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Investigation on Impact Resistance of Steel Fibre Reinforced Concrete

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Abstract: ***Through concrete has very good compressive strength, it has inherent disadvantage of being weak in bearing tensile and impact loads. It has been demonstrated that addition metallic fibres to control mix enhances the tensile property of the concrete. In this investigation, an attempt was made to study the impact resistance of steel fibre reinforced concrete. A simple, practical and economical drop weight test was performed on fibre reinforced concrete as per ACI committee 544. Hooked end steel fibres were randomly dispersed in concrete. Fibre dosages of 0.5%, 1%, and 1.5% by volume of concrete were used in the experimental stud . The results indicated that increasing the volume fraction of fibre increased the impact resistance of concrete specimen compared to conventional concrete.***

Keywords: Fibre reinforced concrete, Steel ,Drop weight test, compressive strength, Impact energy

1. Introduction

Concrete is the most widely used construction material in this world. Generally concrete has low ductility and impact resistance on bridge decks, Aircrafts etc., hence steel fibres are added with concrete mix. Due to an increasing use of FRC (fibre-reinforced concrete) in construction like bridge decks and military industries against impact loads, these concretes are important role in human life. Adding fibres to concrete increases its ductility, tensile strength, flexural strength and resistance against dynamic and impact loads. The aspect ratio (L/d) and volume fraction (Vf) are important fibres parameters in FRC. When cracks are initiated in FRC, the fibres bear the applied loads, when the load increases the fibres tend to transmit the excess stresses to the matrix. If these stresses exceed the fibre-matrix bond strength, which in turn is influenced by fibre properties the fracture process may lead to fibres pullout or rarely rupture of the fibres. Thus, fibre reinforced concretes are more ductile than other concretes.

It was reported that steel fibes were effective in improving strength properties of the concrete [1]. Different guidelines are suggested by various impact test methods such as projectile impact test, drop weight test and explosive test and they may be used for the investigation of impact resistance of concrete [2-3]. Among these methods the Drop weight test proposed by the ACI (American concrete institution) committee 544 is the simplest method for evaluating the impact resistance of Fibre [4]. Experimental results from concrete specimens containing 0.5% to 1.5% of mono fibres showed that the impact resistance of concrete increased both for initial crack and final crack compare with plain concrete. Marar et al. [5] showed that for FRCs containing 0.5%, 1%, 1.5% and 2% hooked-end steel fibres with aspect ratios of 60, 75 and 83, the samples with a higher fibre content (in all of aspect ratios) had a higher impact strength; also for specimens with 2% fibre content and aspect ratios equal of 60, 75 and 83, the absorbed energies increased by 38, 55 and 74 times, respectively. Ramakrishnan et al. [6] reported that steel fibres increased the impact resistance of FRCs up to six times compared with the impact resistance of plain concrete. Using a drop hammer apparatus, Nataraja et al. [7] investigated the impact strength of steel fibre-reinforced concrete with an aspect ratio of 40 and two strength types, 30 MPa and 50 MPa. The results showed that the impact strength of all of the samples for the first crack and final fracture increased as the volume fraction of fibres increased. They found that a 0.5% fibre content led to the impact resistances of the FRC sample at the first crack and final fracture increasing 3 and 4 (times greater) than the results from the plain concrete respectively. The main objective of this project is to study the Impact resistance parameter of fibre reinforced concrete with mix proportion of fibres for M30 grade concrete and comparing with the conventional concrete and to know the optimum percentage of addition of fibres to concrete and finding maximum ratios.

2. Experimental Study

The experimental investigation was focused on the effect of various fibre dosages on impact resistance of FRC. Mix proportion was designed using IS 10262-2009 [14] and IS 456-2000 [15] with mean target strength of 38.25 MPa (M30) for control mix. Ordinary portland cement (type 1) was used in this study. A coarse aggregate with a maximum nominal size of 19 mm and a fine aggregate with a fineness modulus of 3.4 were used in the experiment. Hooked-end steel fibres were used; their geometry and apparent shape are shown in Fig. 1 and their properties are listed in Table 1. Super plasticizer of SP-430 was used to adjust the workability of mixtures.

Figure 1: Steel fibres

Table 1: Physical Properties of steel fibres

Fibre	*Diameter(μm)*	*Specific Gravity*	*Modulus of Elasticity (GPa)*
Steel	5-500	7.84	200

Crushed granite stones of size 20 mm and 10 mm were used as coarse aggregate and river sand was used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm and 10mm were 2.58 and 0.3% respectively. The bulk specific gravity in oven dry condition and water absorption of the sand were 2.62 and 1% respectively.

