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BEHAVIOR OF REINFORCED CONCRETE BEAMS WITH BASALT FIBERS ADDED TO THE MIX

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Abstract: **Among the rapid development of fibers in the field of civil engineering, Basalt Fibers are new type of fibers recently introduced in the market. In this research eleven beams of M 25 grade of concrete with dimensions 150 mm width, 300 mm depth and 1800 mm support to support length were casted with the addition of basalt fibers (0%, 0.25%, 0.625% and 1%) from the concrete volume, to study the behavior of reinforced concrete beams with basalt fibers. The parameters studied were the percentage of basalt fibers, fiber locations and the reinforced ratio. Crack pattern, Load deflection curves, stiffness and load carrying capacity were investigated for each beam. From this study it was concluded that basalt fibers have positive effect on the behavior of under reinforced beams and can change the behavior of over reinforced beams to more ductile one.**

Keywords**: Basalt Fiber, Concrete, Flexure Strength, Under Reinforced Beams, Over Reinforced Beams.**

1. INTRODUCTION

Concrete carry compression force and a small percentage of tension force, so when a beam is loaded and the tensile stresses at the bottom exceeds the tensile capacity of the concrete, cracks begins to propagate and the tension force will be resisted by the reinforcement. As known from the general properties of fibers concluded from different researches that adding fibers like steel fiber and glass fiber can contribute with steel reinforcement in carrying tension stresses induced in the tension zone if added to the mix in a certain limit, in addition to controlling cracks by its bridging action [1], [2].

This commonly used in under reinforced sections, while the effect of fibers in over reinforced sections is not taken into consideration in different researches due to the prohibition of different codes for using this type of section because the brittleness at failure without significant warning, However, using this type of section may be a solution if limited depth is provided.

In this research under reinforced beams and over reinforced beams are been examined by adding basalt fibers (B.F) in the mix, a relatively new type of fibers, to estimate the amount of improvement that basalt fibers contribute in the behavior of both types.

2. LITERATURE REVIEW

Md. Tabsheer Ahmed (2013), [3] tested cubes and beams with basalt fibers (0.25%, 0.5%, 0.75%, 1%) by the weight of cement, maximum increase in both compressive and flexural strength was reported at 1%. **Tumadhir M. Borhan (2013), [4]** tested concrete cubes with basalt fibers (0.1%, 0.2%, 0.3% and 0.5%) from the concrete volume at age 7,28 and 90 days. She concluded that maximum compressive strength was at 0.3%, while lower compressive strength was at 0.5% at different tested ages, she stated that this decrease may be due to poor areas of interface between the constituents as the percentage of basalt fibers increased. **R. Singaravadivelan (2013), [5]** tested beams with basalt fibers percentage (0.5%, 1%, 1.5%, 2% and 2.5%) from the concrete volume and maximum load carrying capacity was reached at 0.5% and 2.5% basalt fibers. **A.E.A.Elshekh (2014), [6]** investigated the effect of basalt fiber with percentage (1%, 2% and 3%) by weight of cement on the fresh properties of high strength concrete, a reduction in slump and workability was observed as basalt fibers content increase. **Ranjitsinh (2014), [7]** casted cubes and beams with basalt fibers percentage (0.25%, 0.5%, 0.75% and 1%) from the concrete volume, maximum compressive strength and flexural strength was recorded for 0.5% basalt fibers then decreased gradually till reaching 1%.

3. MATERIALS CHARACTERISTICS

The materials used to cast the specimens were (sand, dolomite, ordinary Portland cement and drinking water). Concrete mix designed to get target cubic compressive strength of 250 kg/m^2 after 28 days, mix proportions are as listed in Table 1**.**

Coarse Aggregate:

Dolomite used from natural sources with nominal maximum size of 20 mm. This nominal size was chosen taking into consideration the dimension of the tested beams as well as the spacing between the reinforcing bars. Batches used were all of good quality, clean and free from organic material.

Fine Aggregates

Natural sand composed of siliceous materials, clean and free from impurities.

Cement

Locally produced high quality ordinary Portland cement (CEM I 42.5 R) packed in sacks of 50 kg each.

