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Research Article

Experimental Studies on Impact Characteristics of Steel Fibre Reinforced Concretes

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Abstract: Research work carried out so far towards the development of concrete that exhibits improved impact resistance than conventional concrete. There are several situations in which concrete structural elements are subjected to impact loading. The behaviour of concrete under impact loads is far from adequate and there is significant variability in the published literature. The primary reason for this is the lack of a standardized technique of testing concrete under impact. In this project, an attempt is made to study the impact resistance of fibrous concrete using ACI drop weight Impact tester. Two grades of concrete's namely M1 and M2 are consideredin this investigation with 0.5, 1.0, 1.5 and 2.0% dosage of steel fiber. The experimental test results of steel reinforced fiber concrete are compared with plain concrete and conclusions are arrived.

Keywords: Fibrous concrete, impact strength, steel fiber

INTRODUCTION

Concrete structures are often subjected to short duration (Static or dynamic) loads. Such originate from sources such as aircraft crashes, missiles and projectiles, wind gust, explosions due to gas and other causes, earthquakes, machine vibrations, construction accidents and pile driving. The experience so far indicates that the structure/elements in areas such as airfield pavements, protective shelters for civil and military purposes, industrial structures in seismic areas, offshore structures, nuclear power plant structures, containers for transporting radioactive materials, crusher, supporting structures, auto shredders and whipping of steam pipe subjected to impact need special attention in design to resist the same.
Some of the literature is reviewed and reported here.

Drop weight method: Chauvel and Razani (1989) have investigated impact resistance of slab are increased by fiber addition together with the ultimate deformation energy Gorst and Wood (1992) has studied special types of specimens to create failure due to flexure, shear and torsion. Steel and polypropylene fiber reinforced concrete is studied for impact load subjecting the specimen to flexure shear and torsion.

Soroushian and Mirza (1982) has studied the effects of collated fibrillated polypropylene fiber on the impact resistance, chloride permeability and abrasion resistant materials and incorporating different types of pozzolanic materials. Plain pozzolan concrete has 40% less ultimate impact resistance than conventional concrete and percentage increase in ultimate resistance of conventional and pozzolan concrete with the addition of polypropylene fibers were 50 and 100%, respectively.

Shivaraj *et al*. (1989) have presented the results of an investigation carried out to determine the flexural, endurance limit and impact strength of steel fiber reinforced refractory concrete at 0.5, 1.0 and 1.5% by volume of fiber. These properties are compared to the same refractory concrete mix without steel fiber. The fatigue strength of increased 61, 159 and 199 to 0.5, 1.0 and 1.5% by volume of steel fiber, respectively. The endurance limit expressed as a percentage of plain concrete modulus of rupture, increased 60, 160 and 200%. When reinforced with 0.50, 1.0 and 1.5% of steel fiber by volume, respectively. The addition of steel fiber also substantially increased the strength of refractory concrete.

Lifshitz *et al*. (1995) have investigated low velocity impact of carbon fiber reinforced epoxy and it was conducted in 48 and 40 layered beams of different combination of 0°, 90°, 45° and -45° stacking sequences. The test setup included an instrumented dropweught and data acquisition system. Beams of two lengths were tested. Long (199 mm) and "short" (55 mm), under impact and quasi-static loading conditions. They acceleration pulse was analyzed in the frequency domain to determine the source of high frequency vibrations and a simple two degree of freedom model was used to distinguish between the force on the Stricker and the force applied to the beam. It is shown that the elastic response of the beams is the same under the two loading regimes.

Zhou and Davies (1995) have investigated thick glass, polyester woven roving laminated plates subjected to low velocity impact using a guided drop weight testing and found that the impact resistance is increased by 36% for thin plates and by 22% for the thick plates.

