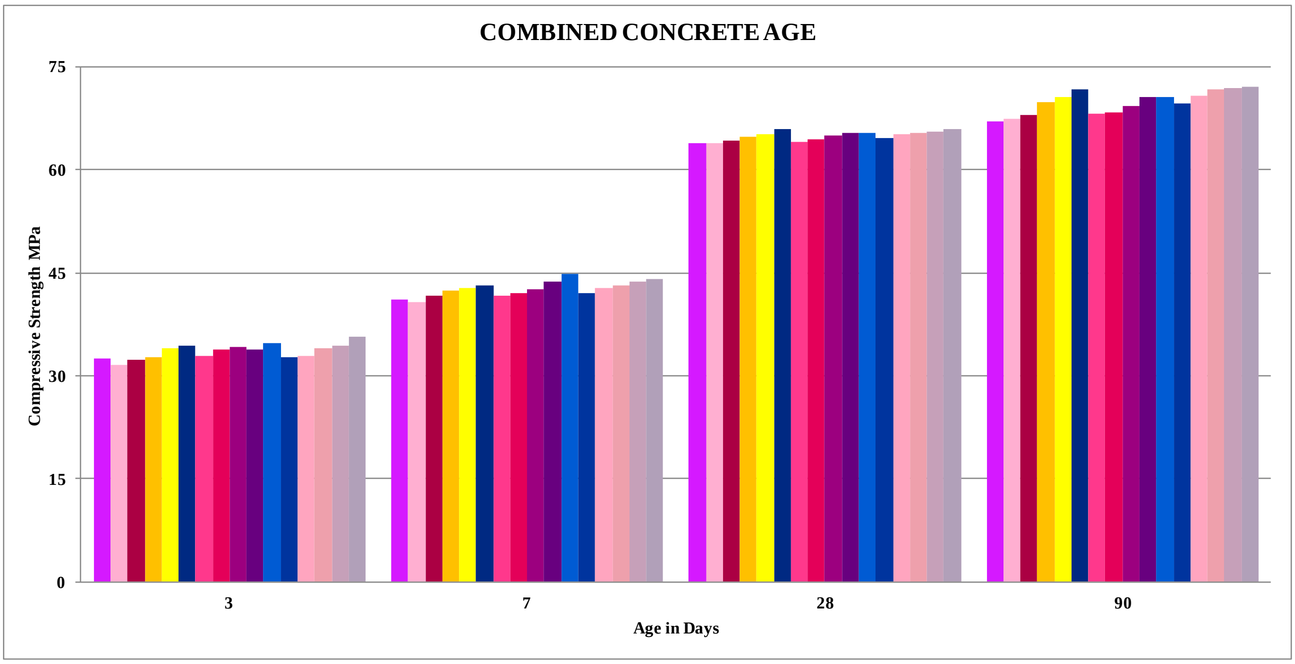

Fig: 6 Compressive-Strength of Combined Age of all Mixes.

