Moment - curvature behavior of basalt fibred concrete beams made with basalt fibre reinforced polymer bars

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Abstract. In the current study the moment - curvature behavior of basalt fibred concrete beams made with basalt fibre reinforced polymer bars and normal beams with steel rebars are evaluated. Basalt fibred reinforced concrete beams of M30 grade were casted with steel and BFRP rebars separately to study the flexural properties of basalt fibre and BFRP bars. From the load –deflection plots, flexural characteristics such as load at first crack, ultimate flexural strength, deflection at the centre and crack width at failure are evaluated. Deflections were measured at the central point and under the load using the deflection meters. The values of moments and curvatures are obtained. Moment curvature relationships are very important to assess out ductility of the structure and the amount of possible redistribution of stresses. The deformations measured are divided by the gauge length (200mm) to obtain the strains at the particular level. From the top and bottom strains, the average curvatures were calculated. From these results, M- Φ diagrams are plotted.

1 Introduction

High temperature resistance, chemical stability, corrosion resistance, thermal conductivity, and insulation are all advantages of basalt fibre. Continuous basalt fibre can be used in a variety of ways. Because of its acid resistance, alkali resistance, high strength, high temperature resistance, low temperature resistance, smoothness, softness, scratch-resistance, and insulation, it is not only used to make reinforced plastics for fibre reinforced cement and fibre reinforced plastic, but also to solve a variety of other problems. In concrete constructions, the use of fibre reinforced polymer tendons (FRP bars) as a replacement for steel bars is a viable option. This approach may be used to tackle the problem of concrete durability caused by steel bar corrosion, as well as satisfy the needs of specific constructions that require electromagnetic interference protection. Currently, civil engineering researchers are studying the performance of FRP bars and concrete structures reinforced with FRP bars, and this novel structure is extensively employed in coastal and subway engineering. FRP bars, on the other hand, have strong tensile strength, low elastic modulus, and linear deformation properties. These features cause brittle

failure, greater fracture widths, and increased deflection, all of which have prevented FRP structures from being widely employed in civil engineering.

2 Methodology

Based on previous work by the authors, a basalt fibre length of 36mm and a dose of 0.4 percent fibre volume of the concrete are considered for the investigation. According to IS 10262, the ratio of components in M30 grade concrete is 1: 1.85: 3.06. Steel rebars and basalt fibre reinforced polymer rebars are utilised in the beams in this investigation.

3 Flexural behaviour of basalt fibre reinforced beams

The number of cracks in under-reinforced beams rose as the load increased. There is give in steel after several cracking phases, thus the P-curve becomes more or less flat until the ultimate load is attained. As the load is increased further, the load drops, indicating fracture propagation. All of the beams broke due to concrete compression, and the load deformation curves were shown up to the point of failure.

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To investigate the flexural characteristics of basalt fibre and BFRP bars, M30 grade basalt fibred reinforced concrete beams were formed with steel and BFRP rebars individually. Flexural parameters such as load at first crack, ultimate flexural strength, deflection at the centre, and crack width at failure are assessed using load–deflection plots. The deflection metres were used to measure the deflections at the central point and under the load. The moment and

curvature values are calculated. Moment curvature relationships are critical for determining the structure's ductility and the amount of stress redistribution that can occur. The strains at each level are calculated by dividing the observed deformations by the gauge length (200mm). The average curvatures of the top and bottom stresses were computed. M-diagrams are created based on these finding

Table 1. Quantities per m³ of concrete for M30 grade concrete

Concrete grade	Cement (Kg/m ³)	Water (ltrs)	Aggregates	
			Fine (kg/m ³)	Coarse (kg/m ³)
M30	372	186	687.6	1139

Table 2. Flexure Test beam details

Beam Section	Grade of Concrete	Beam type	Tension Reinforcement	Nominal Compression Reinforcement	Shear Reinforcement	Beam dimensions
Under reinforced	M30	Conventional Concrete Beam	2 Nos - 10mm ϕ Fe 415 steel bars	2 Nos - 8mm ϕ Steel bars	2 legged - 8mm ϕ Steel @100mm c/c	100 mm x 150 mm x 1100 mm
		BFRP Concrete Beam	2 Nos - 10mm ϕ BFRP bars	2 Nos - 8mm ϕ Steel bars	2 legged - 8mm ϕ Steel @100mm c/c	100 mm x 150 mm x 1100 mm

