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Impact Resistance of Glass Fiber Reinforced Concrete

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Abstract—*In this research, the impact resistance of M30 and M40 grade concrete with anti-crack high dispersion glass fibers (GFRC) of 12 mm in length and fiber volume fractions (V_f) of 0.5, 1, 1.5, and 2% is investigated using the drop weight test method as suggested by ACI Committee 544. The impact test was conducted using the standard drop weight test as recommended by ACI committee 544. According to the results of the drop weight test, adding glass fibers to concrete increases first crack impact resistance as compared to standard concrete (NC) of the same strength.. Maximum increase in impact resistance for both the grades of concrete is observed at 2 % V_f for GFRC. Also increase in ultimate failure impact resistance for M30 grade concrete is observed at 2 % V_f. In case of M40 grade concrete it is seen that impact resistance at ultimate failure increases upto 1.5 % V_f but reduces at 2 % V_f. No significant increase is observed in post cracking impact resistance. Ductility index of GFRC is found be nearly equal to that of NC.*

Key words: Drop Weight Test, GFRC, Impact test, ACI Committee, Glass Fiber, Impact resistance.

1. INTRODUCTION

High-rise buildings, factory floors, airport and highway pavement, industrial floors, bridge decks, thin-shell structures, and other structures can be subjected to impact loads over their lifespan in modern times. It could happen on a scheduled or unscheduled basis. For example, a high-rise building may be impacted by an aircraft crash or earthquake loads, and an industrial floor may be impacted by the drop of a heavy instrument, among other things. As a result, they need a construction material capable of absorbing more impact loads than standard construction materials. Since GFRC is made of water, cement, sand, coarse aggregate, fly ash, superplasticizer, and anti-crack high dispersion glass fibers, GFRC can meet the demand for energy absorption before failure. Glass fibers are short, discrete lengths of glass with an aspect ratio of 857:1 that are small enough to be quickly distributed in a fresh concrete mixture using standard mixing procedures. When a specimen is exposed to impact loads, the glass fibers in GFRC act as an energy absorber, absorbing the impact loads even after a crack has formed on the concrete specimen, delaying the specimen's eventual failure and, as a result, increasing the concrete's impact resistance. The ability to absorb significant quantities of energy after the first crack and the resistance to effects, i.e. unexpectedly applied loads, are thus recognized as essential characteristics of fiber reinforced concrete. Many studies have shown that adding fibers to concrete increases its energy absorption and cracking resistance. This energy absorption of GFRC is termed as toughness under impact.

Numbers of test are available to evaluate impact resistance of concrete. ACI committee 544 recommends several tests, including the drop weight test, charpy impact test, projectile impact test, constant strain rate test, explosive test, and split Hopkinson bar test. The drop weight test is the most commonly used to carry out experimental work because it is the simplest to carry out. A standard laboratory drop weight testing equipment available in marathwada institute of technology was for testing. The number of blows required to form the first noticeable crack (N1) and the number of blows required to trigger the concrete specimen's ultimate failure were determined in the test (N2).
The impact energy produced by repeated drop weight hammer test is calculated by the following equation:

$$E1\ (Static) = m \times g \times h \times N$$

$$E2\ (Dynamic) = \frac{1}{2} \times m \times v^2 \times N$$

$$H = \frac{gt^2}{2}$$

$$v = g \times t$$

Where,
m = mass of the hammer (kg).
g = acceleration due to gravity (m/s^2).
h = height of fall of hammer (m).
v = velocity of hammer at impact (m/s).
N = number of blows.

A 150 mm diameter and 63.5 mm height concrete specimen is casted for this test. It's possible that the effect findings will deviate further. This may be attributed to the following factors.
1) First crack on specimen can identified visually, which may occur in any direction.
2) Impact loads acts on single point on specimen, it may happen that impact is applied on a hard particle of coarse aggregate or soft area of mortar or on the higher concentration of Glass fibers.
3) As concrete is heterogeneous material. The variation of mix design may cause the change in impact resistance,

including aggregate type and shape, geometry of the fiber, fibers distribution, etc.
4) It is difficult to maintain exact height of fall as it handmade process.

This experimental work is carried to investigate effect of Glass fibers V_f on improving the impact resistance of GFRC and to study behavior of concrete under impact loads. This research will help to expand the use of GFRC in modern systems and will explain concrete behavior under impact loading.

2. SYSTEM DEVELOPMENT

2.1 Materials

Pozzolona Portland cement was used in the programme in this experimental investigation. Cement used had a specific gravity of 2.88. Since fly ash was already present in PPC cement, it was not used. High dispersion anti-crack glass fibers were used. Anti-crack high dispersion glass fibers are shown in Figure 2.1, and their properties are mentioned in Table 2.1.