Wang *et al*. (1996) has used polypropylene and steel fiber in impact tests on small on small concrete beams. Polypropylene fiber, less than 0.5% gave a modest increase in fracture energy. Steel fibers could bring about much greater increase in fracture energy. Fiber break-in was the primary failure mechanism for steel fibers less than 0.5%. Fiber pull out was the primary mechanism for failure with fibers more than 0.75%.

Chu and Bentur (1997) has investigated polypropylene fibers in impact test on small concrete beams. The impact resistance is increased by 29% for the beam in presence of polypropylene fibers.

Instrumental impact testing method: Bentur *et al*. (1989) has investigated the effects of low volumes of fibrillated fiber reinforcement on the proprieties of concrete, in particular on impact resistance. Low content of polypropylene fiber reinforcement 0.1 to 0.5% had only a small positive influence on the impact resistance of both normal and high strength concretes.

Bischoff and Yamura (1990) have studied polystyrene aggregate to minimize potential impact damage to structure-low crushing strength and a high degree of deformability-energy absorbing material properties demonstrate through experiments on impact testing.

Soukatchoff *et al*. (1993) has found that energy absorption capability of GRC plates can be realistically estimated by the energy loss of the hammer during impact. It was found that the absorbed energy was linearly related to the plate's thickness. No significant changes in the energy absorption of GRC plates were found due to change to change boundary conditions.

The above literature available provided very little information in this field (i.e., the impact resistance of concrete and fiber reinforced concrete). For the rational design of concrete structures subjected to impact and impulsive loading, the constitutive properties of concrete over a wide range of strain rates are required.

Several investigators have employed a variety of tests to assess the impact resistance of concrete and FRC. Although useful in ascertaining the relative merits of different composites, most of these tests have not yielded basic material properties. Till today, the concrete and material industry are not provided with an acceptable impact test that demonstrates the relative brittleness, resilience and impact resistance etc. So it is necessary to make attempts to know the actual behaviour of FRC under impact loading. The present investigation aims to study the general aspects of behaviour of FRC subjected to impact loading.

MATERIALS AND METHODS

Mix design: All the samples were prepared using designed mix. Mix design for the M1grade concrete (1:1.10:2.40 with w/c 0.40) was done based on I.S. Code method. M2 grade concrete (1:1.14:1.12 with w/c 0.38) was based on ACI method. The No. of specimens for M1 and M2 grade concrete are shown in Table 1.

Casting of specimens: As per ACI committee 544.2R-5, specimens of dimension 152.5 mm DIA and 65 mm height were prepared for an impact strength test.

ACI drop weight method impact test specimens: The disc specimens are cast in plastic moulds and the compaction was effected through a needle vibrator. To eliminate the effect of possible fibers orientation, the moulds were initially half filled, the mix was vibrated and then the other half was filled and the vibration was continued. No signs of segregation or air bubbles were observed during casting. The specimens were demoulded after 24 h and curved by immersing them in water.

Experimental setup-ACI Drop weight impact tester: The experimental set up is as shown in Fig. 1, the test specimens is to move horizontally, 2.8 mm off the centred between the four positioning lugs. The steel ball is free to move vertically with the sleeve 45 N drop hammers through a height of 457 mm to cause the first visible crack and ultimate failure.

Testing procedure: Thickness of the specimens is recorded to the nearest millimetre at its centred and at the end of a diameter prior to the test. The specimens were placed on the base plate with finished face up and positioned within four lugs of the impact testing equipment. The bracket with the cylindrical sleeve ball is placed on the top of the specimens within the bracket. The drop hammer was then placed with base upon the steel ball and held vertically. The hammer was dropped repeatedly and the number of blows required for the first visible crack to form at the top surface of the specimen and for ultimate failure was recorded.

The first crack was based on base visual observation. White washing the surface of the test, specimens facilitated the identification of this crack. Ultimate failure is defined in terms of the numbers of required to open the crack in the specimens sufficiently to enable the fractured Pieces to touch three of the four positioning lugs plates. The stage of ultimate failure is clearly recognized by the fractured specimens butting against lugs on the base plate.