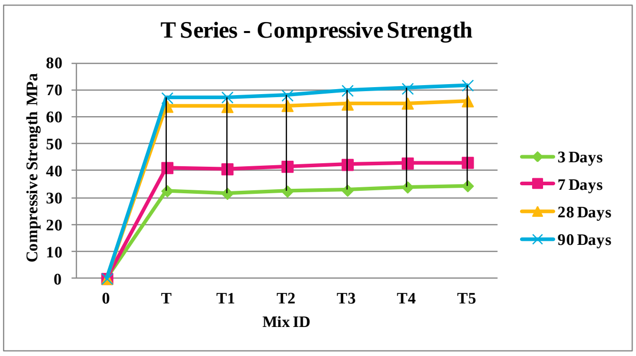

Fig: 7 Compressive-Strength of T-Series Mixes

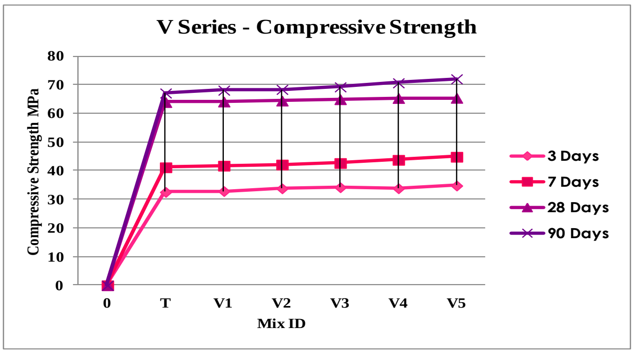

Fig: 8 Compressive-Strength of V-Series Mixes

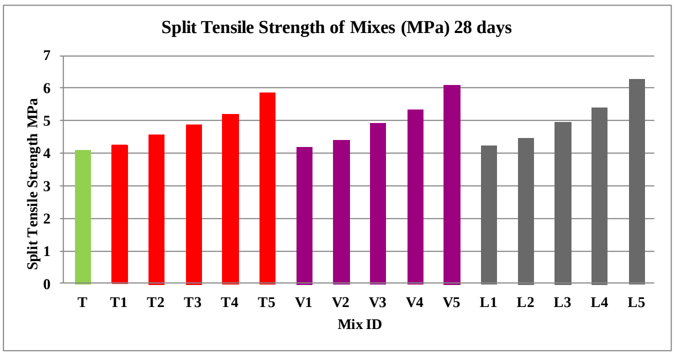

Fig: 9 Split Tensile Strength of T-Series Mixes

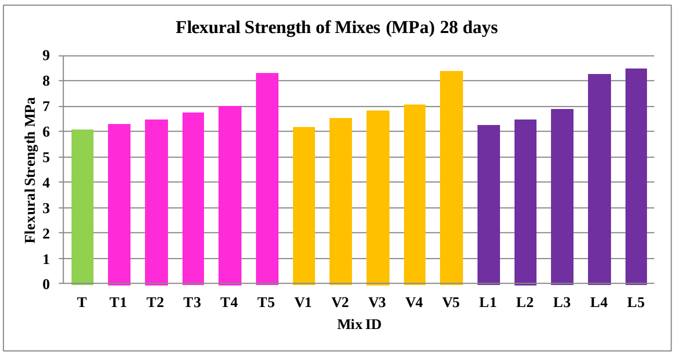

Fig: 10 Flexural Strength of V-Series Mixes

Table 3.3 Split Tensile and Flexural Strength of HSHFRSCC Mixes

Sl. No.	Mix ID	Split Tensile Strength of Mixes (MPa)	Flexural Strength of Mixes (MPa)
		28 days	28 days
1.	T	4.1	6.08
2.	T1	4.24	6.29
3.	T2	4.57	6.48
4.	T3	4.89	6.73
5.	T4	5.21	7.02
6.	T5	5.85	8.31
7.	V1	4.18	6.18
8.	V2	4.41	6.52

9.	V3	4.91	6.83
10.	V4	5.35	7.07
11.	V5	6.10	8.39
12.	L1	4.21	6.23
13.	L2	4.48	6.49
14.	L3	4.97	6.88
15.	L4	5.42	8.23
16.	L5	6.26	8.48

Table 3.2 contrasts the compressive strength of HSHFRSCC mixtures with and without GGBS and Silica fumes as a mineral component at ages of 3, 7, 28, and 90 days at a w/c ratio of 0.33. For all series concrete mix and standard concrete mix, the compressive strength values vary from 31.62 MPa to 72.20 MPa. In all series as per Fig 6, it was found that the compressive strengths rose as the curing durations lengthened. Beyond age 28, the pozzolanic reaction increases the compressive strength of concrete by increasing the proportion of GGBS and silica fume (days). This shows that additional C-S-H gels are generated and hydration processes continue when curing times are prolonged, increasing the compressive strength of concrete. All hybrid fibre reinforced specimens showed more compressive strength than conventional specimens, however among them, specimens with steel + polypropylene of 2% addition showed outstanding performance in compression, while the other hybrid reinforced specimens showed fair performance of increased strength compared with their subsequent mix's. Also, it may be suggested that specimens with steel and polypropylene fibre of varying percentage had incremental trend in compressive strengths.

The split-tensile strength results from the HSHFRSCC series are shown in Table 3.3. The splitting-tensile strength data, which range between 4.1 to 6.26 MPa, are shown in the Fig 10. According to experimental findings, GGBS along with Silica fumes in varying proportions in addition with hybrid fibres increase the splitting-tensile strength of HSHFRSCCs. This improvement in strength may be attributable to the utilization of GGBS+ Silica fume with induction of hybrid fibres in varying percentage improved filling properties and their stronger connection with the cement paste in the combinations.