Fig.1. Flexural testing of M30 grade basalt fibred concrete made with BFRP bars

Table 3. Flexural load capacities and deflections of BFRP and conventional steel beams

Property	Steel reinforced concrete beam	Basalt reinforced concrete beam
Load at First Crack	13.3 kN	28.8kN
Maximum Load Capacity, F	38.6 kN	47.7 kN
Moment Carrying Capacity, M	9.52 kN.m	11.23kN.m
Deflection at Mid-span, D	5.7mm	15mm
Crack Width at failure	1mm	5mm

Table 4. M- Φ values of M30 grade basalt fibred concrete beams made with basalt fibre reinforced polymer (BFRP) bars

Beam 1		Beam 2		Beam 3		Beam 4	
No fibre + Steel rebars		Basalt fibre + Steel rebars		No fibre + BFRP rebars		Basalt fibre + BFRP rebars	
M kN-m	Φ	M kN-m	Φ	M kN-m	Φ	M kN-m	Φ
0	0	0	0	0	0	0	0
0.83	7.39E-07	0.83	7.78E-07	0.83	8.02E-07	0.83	1.01E-06
1.67	7.39E-07	1.67	7.78E-07	1.67	8.02E-07	1.67	1.21E-06
2.50	1.47E-06	2.50	1.55E-06	2.50	1.6E-06	2.50	2.02E-06
3.33	2.22E-06	3.33	2.34E-06	3.33	2.41E-06	3.33	2.83E-06
4.17	2.96E-06	4.17	3.11E-06	4.17	3.21E-06	4.17	3.63E-06
5.00	3.70E-06	5.00	3.89E-06	5.00	4.01E-06	5.00	4.43E-06
5.83	4.06E-06	5.83	4.28E-06	5.83	4.41E-06	5.83	5.04E-06
6.67	4.81E-06	6.67	5.06E-06	6.67	5.22E-06	6.67	5.85E-06
7.50	5.55E-06	7.50	5.84E-06	7.50	6.02E-06	7.50	6.65E-06
8.33	6.28E-06	8.33	6.62E-06	8.33	6.82E-06	8.33	7.46E-06
9.17	7.02E-06	9.17	7.39E-06	9.17	7.62E-06	9.17	8.26E-06
10.00	7.77E-06	10.00	8.18E-06	10.00	8.43E-06	10.00	9.67E-06
10.83	9.22E-06	10.83	9.70E-06	10.83	1E-05	10.83	1.09E-05
11.00	9.95E-06	11.00	1.05E-05	11.67	1.08E-05	11.67	1.17E-05
				12.17	1.16E-05	12.50	1.25E-05
						13.00	1.33E-05

Fig.1. M- Φ plot of with and without basalt fibred M30 grade reinforced concrete beams made with steel rebars

Fig.2. M-Ø plot of with and without basalt fibred M30 grade reinforced concrete beams made with basalt fibre reinforced polymer (BFRP) rebars

Fig.3. M-Ø plot of non-fibrous M30 grade reinforced concrete beams made with steel and basalt fibre reinforced polymer (BFRP) rebars

Fig.4. M-Ø plot of basalt fibred M30 grade reinforced concrete beams made with steel and basalt fibre reinforced polymer (BFRP) rebars