Mixing Water

Drinking water used for mixing and curing for all specimens

Reinforcement Steel

Different reinforcement diameters and types used in this study. High tensile deformed steel bars of 10, 12 and 16 mm diameter were used as top and bottom steel for beams and denoted by (Y), While mild smooth steel 8 mm diameter was used as stirrups in all beams and denoted by (Φ).

Basalt Fibers

The basalt fibers used was purchased from **"Basaltex" Company [8],** in Belgium with properties as listed in Table 2.

4. MIXING

Sand, coarse aggregate and half amount of fibers added to the mechanical mixer and mixed for about one minute. Cement and the rest amount of fibers were added without adding of water for another one minute to insure better dispersion of the fibers throughout the mix, then water is added gradually to the mixer and continued in mixing for about 5 minutes to obtain homogenous mix for all constituents.

It was observed that mixes with different fibers content was less workable than those without fibers, this may be due to the absorption of certain amount of moisture by the fibers. Therefore, water to cement ratio was increased from 0.5 in the control mix to 0.65 for mixes with various fiber content, to ensure better dispersion of fibers with same consistency as the control mix

Table 1: Mix Proportions

Mix number	% of Basalt Fibers	Cement (kg)	C.A (kg)	F.A (kg)	Basalt Fiber (kg)	Water (kg)
1	0%	350	1320	640	-	175
2	0.25%	350	1320	640	6.675	227.5
3	0.625%	350	1320	640	16.687	227.5
4	1%	350	1320	640	26.7	227.5

Table 2: Basalt Fibers Properties

Property	Standard
Density	2670 kg/m^3
Chop length	25.4 mm
Filament diameter	13 µm
Melting point	1350 ±100 °C
Elongation at break	2.5 ±10 %
E- Modulus	84 GPa
Color	Golden brown

5. EXPERIMENTAL PROGRAM

Experimental work consists of eleven Beams and twelve cubes. The beams with dimensions 150 mm width, 300 mm depth and 2000 mm length were casted with different basalt fiber ratios 0%, 0.25%, 0.625% and 1% from the concrete volume and tested under Three Point Bending Test.

The eleven beams classified into four groups as listed in Table 3. First group consists of two concrete beams without basalt fibers as control beams; one classified as under reinforced beam with 2Y12 bottom, 2Y10 top reinforcement and 5Φ8 stirrups, while the other classified as over reinforced beam with 5Y16 bottom, 2Y12 top reinforcement and 7Φ8 stirrups as shown in Figure 1 and Figure 2.

Each group in the rest groups consisted of three beams to investigate different parameters as listed as below.

Three concrete cubes with dimensions 150x150x150 mm were casted for each basalt fiber ratio to estimate average compressive strength.

