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Comparative assessment of impact toughness behavior of hybrid fibre reinforced concrete

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Abstract **– Many studies were made in the recent years related to analysis the toughness behavior of fibre reinforced concrete under impact loading condition. This study focus on the investigation of hybrid fibre reinforced concrete using polypropylene fibre and steel fibre unde impact loading. The concrete mixes were arrived based on the packing density of the aggregates. Three mixes were arrived having the combination of polypropylene fibre (PP) and steel fibre (SF) in varying proportions with different aspect ratio. The experimental set was made as per Indian Standards. The test results evidently shows the combination of 50% of 60mm steel fibres and 50% of 35mm steel fibres has recorded highest toughness value under impact. Correspondingly the other hybrid combination of polypropylene and steel fibres has also exhibited a higher value than the plain concrete. This study shows a comparative study on the behavior of hybrid fibre concrete to the plain concrete under impact loading condition.**

Keywords- **impact; toughness; hybrid; steel fibre; polypropylene fibre.**

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I. Introduction

In the past few decades, researches were made to study the behavior of concrete under impact loading **[1-2]**. After the evolution of hybrid combination of two or more fibres in a concrete matrix, wider studies on the behavior of hybrid concrete under impact loading became an emerging area. It is evidently proven in many studies that the performance of fibre addition in the concrete increases the mechanical and durability property of concrete **[3]**. But these studies were done with static loading condition. The performance of fibre concrete under dynamic loading such as impact condition is focused in recent decade only **[4]**. In this study, the concrete which was arrived based on three phase interaction of concrete materials. Two types of fibres with different aspect ratios were used in this study. Polypropylene fibre (PP) of 47mm and 23.5mm and steel fibre (SF) of 60mm and 35mm were taken in different proportions. This paper shows the comparative assessment between plain concrete and other hybrid concrete mixes.

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

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	47mm	23.5mm	60mm	35mm
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

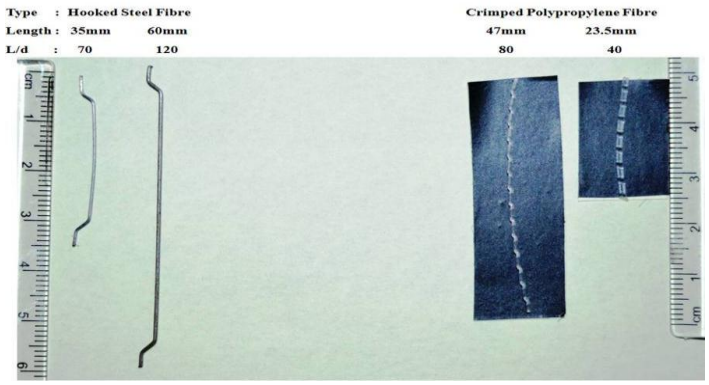

Figure 1. Types of fibres used

III. Experimental methodology

A circular concrete slab specimen of dimension 400mm diameter and 40mm thick were casted with different hybrid fibre combinations and cured for 28 days under normal condition. The cured specimens were tested under impact loading condition as per specification. The experimental arrangement is shown schematically in Fig 2.

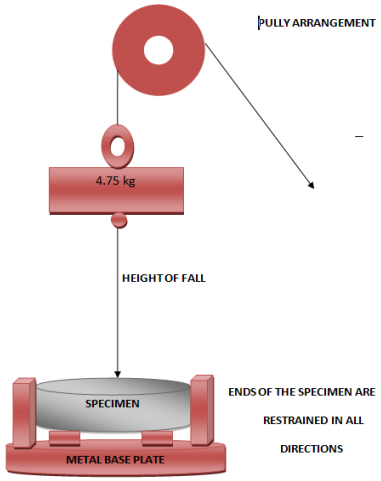

Figure 2. Experimental set up for assessment of Impact toughness

As per specification, a pulley arrangement is made in such a way to carry a load of 4.75kg solid mass which is used to create the impact load on the specimen. The specimen is placed on a metallic base such that the ends of the specimen are restrained in all direction.

The concept behind restraining the ends is to make the maximum energy imposed on the specimen will be completely absorbed by the specimen.

Figure 3 Specimen under restrained condition.

IV. Result & discussion

The specimen in kept in the metallic base and the load of 4.75kg is raised to a height of 0.5m with the help of a pulley arrangement and dropped suddenly on the specimen. The number of blows is counted which cause the first crack and ultimate failure and tabulated in Table 2.

Based on the test results, the control mix reaches the ultimate failure at 3 blows cause by the impact load. From Table 2, it is clear that all the other hybrid mixes shows a comparatively higher value than the plain concrete mixes. Other significant observation shows the hybrid mixes initially develops crack and does not fails suddenly even under impact loading condition.