Table 1: Specimen details

Sl. No.	Name of the property	Dosage of fibres	No. of specimens for M1 grade concrete	No. of specimens for M2 grade concrete
1.	Impact strength	0.0%, 0.5% 0.1%, 1.5% 0.2%	5×5 = 25	5×5 = 25

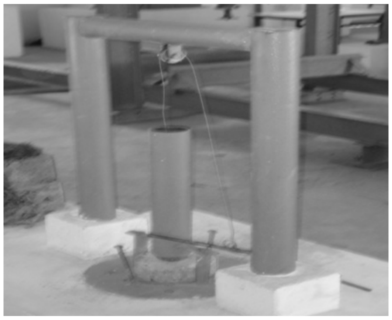

Fig. 1: Shows experimental setup for ACI drop weight impact test

Fig. 2: Failure pattern of plain concrete

Fig. 3: Failure pattern of steel fibre concrete

With fiber reinforced concrete specimens the pieces were not often broken clearly, whereas in plain concrete specimens were clearly broken.

RESULTS AND DISCUSSION

Results: The results of impact strength measured as no. of blows for first cracking and failure show a wide variation. The failure pattern of Plain and Steel Fiber Reinforced Concrete specimens are shown in Fig. 2 and 3. Using means of measures of deviation, the characteristic value number of blows for first and ultimate cracking are obtained as:

$$NCK = N-1.64\times S$$

where,
NCK = Characteristics no of blows
N = Average no of blows
S = Sample deviation

DISCUSSION

Table 2 Shows Nck values for M1 and M2 Grade of concrete. Table 3 and 4 Show the improvement in no of blows of fiber concrete over plain concrete for first crack and ultimate strength. From Table 3 additions of 0.5, 1.0, 1.5 and 2.0% of steel fiber in plain concrete shows the improvement in no of blows for first crack to an extent of 23.57, 38.92, 53.69 and 48.86% for M1 grade of concrete and 20, 49.10, 77 and 62.37% of M2 grade concrete, respectively.

From the Table 4 it is concluded that the addition of 0.5, 1.0, 1.5 and 2.0% of steel fiber in plain concrete shows the improvement in no of blows for ultimate strength to an extent of 20.80, 36.52, 50.93, 48.79%, for M1 grade concrete and 19.41, 46.52, 58.24 and 53.84%

Table 2: N_{CK} values for M1 and M2grade concrete

Grade of concrete	N_{CK} Value for first crack in blows					N_{CK} Value forultimate crackin blows				
	0%	0.5%	1.0%	1.5%	2.0%	0%	0.5%	1.0%	1.5%	2.0%
M 1	352	435	489	541	524	373	473	510	565	555
M 2	505	600	753	894	820	546	652	800	864	840

Table 3: Improvement in no of blows of fiber concrete over plain concrete for first crack

Grade of concrete	N_{CK} Value for first crack in blows					Improvement in no of blows of Fiber Concrete over Plain Concrete for first crack			
	0%	0.5%	1.0%	1.5%	2.0%	0.5%	1.0%	1.5%	2.0%
M 1	352	435	489	541	524	23.57	38.92	53.69	48.46
M 2	505	606	753	894	820	20.00	49.10	77.00	62.37

Table 4: Improvement in no of blows of fiber concrete over plain concrete for ultimate strength

Grade of concrete	N_{CK} Value for ultimate strength In no. of blows					Improvement in no of blows of Fiber Concrete over Plain Concrete for ultimate strength.			
	0%	0.5%	1.0%	1.5%	2.0%	0.5%	1.0%	1.5%	2.0%
M 1	373	473	510	563	555	20.80	36.52	50.93	48.79
M 2	546	652	800	864	840	19.41	46.52	58.24	53.84

Table 5: Comparison of percentage improvement in no of blows by different dosage of fiber in plain concrete