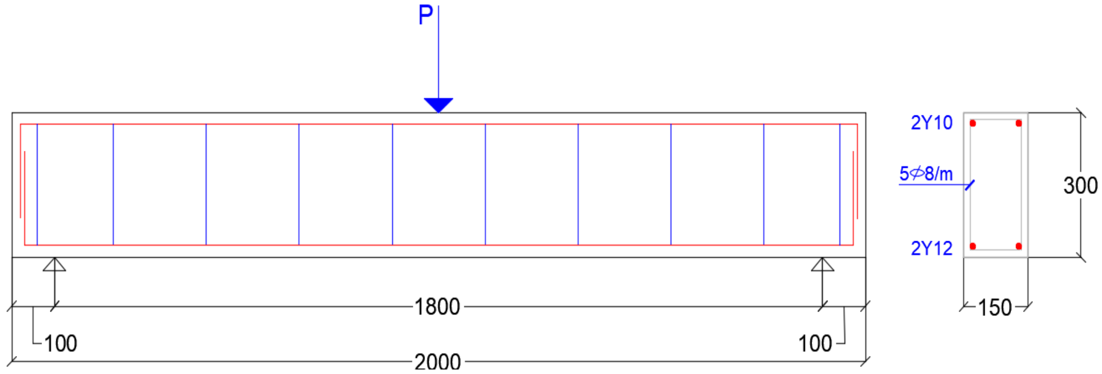

Figure 1: Typical Detail for Under Reinforced Beams

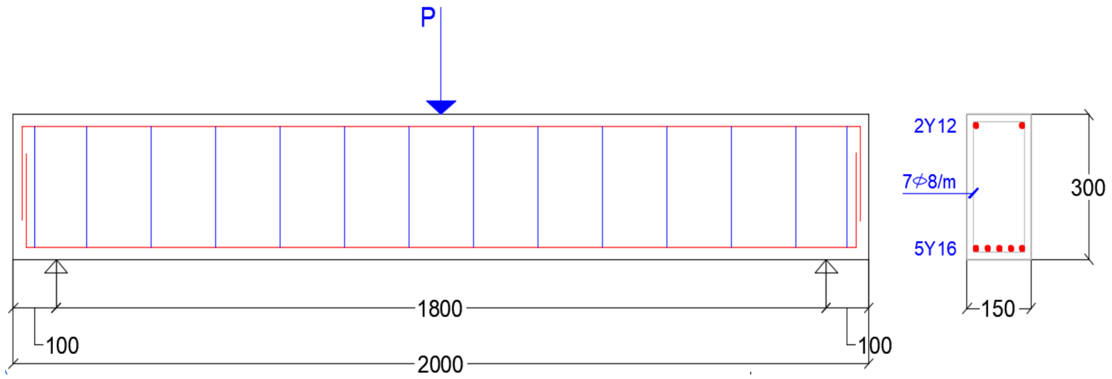

Figure 2: Typical Detail for Over Reinforced Beams

Table 3: Specimens Details

Group	Specimen	Fiber %	Fiber Location	Bottom Steel	Top Steel	Vertical Stirrups	Type of Section
0	B-0-1	0%	None	2Y12	2Y10	5Φ8/m	Under Reinf.
	B-0-2		None	5Y16	2Y12	7Φ8/m	Over Reinf.
A	B-A-1	0.25%	Lower Third	2Y12	2Y10	5Φ8/m	Under Reinf.
	B-A-2		Lower Half	2Y12	2Y10	5Φ8/m	
	B-A-3		Upper Half	5Y16	2Y12	7Φ8/m	Over Reinf.
B	B-B-1	0.625%	Lower Third	2Y12	2Y10	5Φ8/m	Under Reinf.
	B-B-2		Lower Half	2Y12	2Y10	5Φ8/m	
	B-B-3		Upper Half	5Y16	2Y12	7Φ8/m	Over Reinf.
C	B-C-1	1%	Lower Third	2Y12	2Y10	5Φ8/m	Under Reinf.
	B-C-2		Lower Half	2Y12	2Y10	5Φ8/m	
	B-C-3		Upper Half	5Y16	2Y12	7Φ8/m	Over Reinf.

6. TEST SETUP

Specimen setup is as shown in Fig.3, all specimens subjected to concentrated load using hydraulic jack at mid span. Three dial gauges for measuring deflections were located at half side of the beam, 300mm apart from each other. The first one was 300mm from the right support, the second followed by 300mm and the third was at the mid span.