These moment curvature plots for under reinforced basalt fibred M30 grade reinforced concrete beams built with basalt fibre reinforced polymer (BFRP) rebars showed a similar pattern to load deflection plots for reinforced concrete beams made with steel rebars. Curvature grows steadily with increasing moment in beams until numerous breaking stages are reached, at which point it increases dramatically with constant moment or with slight variations in the moment. Until the ultimate moment, the M-curve becomes more or less flat. Finally, all of the beams collapsed due to concrete compression, and the moment curvature plots were produced up to the point of failure. Visible flexural fractures occurred at 70 percent to 80 percent of the ultimate load of each beam in conventional concrete beams built with steel rebars, and at 75 percent to 85 percent of the ultimate load of each beam in beams made with BFRP rebars. The fracture began to expand significantly, suggesting higher steel stresses than the yield strain. Tension failure, also known as ductile failure, was seen in all of the beams. There is a lot of swelling along with the cracks. Cracks spread towards the top of the beam when the weight was raised further. The fissures got more apparent when the beams were forced to bend more, and the concrete was crushed at one or both ends. The load reduced as the beam deflection increased, which was accompanied by concrete spalling. All basalt fibred M30 grade reinforced concrete beams constructed with steel and basalt fibre reinforced polymer (BFRP) rebars exhibit the same crack pattern. Deflections at service loads are less than the maximum allowed deflection of 4.8 mm, i.e. Span/250, prescribed by IS 456-2000 in basalt fibred M30 grade reinforced concrete beams constructed with steel and basalt fibre reinforced polymer (BFRP) rebars. As a result, the usage of steel and basalt fibre reinforced polymer (BFRP) rebars does not contradict

the codes of practice's serviceability requirements. Except for the increased values of loads at ultimate and at first crack in basalt fibred M30 grade reinforced concrete beams made with basalt fibre reinforced polymer (BFRP) rebars, the load deflection and moment –distribution behaviour of basalt fibred M30 grade reinforced concrete beams made with steel and basalt fibre reinforced polymer (BFRP) rebars is observed to be similar. Curvature rose progressively in under-reinforced beams as the moment increased, up to numerous breaking stages and beyond, and subsequently curvature increased dramatically at constant moment or with slight variations in the moment. Until the final moment is achieved, the M-curve is more or less flat. Because all of the beams broke due to concrete compression, moment curvature graphs were generated up to the point of failure. All under-reinforced beams built with BFRP bars behave in the same way. The rise in the horizontal plateau of the moment-curvature plots and the increase in ultimate moment in reinforced beams produced with BFRP bars than in regular beams constructed with steel rebars are the variations noted in the moment-curvature behaviour of BFRP rebar beams.

The moment curvature plots for BFRP-reinforced beams were found to follow a similar pattern to the load deflection plots of beams. Curvature rose progressively in under-reinforced beams as the moment increased, up to numerous breaking stages and beyond, and subsequently curvature increased dramatically at constant moment or with slight variations in the moment. Because all of the beams broke due to concrete compression, moment curvature graphs were generated up to the point of failure. The rise in the plateau of the moment-curvature plots and the increase in ultimate moment in reinforced beams produced with BFRP bars than in regular beams with steel rebars are the variations detected in the moment-

curvature behaviour of reinforced beams manufactured with BFRP bars. The rise in the plateau of the moment-curvature plots and the increase in ultimate moment in beams with BFRP bars and basalt fibre than in normal beams with steel rebars are the variations detected in the moment-curvature behaviour of copper slag based reinforced concrete beams.

4 Conclusions

1. Visible flexural fractures occurred at 70 percent to 80 percent of the ultimate load of each beam in conventional concrete beams built with steel rebars, and at 75 percent to 85 percent of the ultimate load of each beam in beams made with BFRP rebars..
2. Deflections at service loads are less than the maximum allowed deflection of 4.8 mm, i.e. Span/250, prescribed by IS 456-2000 in basalt fibred M30 grade reinforced concrete beams constructed with steel and basalt fibre reinforced polymer (BFRP) rebars. As a result, the usage of steel and basalt fibre reinforced polymer (BFRP) rebars does not contradict the codes of practice's serviceability requirements.
3. Except for the increased values of loads at ultimate and at first crack in basalt fibred M30 grade reinforced concrete beams made with basalt fibre reinforced polymer (BFRP) rebars, the load deflection and moment –distribution behaviour of basalt fibred M30 grade reinforced concrete beams made with steel and basalt fibre reinforced polymer (BFRP) rebars is observed to be similar.
4. The rise in the plateau of the moment-curvature plots and the increase in ultimate moment in reinforced beams produced with BFRP bars than in regular beams with steel rebars are the variations detected in the moment-curvature behaviour of reinforced beams manufactured with BFRP bars. The rise in the plateau of the moment-curvature plots and the increase in ultimate moment in beams with BFRP bars and basalt fibre than in normal beams with steel rebars are the variations detected in the moment-curvature behaviour of copper slag based reinforced concrete beams.

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