Fig -2.1: Anti-crack high dispersion glass fibers

Table -2.1: Properties of Anti-Crack High Dispersion Glass Fibers

Sr. No.	Property	Typical value
1	Number of fibers	214 millions/kg
2	Aspect ratio	857:1
3	Specific surface area	150 m^2/kg
4	Tensile strength	1700 MPa
5	Modulus of elasticity	72 GPa
6	Corrosion resistance	Very high
7	Specific gravity	2.68
8	Density	26 kN/m3
9	Filament diameters	14 microns
10	Filament length	12 mm

Coarse aggregate of maximum size 10 mm are used. It has specific gravity of 2.74. Natural sand with a maximum size of 4.75 mm and a specific gravity of 2.70 is used as fine aggregate. Glass fibers in concrete had a negative impact on workability, so a superplasticizer called Conplast SP 430 was applied to the mix to increase concrete workability. Five types of concrete samples with different dosage of Glass fibers are tested. The concrete mix is designed according to IS: 10262- 2019 of concrete mix design. The mix proportion of concrete is given in table no. 2.2 and 2.3. Glass fibers were added to concrete mix at volume fraction (V_f) of 0, 0.5, 1, 1.5 and 2%.

Table -2.2: Mix proportion for M30 grade

Sr. No.	Material	Quantity of material (kg/m^3)
1	Water	176.38
2	Cement	420
3	Fine aggregate	825.595
4	Coarse aggregate	969.247
5	Superplasticizer	4.620

Table -2.3: Mix proportion for M40 grade

Sr. No.	Material	Quantity of material (kg/m^3)
1	Water	160.68
2	Cement	446.33
3	Fine aggregate	778.62
4	Coarse aggregate	1036.19
5	Superplasticizer	4.910

2.2 Testing Methods

The impact resistance of concrete is affected by the way it is mixed. As a result, uniform mixing of concrete is ensured by well dispersion of Glass fibers into fresh concrete mix, which is then allowed to mix for an additional 2 minutes in a mechanical concrete mixer after formulation of fresh concrete mix. Three cubical specimens with dimensions of 150 × 150 × 150 mm were cast for compressive strength testing. 5 disc specimens of size 150 mm diameter × 63.5 mm height were casted for each type of concrete. Thus total 25 disc specimens were casted. After casting, specimens were demoulded after 24 hours and cured in water tank for 28 days. Fig. 2.2 shows both types of specimens casted for compressive strength test.

Fig -2.2: Cubical and disc concrete specimen respectively

Drop weight test was used to determine impact resistance of concrete. Fabricated drop weight test equipment is used. The impact test was carried according to recommendations of ACI Committee 544. The test was carried out by dropping a hammer weighing 4.54 Kg from a height of 457 mm repeatedly on a 63.5 mm diameter hardened steel ball, which is placed on the top of the center of the cylindrical disc, as shown in Fig. 2.3. The instrument was fabricated as per the recommendations of ACI Committee 544- 2R report. Impact energy produced by this equipment is same as produced by standard drop weight test equipment. The number of blows to form first visible crack on the disc was recorded as the first-crack impact strength (N1). After formation of first crack, hammer is allowed to continuously dropped on specimen until it break the cracked disc into pieces touching three of the lugs. The number of blows to cause ultimate failure by touching action was recorded as the failure impact strength (N2). Thus, N1 represents first crack impact resistance while N2 represents failure impact resistance of concrete.

Fig- 2.3: Fabricated drop weight test equipment

3. RESULTS AND DISCUSSION

3.1 Compressive strength test results of concrete:

The average compressive strength of M30 grade concrete was 32.89 MPa, while M40 grade concrete had a compressive strength of 45.33 MPa. The load carried by three cubical specimens averaged over 740 kN for M30 grade and 1020 kN for M40 grade. As a result, the design mix of provided concrete satisfies the strength requirements for the chosen concrete grades.

Table -3.1: Test results of compressive strength of concrete specimen.

Grade of concrete	Average load carried (kN)	Average compressive strength (MPa)
M30	740	32.89
M40	1020	45.33

To ensure quality control, compressive strength was measured. The compressive strength results showed little difference, indicating strong quality control in concrete manufacturing.

3.2 Comparison of impact resistance of Normal concrete (NC) and Glass fiber reinforced concrete (GFRC):

The ductility index is the ratio of energy absorbed at ultimate failure of the concrete specimen to the energy absorbed for the development of first crack (E2/E1). The values for ductility index for M30 and M40 grade of concrete are given in table 3.2 and 3.3 respectively.

Table -3.2: Ductility index for M30 grade of concrete.

