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Study on Impact Strength of Concrete by Using Basalt Fibre

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Abstract:- This paper presented an experimental investigation on the impact failure energy of high strength concrete by basalt fiber. Basalt fibers are relatively cheaper and new fibers for concrete which are investigated by a few researchers. Two different grade (M40 and M50) of concrete were used as the basalt fiber in various volume fractions such as 0.3%, 0.6%, 0.9% and 1%. The samples were tested under instrumented falling impact loading and compared with conventionally cured ones. The results indicated that the concrete containing 0.9% volume fraction of fiber gave the best performance under impact loading.

I. INTRODUCTION

Concrete is one of the most conventionally consumed construction materials. Concrete has several advantages such as durability, formability and desired mechanical strength which gives it an edge over the other conventional building materials but it has few disadvantages such as low tensile strength and strain capacity. Due to high corrosion resistance, high ductility and sufficient durability, FRC is widely used especially in the military and marine fields, for instance, in fortified structures, blast resistant structures, offshore platforms, the exploitation of undersea oil engineering, etc.

Fiber inclusion in matrix greatly influences the properties of concrete and various studies have shown that the fibers can significantly improve the engineering properties of the concrete.Different types of fibers such as asbestos, cellulose, steel, polypropylene, PVA, carbon, basalt, aramid, polyethylene and glass have been used to reinforce cement products. Basalt fibre (BF), is a new kind of inorganic fibre extruded from melted basalt rock and is currently available commercially. The manufacturing process of this kind of fibre is similar to that of glass fibre, but with less energy consumed and no additives, which makes it cheaper than glass or carbon fibres.

It is known that the BF has better tensile strength than the E-glass fiber, greater failure strain than the carbon fiber as well as good resistance to chemical attack, impact load and fire with less poisonous fumes. So, BF has a potential to be a suitable replacement for glass, steel and carbon fibers in many construction applications.

Other advantages such as high modulus, heat resistance, good resistance to chemical attack, excellent interfacial shear strength and currently commercial availability, enable BF a good alternative to glass, carbon or aramidic fibre as a reinforcing material in concrete composite showed that the performance of dynamic modulus of elasticity and quality loss of BF concrete in freezing and thawing process is obviously better than the plain concrete. Although several types of fibers have been used in concrete, however there is only limited information available on mechanical properties and fracture behavior of high strength concrete incorporating BF which is of great importance in understanding the material behavior and in designing structures.

The main objective of this investigation is to study the effect of the impact behavior of basalt fibre concrete, compared with conventional concrete. The impact strength of basalt fibre concrete were tested and analyzed in this study.

Figure – 1 Basalt fibre

II. EXPERIMENTAL STUDY

A. Material and mixture proportion

Ordinary Portland Cement (OPC) 53 grade corresponding to ASTM Type I cement with a specific gravity of 3.15 was used in concrete mixtures. The coarse aggregates consisted of gravel with a maximum size of 15 mm. River sand was utilized as fine aggregates. The concrete specimens were demolded 24 h after casting and then subjected to curing at 95% relative humidity (RH) for 28 d. Afterward, the 28 d concrete strength was determined . The average concrete cubic compressive strength was fcu = 48.25 MPa, and 58.25 MPa the average value of axial compressive strength of three concrete specimens for M40 and M50 grade of concrete was fc = 42.8 MPa and 53.8MPa. Four different volume fractions (0.3%, 0.6%, 0.9%, and 1%) of BF respectively, were adopted to study their effect on the properties of concrete. Detailed impact properties and the pictures of the basalt fiber used in this study are presented in Table 2, Table 3 and Fig. 1 respectively. The nomenclature adopted was: BF representing the basalt fiber reinforced concrete, respectively and the numbers written after BF letters indicating the percentage of fiber added in the concrete.

B. Mixing and curing

The mixing process started with the dry mixing of the coarse and fine aggregates for 1 min. Then, the cement was added and followed by the dry mixing for another 1 min. Further, fibres were added into the dry mixture for another 1 min. Finally, water was added slowly. The fresh concrete was mixed for 3 min to ensure even dispersion of fibres in the concrete. The fresh concrete was cast in 150×150×150mm molds for impact strength test. In this study, every test result consists of the average of three replicate tests. After casting, specimens were cured at 20˚C in molds covered by a polyethylene film to prevent moisture loss. Then, the specimens were de-molded after 24 h and were moved to saturated lime water at 20˚C until the testing.