Grade of concrete	For first crack			For ultimate strength		
	0.5%~1.0%	0.5%~1.5%	0.5%~2.0	0.5%~1.0%	0.5%~1.5%	0.5%~2.0%
M1	65.12	127.78	107.29	75.57	144.85	134.56
M2	145.50	285.50	211.85	139.67	200.00	177.38

Table 6: Comparison of test results of M1 grade concrete with M2 grade of concretes

Grade of concrete	N_{CK} value for first crack in blows					N_{CK} value forultimate crackin blows				
	0%	0.5%	1.0%	1.5%	2.0%	0%	0.5%	1.0%	1.5%	2.0%
M 1~M 2	43.46	39.91	53.98	65.24	56.98	46.38	37.84	56.86	53.46	51.35

Table 7: Cost comparisons of different artificial fibers

Sl.No	Name of the fiber	Dosage in kg/m^3	Cost per m^3in Rs.
1.	Steel (0.5%)	40	2000.00
2.	Polypropylene (0.1%)	0.910	745.00

of M2 grade concrete, respectively. Table 5 shows a comparison of percentage of improvement in no of blows between different dosages of fiber content in plain concrete. The addition of 1.0, 1.5 and 2.0% of steel fiber in plain concrete shows improvement in no of blows over 0.5% of steel fire in plain concrete are 65.12, 127.78, 107.29 and 75.57%, 144.85%, 134.56% of M1 grade concrete at first crack and ultimate strength and 145.50, 285.50, 211.85 and 139.67, 200, 177.38% for M2 grade of concrete first crack and ultimate strength, respectively. Table 6 Comparison of test result, M1 grade concrete with M2 grade concrete. The percentage of improvement in number of blows increases to an extent of 39.91, 53.98, 65.24 and 56.98% for first crack and 37.84, 56.86, 53.46 and 51.35% for ultimate strength of M2 over M1 grade of concrete with the inclusion of 0.5, 1.0, 1.5 and 2.0% of steel fiber in plain concrete, respectively. Table 7 shows the cost comparison of steel fibers with other available artificial fibers.

CONCLUSION

The following conclusion is presented based on experimental results from the investigation.

For M1 grade of concrete:

- The addition of 0.5, 1.0, 1.5 and 2.0% of dosage of fiber in concrete improves the characteristic no of blows to a maximum extent of 23.57-53.69% 20.80-50.93% for first Crack and 14.95-45.98% for ultimate strength.
- The addition of 1.0, 1.5 and 2.0% of steel fiber in plain concrete shows improvement in no of blows over 0.5% incorporation of steel fiber are 65.12, 127.78, 107.29 and 75.57, 144.85, 134.56% of M1 grade concrete at first crack and ultimate strength.

For M2 grade of concrete:

- The addition of 0.5, 1.0, 1.5 and 2.0% of dosage of fiber in concrete improves the characteristic no of blows to a maximum extent of 20.00- 77.0%, 19.41-58.24% for first Crack and 19.415-58.24% for ultimate strength.
- The addition of 1.0, 1.5 and 2.0% of steel fiber in plain concrete shows improvement in no of blows over 0.5% incorporation of steel fiber are 145.50, 285.50, 211.85 and 139.67, 200, 177.38% of M2 grade concrete at first crack and ultimate strength.

Comparison between the M1 grade of concrete with an M2 grade of concrete: The percentage of improvement in number of blows increases to an extent of 39.91, 53.98, 65.24 and 56.98% for first crack and 37.84, 56.86, 53.46 and 51.35% for ultimate strength of M2 over M1 grade of concrete with the inclusion of 0.5, 1.0, 1.5 and 2.0% of steel fiber in plain concrete, respectively.

From the experimental investigation it is conclude that addition of 1.5% of steel fibre in plain concrete shows improvement in impact characteristic of M1 and M2 Grade concrete.

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