

Impact Testing on Reinforced Concrete Slab with Bfrp Bars as Reinforcement



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Abstract: Basalt Fibre Reinforced Polymer (BFRP) bar is an alternative to steel and glass fibre for reinforced concrete. Their unique characteristics makes them favourable compared to the other alternative materials. According to previous studies the BFRP bars are lighter and stronger than steel and has higher bending strength. But the research regarding the impact strength of BFRP bars are very limited. But the impact strength of materials is very important for many critical designs due. Thus, prompting the study of impact strength of BFRP bars. Basic tests were done to determine the strength of the materials to be used. Slabs of 550mm x550mm x50mm are made with varying centre to centre distance between bars in both cases of steel and basalt bars. The slabs are subjected to impact loading through the drop weight impact and the values such as crack length, width and depth are observed, and the result is observed in the form of ultimate crack resistance. Even though slabs with maximum centre to centre distance between bars failed very easily in both cases, the slabs with minimum centre to centre distance between bars gave considerable impact strength.

Keywords: BFRP, Slab, Drop weight impact.

I. INTRODUCTION

BFRP bar is an alternative to steel and glass fibre for reinforced concrete. They are manufactured from basalt fibre using pultrusion technique. The surface of the bars is profiled and sanded for better adhesion in concrete. Researches show that the BFRP bars are stronger and more flexible than the steel bars. But researches regarding the impact strength of the bars are very limited. But impact value of materials is also very important factor in design of critical structures due to the increase in natural and manmade disasters such as earthquake, tsunami, toppling of rocks, vehicular accidents and terrorist attacks, the structures are subjected to high velocity shock loads. Even though the impact loading on structures is relatively low in day to day life, the structural elements should be tested against the impact loading to protect the structures and also civilian life in case of the above-mentioned reasons.

Chenchen Li et al. studied the effect of high temperature on the bond performance between BFRP and concrete. In this study the bond performance was determined through direct pull-out test and the results were compared with Glass Fibre Reinforced Polymer (GFRP) bars. The test was done from room temperature 20°C to highest temperature of 350°C. 100mm concrete cubes with varying bond length from 2.5d to 20d were used for this study.

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The result showed that with the increase in temperature the bond performance of both bars decreased but the effect was more severe in case of the GFRP bars. Also,

It was determined that the surface treatment the resin type used had more significant effect in bond performance than the FRP used. It is also determined that the increase in bond length resulted in increase in bond performance. After various exposure treatment, it is determined that the BFRP bar and concrete has more bond performance than GFRP bar and concrete, and the degree of improvement was noted as 42.4-57.3%.

Mohamed Hassan et al. investigated the bond durability of BFRP bars embedded in concrete in aggressive environments. The lack of understanding of bond-durability of BFRP bars is a hindrance to their wide acceptance in the field. This paper presents an experimental investigation aimed to assess the short and long-term bond durability of BFRP bars through accelerated tests in an alkaline solution at different temperatures. This study provides an insight into how the bond behaves in long-term environmental condition. The pull-out blocks are cast and cured then immersed in an alkaline solution inside a large steel tank, while the free length of BFRP bars remained fully unconditioned inside the environmental chambers. The alkaline solution used consists of 118.5g calcium hydroxide, 4.2g potassium hydroxide and 0.9g of sodium hydroxide in 1L of deionized water. The pH value of the alkaline solution was 12.9. In order to accelerate the bond degradation, the specimen was subjected to elevated temperature of 60 degree centigrade for the exposure period of 6 months. Then the specimens are subjected to pull-out test. All the BFRP specimen failed in typical pull-out mode by slip through free end. Generally, the bond strength increased while increasing the temperature when the specimens were exposed to accelerated conditioning environment because of the increase in strength of concrete during immersion.

Jadon Duicet al. studied the performance of concrete beams reinforced with basalt fibre composite rebar. Eight large scale concrete beam specimens were analysed for their shear and flexural behaviours. The effect of steel versus BFRP shear and flexural reinforcement at two different reinforcement ratios are characterised and discussed for this study. Results in terms of the crack pattern, load-deflection response, deformability, load-strain response, ultimate capacity, and mode of failure were observed. It is observed that at low reinforcement ratio BFRP reinforced beams exhibited greater number of flexural cracking and shear cracking than their steel counterparts, and at higher reinforcement ratios, less shear cracking and slightly steeper shear crack angles are exhibited by BFRP reinforced beams.

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It is also observed that despite the low elastic modulus and low energy absorption of BFRP rebar, BFRP reinforced beams exhibited acceptable deformability.

Özgür Anil et al. studied the low velocity impact behaviour of RC slabs with different support types. Two support types such as fixed and hinge support, with 4 different layouts such as support at 4 sides, 3 sides, 2 adjacent sides, 2 opposite sides were studied. It is noted that support type and layout have significant effect in impact loading. Considering the support type fixed support obtained better result than the hinged support. Considering layout support at 4 sides obtained higher impact value than any other support layout. And the slab with support at 2 adjacent sides obtained lowest impact value than any other layout. It is also noted that the increase in number of drops resulted in decrease in acceleration but increase in velocity and displacement.

In this study RCC slabs with both BFRP bars and steel bars are made and then tested with drop weight to determine their impact strength through the crack resistance value.