Table - 1. Mixing proportion for 1m^3

Mixture	W/B	Water Kg/m^3	Cement Kg/m^3	Fine Aggregate Kg/m^3	Coarse Aggregate Kg/m^3	Volume Fraction V_f	Fiber Kg/m^3
M40 (0%)	0.40	160	400	660	1168	0	0
M40 (0.3%)	0.40	160	400	660	1168	0.3	7.9
M40 (0.6%)	0.40	160	400	660	1168	0.6	15.9
M40 (0.9%)	0.40	160	400	660	1168	0.9	23.8
M40 (1%)	0.40	160	400	660	1168	1	26.5
M50 (0%)	0.35	147.6	422	621	1284	0	0
M50 (0.3%)	0.35	147.6	422	621	1284	0.3	7.9
M50 (0.6%)	0.35	147.6	422	621	1284	0.6	15.9
M50 (0.9%)	0.35	147.6	422	621	1284	0.9	23.8
M50 (1%)	0.35	147.6	422	621	1284	1	26.5

C. Impact Test

The impact resistance of the specimens was determined in accordance with the procedure proposed by the ACI Committee 544.2R-89. For this purpose, from each batch, six specimens were used and the specimens were subjected to drop weight test. The impact load was applied with hammer onto a 5.180 kg ball of 60.2 mm diameter, dropped repeatedly from a 580 mm height on the center of the top surface of the specimens. The drop weight test arrangement was as shown in Figure 2. In each test, the number of blows (N1) required to produce the initiation of crack was recorded as the initial crack strength, and the number of blows (N2) needed to cause failure of the specimen was recorded as the failure strength; this method has been used by several researchers.

The energy absorption capacity of each specimen used in this test was calculated using Equation (1):

$$\textit{Impact Energy } U = NmgH \quad \ldots\ldots\ldots(1)$$

Where,

N = Number of blows
m = Weight of the drop cylinder
g = Loading due to acceleration
H = Height of free fall.

Figure -2 Drop weight impact test

III. TEST RESULT AND DISCUSSION

The number of blows required to cause the first visible crack (N1) and final failure (N2) of concrete specimens are indexed in Table-2 and Table 3 and the impact energy corresponding to number of blows are shown in Figure-2. The impact energy of specimens during every blow can be calculated as follows. Substituting the corresponding values in following Equation.

Impact energy for initial failure = N1mgH.

Impact energy for ultimate failure = N2mgH.
Initial impact energy, U1= 24x5.180x9.81x0.58 = 707.36Nm.
Ultimate impact energy, U2= 34x5.180x9.81x0.58= 1002.09Nm.

By adding 0.3%, 0.6%, 0.9% and 1.0% dosage of basalt fiber in M40 concrete the energy input necessary to cause the visibility of first crack was increased by 120%, 130%, 150% and 124%, respectively and the energy necessary to cause failure of concrete specimen was increased by 108%, 125%, 142% and 112% over the plain concrete specimen. Similarly for 0.3%, 0.6%, 0.9% and 1.0% dosage of basalt fibre in M50 concrete, the energy required to cause the initiation of first crack was increased by 121%, 134%, 150% and 131% respectively, and the energy required to cause failure of concrete specimen was increased by 125%, 137%, 154% and 139% over the plain concrete specimen. Hence it was observed that, increasing the volume fraction of basalt fiber increases the impact energy of concrete upto 0.9% significantly, in both the first crack stage as well as failure stage. This proves that the basalt fibers act as an effective crack arrestor in case of FRC, when an impact load is encountered. Thus the plain concrete exhibits an early brittle failure when compared to FRC which shows better ductile properties.

Table- 2. Impact Strength for M40 Grade Concrete

Grade of concrete	**Fiber content in %**	**Impact energy for initial failure (U1)**	**Impact energy for ultimate failure (U2)**
M40	0	1738.9 (59 blows)	2063.12 (70 blows)
M40	0.3	2092.59 (71 blows)	2239.96 (76 blows)
M40	0.6	2269.43 (77 blows)	2593.64 (88 blows)
M40	0.9	2623.11 (89 blows)	2934.69 (93 blows)
M40	1	2169.43 (73 blows)	2323.11 (79 blows)

Table-3. Impact Strength of M50 Grade Concrete.

Grade of concrete	Fiber content in %	Impact energy for initial failure (U1)	Impact energy for ultimate failure (U2)
M50	0	1797.86 (61 blows)	1886.28 (64 blows)
M50	0.3	2181.01 (74 blows)	2357.85 (80 blows)
M50	0.6	2416.80 (82 blows)	2593.64 (88 blows)
M50	0.9	2711.53 (92 blows)	2917.84 (99 blows)
M50	1	2357.85 (80 blows)	2623.11 (89 blows)

IV. CRACK PATTERN

The crack pattern for different proportions of fibre added is shown in fig 4. The plate in which 0% fibres were added brittle mode of failure was observed and it was broken into two pieces. Adding the fibre to concrete lead to encounter the ductile mode of failure and bridging the number of cracks which displays the beneficial effects of adding fibre to concrete.

Figure – 4. Crack Pattern

IV. CONCLUSION

The performance of fibre concrete plate under impact loads was very positive especially in basalt fibre reinforced concrete. Under impact loading, a ductile failure was observed in non fibrous concrete. The failure pattern of plate shows that incorporation of basalt fibre as an arrestor of crack propagation considerably improves the ability of concrete to absorb kinetic energy.

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