3. Mix Design

In this study, water cement ratio of 0.5 was adopted for M30 grade concrete and steel of 0.5%, 1%, 1.5% volume fractions were used

Table 2: Content of mix proportions used

Constituents	*Content KG/ m^3 of concrete*
Cement	394.32
Fine aggregate	623.45
Coarse aggregate	1097.81
Water content	197.16
Fibres	
0.5%	11.56
1%	23.12
1.5%	34.69
Super plasticizer	9.38

4. Test Method

The impact test was performed in accordance with the impact testing procedures recommended by ACI Committee 544. The test was carried out by dropping a hammer weighing 44.7N (10 lb) from a height of 457mm (18 inch) repeatedly on a 64mm (2.5 inch) hardened steel ball, which is placed on the top of the centre of the cylindrical specimen (disc) as shown in Fig 4

The test continued until failure. For each specimen, two values were identified corresponding to initial and ultimate failure. The former value measures the number of blows required to initiate a visible crack, whereas the latter measures the number of blows required to initiate and propagate cracks until ultimate failure. According to the ACI committee, the ultimate failure occurs when sufficient impact energy has been supplied to spread the cracks enough so that the test specimen touches the steel lugs. However, in this study, if the specimen separated completely into halves before touching the lugs, then this was declared the point of ultimate failure. From this test, impact energy absorption capacity of each specimen was calculated by the equation

Impact Energy (E imp) = $(0.5mv^2)$ n -------------------- (1)

Where m =mass of the hammer

n= no of blows

V= Impact velocity

Figure 2: Drop weight test set up

5. Results and Discussion

The results are based upon the number of blows that are required to initiate initial crack and number of blows that are required for final crack. Impact resistance of mono fibre reinforced concrete was calculated at different curing periods and compared to conventional concrete. The impact energy was calculated as follows

$$H= (gt^2)/2 \quad \text{---------------} \quad (2)$$

$$V= g*t \quad \text{----------------} \quad (3)$$

$$m= W/g \quad \text{--------------} \quad (4)$$

where V is the velocity of hammer by impact g is acceleration due to gravity, t is the time required for hammer to fall from a height of 457mm, H is the height of the hammer, weight of the hammer substituting the known values in equation 2 we get

$457= (9810\ t^2)\ /2$

t= 0.3052 sec

V= 9810 x 0.3052 = 2994.01 mm/s

The above value substitute in Impact energy equation 1 we get

EImp= $(0.5 \times 44.3 \times 2994.01^2)/9810 = 20.345$ (n) KN-mm

Table 3: Impact resistance for initial crack

Fibre dosage	Number of blows for Initial crack	Impact energy(KN-mm)	% increase in impact energy
PCC	22	447.59	-
0.50%	121	2461.75	450.00
1.00%	168	3417.96	663.64
1.50%	241	4903.15	995.45

Table 4: Impact resistance for final crack

Fibre dosage	*number of bows for final crack*	*Impact energy (KN-mm)*	*% increase in impact energy*
PCC	30	610.35	-
0.50%	155	3153.48	416.67
1.00%	197	4007.97	556.67
1.50%	309	6286.61	930.00