II. EXPERIMENTAL PROGRAMME

2.1 Materials used

For this study Ordinary Portland Cement (OPC) 53 grade with the specific gravity of 3.15 is used for the concrete. River sand with specific gravity of 2.7 which lies under zone II with fineness modulus of 2.74 as per IS codes is used as fine aggregate. 20mm coarse aggregate with specific gravity of 2.75 is used. For reinforcement purposes Fe₄₁₅ steel and BFRP bars are used.



Figure 1. BFRP bars



Figure 2. Steel bars

2.2 Mix proportion

M₄₀ grade of concrete which reaches the characteristic compressive strength of approximately 48MPa is used for the specimens throughout the study. The mix proportion is done using IS: 10262-2009. The proportion of M₄₀ grade of concrete is calculated as 1:1.7:2.4. Table 1 shows the mix proportion of materials for 1 m³ of concrete. Water cement ratio of 0.43 is used for concrete.

Table 1. Mix proportion of concrete for 1m³.

Cement (kg)	Water (lit)	Fine Aggregate (kg)	Coarse Aggregate (kg)
450	192	754	1061
1	0.43	1.7	2.4

2.3 Mixing, casting and curing

Concrete is mixed with the help of concrete mixture. Slabs with varying centre to centre distance between bars are casted. Spacing used for the reinforcement in this study are 75 mm, 100mm, 125 mm. size of the slab specimen used is 550mm × 550mm × 50mm for both cases.

A clear cover of 15mm is used for all specimens. The size of the bars used is 8mm. The slabs are casted and left in laboratory for 2 days before demoulding. The slabs are cured for 28 days before testing.

2.4 Testing

The impact test is done on slabs using drop weight impact. Slabs are tested with hinged support at all sides. A steel ball of 3.75kg is dropped from the height of 1.2m for this study. Number of drops required to create the first crack and ultimate failure of the slabs are recorded. And also, the total length and width of the crack at the ultimate failure are also recorded.



Figure 3 Impact test setup

III. RESULTS AND DISCUSSION

The numbers of blows to reach the ultimate failure of RC slabs with steel bars are 47 and 34 for the slabs with 100mm and 125mm spacing between rods respectively. The RC slab with minimum centre to centre distance between bars (75 mm) obtained highest number of blows before ultimate failure. Table 2 contains the values observed during the testing of slabs with steel bars (minimum spacing only). Similar to that of slabs with steel bars, slabs with BFRP bars also fail very easily when the spacing between the bars increases. The numbers of blows required for the ultimate failure of slabs are 50, 35 for the slabs with 100 mm and 125 mm spacing respectively. And the number blows obtained by the slab with minimum spacing is explained in Table 3.

Table 2 Values observed during the impact testing of slab with steel bar (minimum spacing)

Specimen id	Number of blows		Ultimate crack measurements (mm)		
	At first crack N _f	At ultimate failure N _u	Total length L _c (mm)	Crack width W _c (mm)	Depth D (mm)
Control slab (75 mm spacing)	67	123	490	0.10	50

Control slab(75 mm spacing)	75	136	488	0.10	50
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with their unique characteristics, makes it a desirable alternate material for steel and other fibre reinforced polymer bars.

Table 3 Values observed during the impact testing of slab with BFRP bar (minimum spacing)

Specimen id	Number of blows		Ultimate crack measurements(mm)		
	At first crack N _f	At ultimate failure N _u	Total length L _c (mm)	Crack width W _c (mm)	Depth D (mm)
Slab with BFRP (75 mm spacing)	91	153	492	0.10	50
Slab with BFRP (75 mm spacing)	94	157	490	0.10	50

With the values observed during the impact test such as number of blows at first crack, number of blows for the ultimate failure and also the crack measurement at ultimate failure such as depth of the crack and width of the crack we can calculate values such as energy absorption at first crack, energy absorption at ultimate failure, ductility index, ultimate crack resistance and crack resistance ratio.

The calculated values of the RC slab with both steel and BFRP bars are explained in Table 4.

Table 4 Results obtained from impact test for RC slab with steel and BFRP bars

Specimen id	E _r (J)	E _u (J)	Ductility index	Cr _u (MPa)	Crack resistance ratio
Control slab (75 mm spacing)	1478.9	2714.9	1.84	1108.1	23.1
Control slab(75 mm spacing)	1655.4	3001.9	1.81	1230.3	25.6
Slab with BFRP bar (75 mm spacing)	2008.6	3377.1	1.68	1372.8	28.6
Slab with BFRP bar (75 mm spacing)	2074.8	3465.4	1.67	1414.4	29.5

IV. CONCLUSION

It is observed that the slabs with BFRP bars produces more number of cracks than the slabs with steel bars, length of the cracks are also longer in the case of slab with BFRP bars. Even though both slabs with steel bars and BFRP bars behave in the same manner under the impact loading, the slabs with BFRP bars has higher energy absorption capacity than the slabs with steel bars..It is also noted that the ductility index of the slab with BFRP bars are relatively lower than the slab with steel bars, so it may not be advisable to use the BFRP bars is earthquake prone zone. The slabs with BFRP bars produce greater number of cracks than the slab with steel bar because of their low ductile nature. The ultimate crack resistance and crack resistance ratio are higher for the slab with BFRP bars, combining it

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