SR. No.	Steel fiber V_f in %	Impact energy at first crack (E1)	Impact energy at ultimate crack (E2)	Average ductility index
1	0	17751	18667	1.018
2	0.5	18362	18667	1.022
3	1.0	35841	36382	1.02
4	1.5	50439	51184	1.02
5	2.0	63446	64557	1.01

Table -3.3: Ductility index for M40 grade of concrete

SR. No.	Steel fiber V_f in %	Impact energy at first crack (E1)	Impact energy at ultimate crack (E2)	Average ductility index
1	0	39077	39610	1.01
2	0.5	49772	50398	1.02
3	1.0	52474	53202	1.03
4	1.5	65448	66636	1.02
5	2.0	76916	77767	1.01

The ductility index for both grades has approximately identical values, as seen in the tables above. The ductility index for various glass fiber volume fractions in GFRC appears to be very close to the ductility index of normal concrete (NC). As a result, it was discovered that the ductility index of concrete is affected by the length of glass fiber. Longer fibers have higher post-cracking impact resistance, which raises the ductility index of concrete. It was also discovered that the number of blows in Glass fiber reinforced concrete increases when compared to normal concrete, increasing the impact energy for both the pre cracking and post cracking stages of concrete.

4. CONCLUSIONS

1) Impact resistance of concrete increases with increase in strength of concrete.
2) Normal concrete shows brittle behavior while glass fiber reinforced concrete shows ductile behavior under impact loading.
3) Addition of glass fibers into concrete shows significant improvement for first crack impact (N1) at 0.5, 1, 1.5, 2% V_f of glass fiber for both the grades of concrete
4) Ductility index for both the grades of concrete and for all the volume fractions of glass fibers is nearly similar to that of normal concrete.

REFERENCES

[1] V. Ramakrishnan, W. V. Coyle, V. Kulandaisamy, and Ernest K. Schrader, Performance Characteristics of Fiber Reinforced Concretes with Low Fiber Contents, ACI Journal, 1981. vol. 78, issue 35, pp 388-394.

[2] Surendra P. Shah et. al., Measurement of Properties of Fiber Reinforced Concrete, ACI Committee-544, 1989, pp 1 – 12.

[3] S. Mebarkia and C. Vipulanandan, Compressive Behavior of Glass-Fiber-Reinforced Polymer Concrete, Journal of Materials in Civil Engineering, 1992, vol. 4, issue 1, pp. 91 – 105.

[4] James I. Daniel et. al., State of the art report on fiber reinforced concrete, ACI committee 544, 1996, pp. 1 – 66.

[5] M.C. Natarajaa, N. Dhangb and A.P. Gupta, Statistical variations in impact resistance of steel fiber-reinforced concrete subjected to drop weight test, Cement and Concrete Research, 1999, vol.29, pp. 989–995.

[6] P. Sukontasukkul, S. Mindess, N. Banthia and T. Mikami, Impact resistance of laterally confined fiber reinforced concrete plates, Materials and Structures, 2001, vol. 34, issue 10, pp. 612–618.

[7] Y. Mohammadi, R. Carkon-Azad, S.P.Singh and S.K.Kaushik, Impact resistance of steel fibrous concrete containing fibers of mixed aspect ratio, Construction and Building Materials, 2009, vol. 23, issue 1, pp 183-189.

[8] Xiang-yu Chen , Yi-ning Ding and C. Azevedo, Combined effect of steel fibers and steel rebars on impact resistance of high performance concrete, Journal of Central South University, 2011, vol. 18, pp.1677–1684.

[9] Tara Rahmani, Behnam Kiani, Mohammad Shekarchi and Abdollah Safari, Statistical and experimental analysis on the behavior of fiber reinforced concretes subjected to drop weight test, Construction and Building Materials, 2012, vol. 37, pp. 360-369.

[10] Priyanka Dilip P and K. Remadevi, A study on the mechanical performance of Hybrid Fiber

Reinforced Concrete, International Journal of software and hardware research in engineering, 2014, vol. 2, issue 2, pp 47-51

[11] Kushal R. Jaiswal and Dr. Sanjay S. Jamkar, A Study on Effect of Steel Fibers on Impact Resistance of High Strength Steel Fiber Reinforced Concrete (HSFRC) Subjected To Drop Weight Test, International Journal for Scientific Research & Development, 2015, vol. 3, issue 09, pp 839 -842.

[12] P. B. Murnal and R. N. Chatorikar, Impact resistance of steel fiber reinforced concrete, International Journal of Research in Engineering and Technology, 2015, vol. 04, issue 13, pp 241–246.

[13] Thong M. Pham and Hong Hao, Axial Impact Resistance of FRP-Confined Concrete, Journal of Composites for Construction, 2017, vol. 21, issue 2, pp 1 – 11.