

Enhancement of Concrete Sustainability under Temperature Variation using Hybrid Fibre Reinforcement

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Abstract

This study focuses on the performance enhancement of concrete structures under adverse conditions using hybrid fibre reinforcement. A carefully designed slag based concrete mix was arrived based on the three phase particle interaction with a significant reduction in the total cement content. Longer and shorter combination of steel (60mm and 35mm) and polypropylene (47mm and 23.5mm) fibres were used in this study subjected to temperature variation (200°C, 400°C, 600°C and 800°C). Many studies proved the performance of fibre under temperature variation but this study elaborates the significance of the type and size of fibres contributes to the sustainability of the concrete under adverse condition. The comparative assessment is made to understand the performance of each fibre combination under temperature effects. Test results show each hybrid combination shows better results than plain concrete and it purely depends on the fibre used. Even though the role of fibre is less in case of compressive strength but the effect of temperature on the type of fibre is clearly showcased elaborately in this paper.

Keywords: Compressive, Hybrid, Slag, Sustainability, Temperature

1. Introduction

The application of fibre in the concrete to develop its mechanical behaviors is a very common and vast area of research in the recent decades. Hybridization of the concrete using multiple fibres to increase the performance of the concrete than mono fibre addition is also studied widely. The durability of such hybrid fibre concrete under varying temperature elevation is focused in this study^{1,8}. The performance of low modulus fibre such as polypropylene and high modulus fibre such as steel fibre were assessed systematically^{2,3,5}. The sustainability of the concrete by addition of such fibres shows a comparatively better performance^{4,6,7}. In this study, a carefully designed slag based concrete is arrived by the three phase particle interaction and its corresponding particle packing density such that it gives a better compressive strength than the

conventional concrete. 50% of cement and 50% of ground granulated blast furnace slag is used in the mix proportion. The ration of coarse aggregate to mortar is used as 60:40 percentages. The tests were conducted as per Indian standard and results were evaluated. The behavior of each combination shows a clear variation and significance of the type and dosage of fibre used.

2. Mix Proportions and Fibre used

The concrete mix proportions were conceptually arrived based on the packing density of the concrete materials considering 50% coarse aggregate and 50% mortar. Ordinary Portland cement confirming IS 12269-19879 locally available river sand belonging to zone II of IS 383-

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Table 1. Concrete proportion for different specimens

Mix ID	Binder (B)		Fine Aggregate (FA)	Coarse Aggregate (CA)	Water	HRWR	Polypropylene Fibre		Steel Fibre	
	Cement	Slag					% V _{fraction} Of V _{mortar}			
	kg/m ³	kg/m ³					kg/m ³	kg/m ³	l/m ³	% V _B
Control Mix	162	162	876	1200	97.2	1	-	-	-	-
HYF 2	162	162	876	1200	97.2	1	0.6	-	1.6	-
SF 11	162	162	876	1200	97.2	1	-	-	2	2
HYF 35	162	162	876	1200	97.2	1	-	0.4	-	2.4

197010, was used. Locally available aggregate of size 12.5 mm and 20 mm size conforming IS 383-197010 were used in this study. High range water reducing plasticizer is used to increase the workability of the concrete as the water/cement ratio is maintained as 0.3. The fibres are added in percentage volume fraction of the volume of mortar. Longer and shorter combination of steel (60mm and 35mm)(SF) and polypropylene (47mm and 23.5mm) (PP) fibres were used.

The mix proportion and fibres used for the study are given in Table 1 and shown in Figure 1.

3. Experimental Methodology

The arrived mix proportions were thoroughly mixed with corresponding hybrid fibres and cube specimen of size 150x150x150 mm were casted and cured for 28 days under normal condition. Mix HYF2 consists of 60% of longer PP fibre (47mm) and 40% of longer steel fibre (60mm). Mix SF11 consists of 50% of longer (60mm) and 50% of shorter (35mm) steel fibre and mix HYF35 consists of 60% of shorter (35mm) steel fibre and 40% of shorter (23.5mm) PP fibres. These specimens were subjected to