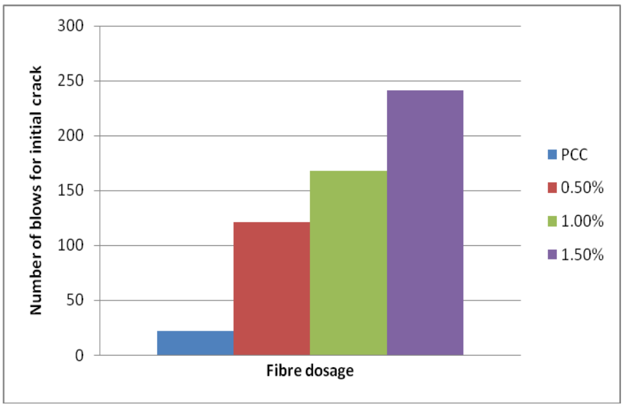

Figure 3: Number of blows taken for initial crack

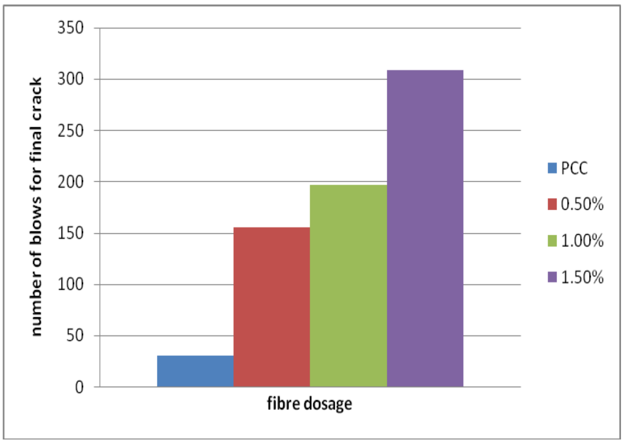

Figure 4: Number of blows taken for final crack

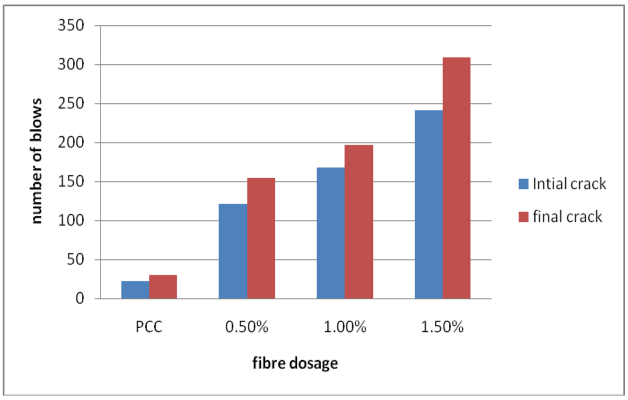

Figure 5: Comparison of number of blows for cracks

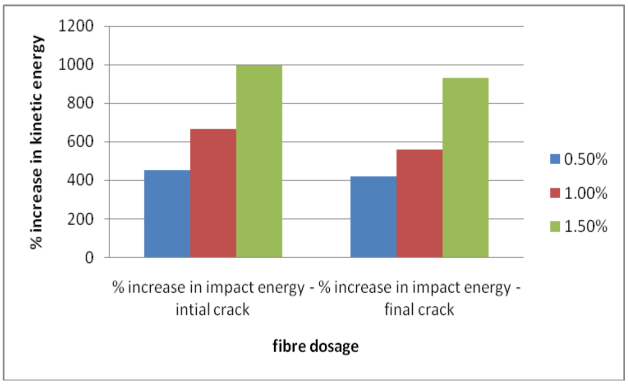

Figure 6: Percentage increase in Impact Energy

Table 5: Comparison b/w strength and number of blows

	Compressive Strength	*Initial crack*	*Final Crack*
PCC	40.92	22	30
0.50%	42.26	121	155
1.00%	43.84	168	197
1.50%	44.93	241	309

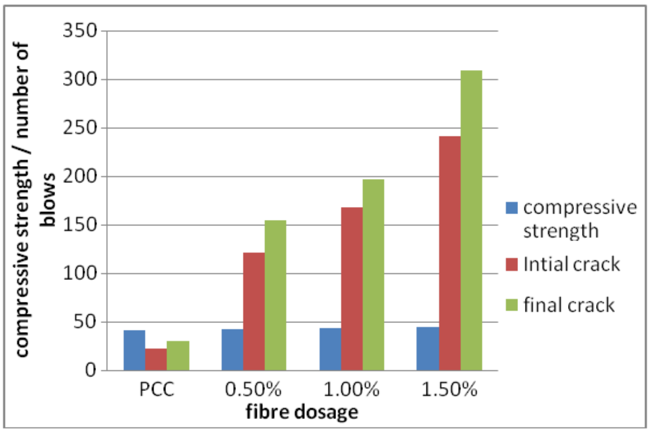

Figure 7: Comparison between compressive strength and number of blows

As it can be seen from figure 3 and 4 that increase in fibre dosage resulted in increase of number blows required for initial and final crack. Maximum number of blows was found to be 241 and 309 for initial and final cracks respectively for a fibre dosage of 1.50%. The difference between number blows for final crack and initial crack increased with increase in fibre dosage as shown in figure 5. Maximum difference was seen for the fibre dosage of 1.50%. Impact energy was directly associated with the number of blows. Impact energy increased with increase in fibre dosage for both initial crack and final crack. As it can be seen from Figure 6 that more increase in impact energy was observed for initial crack as compared to final crack for all the fibre dosages.[8-9]

Furthermore, Compressive strength also followed the same trend as that of impact resistance. Although the change in compressive strength was not as substantial as that of impact resistance, slight increase in compressive strength was observed with increase in fibre dosage as shown in Figure 7.[10]

6. Conclusions

Based on the results of this experimental investigation, the following conclusions can be drawn:

1) Steel fibres were found to be effective in improving impact resistance of the concrete
2) Impact resistance increased with increase in fibre dosage and the maximum resistance in terms of number of blows was found for a fibre dosage of 1.50%
3) Compressive strength increased slightly with increase in fibre dosage. However, the rate of increase in compressive strength was not at par with that of impact energy.

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