However, among all hybrid fibre reinforced specimens, those with steel + polypropylene fibre with 2% showed superior performance in split tension when compared to other hybrid reinforced specimens, which showed a moderate increase in the performance in split tensile strength. All hybrid fibre reinforced specimens showed an incremental trend split tensile strength than conventional specimens. The VB5 and LC5 , with splitting-tensile strengths of 6.10 and 6.26 MPa, respectively, produced the highest splitting-tensile strengths from the HSHRFSCC series, in which the curing durations were applied for 28 days.

Table 3.3 displays the flexural strength of the HSHFRSCC Mixes with water cement ratio 0.33 at the age of 28 days.According to Fig. 10, LC5 has a greater flexural strength (8.48) than all other blends and conventional materials put together. The particle size of the mineral admixture silica fume and hybrid fibre has a major impact on the flexural strength development of the HSHFRSCC mix.

3. Findings and discussion

Many of the results drawn from the study cannot be generalized because they are all based on a single study that used a specific set of tested materials and specific research conditions.

According to the outcomes of the tests: The findings of the study suggested that GGBS and Silica fume of varying replacement with induction of hybrid fibre (steel+ polypropylene) could be helpful in the development of HSHFRSCC.

It is also estimated that employing GGBS and Silica fume in SCCs will aid in waste management.

In all HSHFRSCC series with GGBS and Silica fume of varied replacement with induction of hybrid fibre (steel+polypropylene) from (0-2%) has fulfilled with all the workability requirements of IS, according to the fresh concrete test results, segregation was not seen. The L5, which were cured for 90 days, had the best compressive strength values in the HSHFRSCC series.

It was shown that HSHFRSCC had greater increases in compressive strength than conventional concrete.

The addition of fibres enhanced the compressive, splitting tensile, and flexural strength in comparison to control mixes. This leads to the conclusion that the hybridization of fibre, namely steel crimped fibre and polypropylene, is helpful in enhancing the strength qualities of planned concrete.

4. References

1. Okamura H & Ouchi M., *Self-Compacting Concrete*. (2003).
2. El-Dieb A S & Reda Taha M M., *Const and Build Mater*, 27 (2012) 585.
3. Bassuoni M T & Nehdi M L., *Cem & Concrete Res*, 39 (2009) 206.
4. Dinakar P, Sethy K P & Sahoo UC., *Mater & Design* 43 (2013) 161.
5. Malhotra V M., *Cem, Conc & Agg*. 104 (1987) 63.
6. Carette G G, Malhotra V M., *Can J Civil Eng*. 14 (1987) 667.
7. Barluenga G & Hernández-Olivares F., *Cem & Concrete Res,* 37 (2007) 1624.
8. Gesoğlu M, Güneyisi E & Özbay E., *Const and Build Mater*, 23 (2009) 1847.
9. Mohamed H A., *Ain Shams Engg J*, 2 (2011) 79.
10. Lian C, Zhuge Y & Beecham S., *Const and Build Mater*, 25 (2011) 4294.
11. Ouchi M., *SSME*, 8 (2012) https://cir.nii.ac.jp/crid/1050282676659792128
12. Boukendakdji O, Kadri EH & Kenai S., *Cem & Concrete Comp*, 34 (2012) 583.
13. Hussain S T & Sastry K., *Int J Res Eng Tech*. 10 (2014) 103.
14. Deshmukh P., *IJSR*, 4 (2015) 694.
15. Pai B H V, Nandy M, Krishnamoorthy A, Sarkar P K & Ganapathy C P., *European Sci J*, 10 (2014) 292.
16. Joe M A & Rajesh AM., *The Int J Engg & Sci*, 8 (2015) 12.
17. Sahmaran M, Yurtseven A & Ozgur Yaman I., *Build and Env*. 40 (2005) 1672.
18. Siddique R, Kaur G & Kunal., *Const & Build Mater*, 103 (2016) 15.
19. Mahapatra C K & Barai S V., *Const & Build Mater*, 160 (2018) 828.
20. Łaźniewska-Piekarczyk B., *Const & Build Mater*, 40 (2013) 659.
21. Łaźniewska-Piekarczyk B., *Const & Build Mater*, 49 (2013) 643.
22. V Limbachiya, E Ganjian, P Claisse., *Const & Build Mater*, 113 (2016) 273.
23. IS 12269, *Spec 53 Grade OPC*, 2013.
24. IS 10262, *Guide Conc Mix Design*, 2019.
25. G C Wang in *Woodhead Publishing Series in Civil and Structural*, (Elsevier Science Publishers, New York) 2016 28.