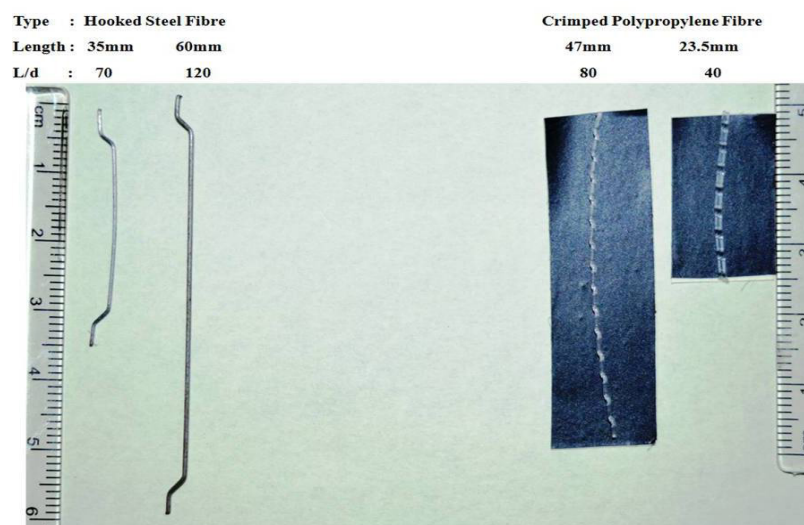
**Figure 1.** Type of Fibres Used.



Figure 2. Cube Specimen Placed in the Muffle Furnace.

elevated temperatures (200° C, 400° C, 600° C and 800° C). The compressive strength of the concrete specimens

was tested and results were analyzed as per IS 516 – 1959¹¹. Figure 2 shows the cubes subjected to elevated temperature in muffle furnace.

4. Test Results and Its Significance

The specimens were subjected to different temperature and tested as per Indian standards. The addition of fibre does not play a vital role in the compressive behaviour because failure is other than fracture. But in case of temperature elevation notable deviation were observed. The test results are tabulated in Table 2 and represented in Figure 3.

It is clearly observed that all the mixes shows a good compressive value and on par with each other under room temperature. At 200°C, the bond gets break and PP fibre melts as its melting point is 160°C. Thus creating a partial void inside the concrete. Correspondingly the strength gets reduced. In cause of SF11 mix, even though only steel fibres were added the mix gets porous and hence the bond between the materials fails.

At 400°C, mix HYF2 and HYF35 shows an on par values and comparatively higher value than the control mix and SF11. The significance is that the PP fibres gets melted completely and fills the minute voids in the concrete and thereby increasing the compressive strength. As described

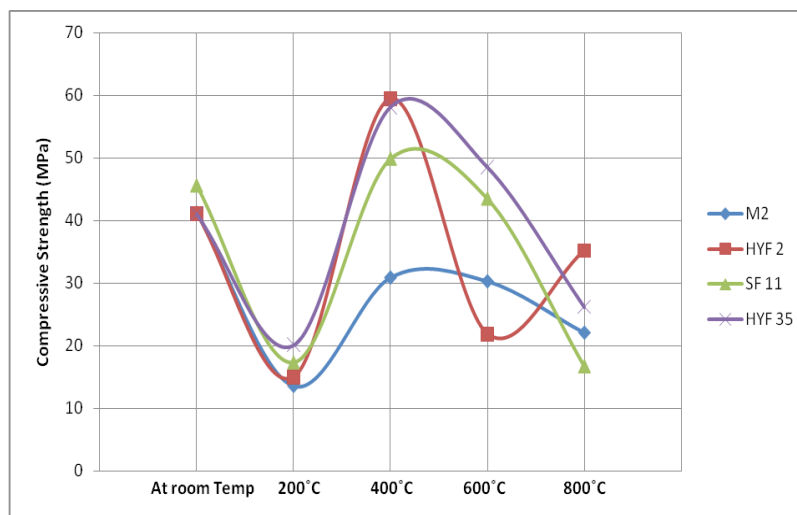


Figure 3. Compressive Strength at Different Temperature.

Table 2. Compressive strength at elevated temperature

Mix Id	Compressive strength MPa				
	Without Temperature variation	200°C	400°C	600°C	800°C
M2	41.25	13.6	30.9	30.3	22.1
HYF 2	41.1	15	59.4	21.9	35.2
SF 11	45.6	17.3	49.9	43.5	16.7
HYF 35	41	20.1	58.1	48.5	26.2

earlier SF11 records a lesser value as the concrete materials become porous.

At 600°C and 800°C, the compressive strength shows a gradual reduction as the PP fibres gets converted to vapour state and thus clear voids will be created in the placements of PP fibres thereby reducing the compressive strength. It shows very clearly that all the hybrid combinations shows a better results than the conventional concrete mix. Mix HYF2 shows a sudden variation because the dosage of PP fibre is more in this combination and hence due to higher temperature elevation the compressive strength shows a sudden drop.

5. Conclusion

The sustainability of the concrete is enhanced under a temperature elevation at 400°C. The significance of the addition of polypropylene fibre (PP) with different lengths and dosage shows a clear variation in the compressive strength and different temperatures. It is a clear fact that fibre does not contribute to the enhancement in the compressive strength but this study shows low modulus and low melting point fibre addition in a definite ratio will significantly shows a strength enhancement under compressive load. Thus usage of such fibres in structures subjected to high temperature can be suggested and applied.

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