Table 2 Evaluation of Impact values of different concrete mixes

Mix ID	Diameter of the specimen (m)	Thickness of specimen (m)	Load		Height of fall (m)	No of Blows	
			kg	N		First crack	Ultimate failure
Control Mix	0.4	0.04	4.75	46.60	0.5	-	3
HYF 2	0.4	0.04	4.75	46.60	0.5	10	14
SF 11	0.4	0.04	4.75	46.60	0.5	65	87
HYF 35	0.4	0.04	4.75	46.60	0.5	19	32

The tabulation also shows at correspondingly higher number of blows the hybrid mixes develops first crack and gradually reaches the ultimate. It is also clear that the combination of steel fibre SF 60mm 50% and SF 35mm 50% has recorded a higher value when compared with other plain and hybrid concrete mixes.

A. Evaluation of impact toughness

Toughness is the energy absorption behavior of specimen due to the imposed load. With respect to the experiment conducted, toughness of the different concrete mixes were calculated and tabulated in below Table 3. From the number of blows taken by the specimen and the product of the free falling weight and height of fall gives the corresponding energy absorption value of the specimen. As the plain concrete attains the ultimate with any prior indication, it does not exhibit first crack toughness and hence the ultimate toughness is calculated. Whereas the hybrid mixes shows a comparatively higher value of toughness with respect to the plain concrete. The toughness of steel fibre combination SF11 consisting 50% of 60mm and 50% of 35mm fibre has recorded the highest value which is relatively so high compared with plain concrete mix.

It is obvious that the hybrid combination which consist only steel fibre will perform better than other hybrid concrete as steel has good energy absorption capacity than polypropylene fibres.The hybrid combination of polypropylene and steel fibres (HYF2 & HYF35) has recorded higher value than plain concrete mix.

Table 3 Toughness evaluation of different hybrid concrete mixes under impact

Mix ID	Fibres	First crack Toughness (Nm)	Ultimate Toughness (Nm)
Control Mix	No Fibre	-	69.90
HYF 2	PP 47mm 60% - SF 60mm 40%	232.99	326.18
SF 11	SF 60mm 50% - SF 35mm 50%	1514.42	2026.99
HYF 35	PP 23.5mm 40% - SF 35mm 60%	442.68	745.56

B. Comparative assessment of impact toughness of hybrid concrete

Even though all the hybrid mixes shows a higher value than plain concrete, each combination exhibits different behavior based on the type of fibre. From the fig 3 given below the comparative assessment can be made. The combination SF11 consisting 50% of 60mm longer fibre and 50% of 35mm shorter fibre has recorded a highest value of toughness both in first crack and ultimate conditions.

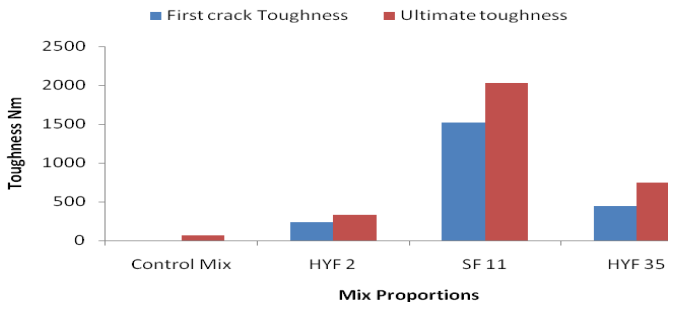

Figure 3. Impact toughness of different concrete mixes

But comparing mix HYF2 and HYF35, the mix consisting of shorter fibres recorded higher value. The amount of steel fibre is more in case of HYF35 and also number of fibres located in the specimen for crack bridging will be more. In mix HYF2 the amount of polypropylene fibre is more and hence the ability to take the energy dispersed by the suddenly load becomes comparatively difficult. These results showing longer fibre combination records lesser value which has a controversy with flexural results **[5]**. But to understand the comparative assessment conceptually in case of flexure the failure is other than fracture. Application of impact load causes a facture failure in the specimen which cannot be resisted by polypropylene fibre. Hence the combination consisting higher percentage of steel fibre absorbs comparatively more energy.

V. Conclusion

The following conclusions can be drawn from the present study within the limitations of the experimental observations recorded during testing. The comparative assessment of hybrid fibre under impact loading is done systematically. The test result evidently shows the mix SF11 shows a greater toughness value. The comparative assessment between mix HYF2, SF11 and SF35 shows clearly that the type of fibre, dosage and aspect ratio has a direct relationship with the energy absorption behavior of the concrete mixes. This study shows a clear comparison of the behavior of hybrid fibre concrete over plain concrete under impact loading condition.

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