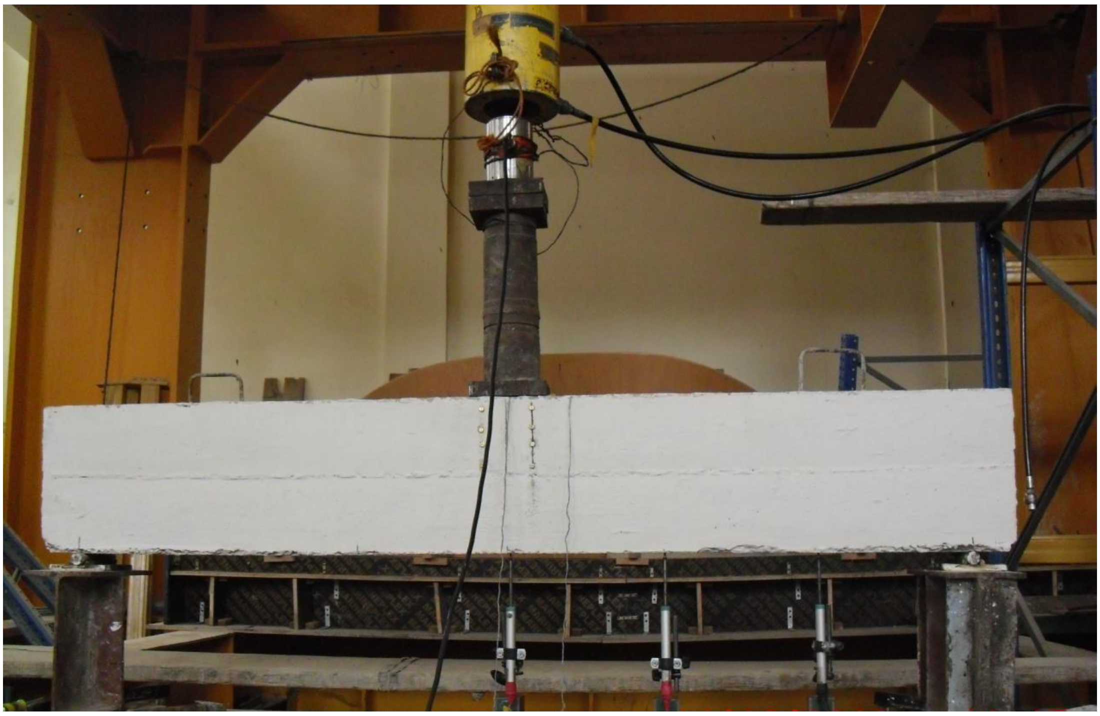

Figure 3: Test Setup

7. RESULTS OF CUBES

Maximum compressive strength recorded for 0.25% basalt fibers, and decreased as the percentage of basalt fibers increased. This may due to high percentage of basalt fibers increases the chance of concrete balling and voids in the mix. Results of average compressive strength are as shown in Figure 4.

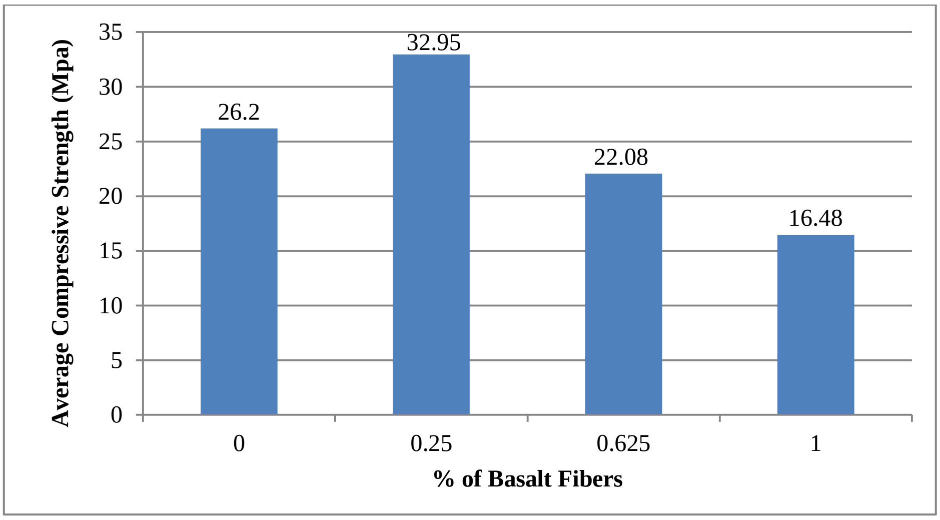

Figure 4: Average Compressive Strength for Tested Cubes

8. RESULTS OF BEAMS

Test values for beams are summarized in Table IV and will be discussed below.

Table 4: Results of Tested Specimens

Group	Specimen	First crack Stage		Failure Stage		Mode of Failure
		P_{cr} (kN)	Δ_{cr} (mm)	P_f (kN)	Δ_f (mm)	
0	B-0-1	17.2	0.249	95.1	56	Flexure failure
	B-0-2	91.2	2.072	233.10	8.17	Shear failure
A	B-A-1	25.3	0.498	98.70	43.27	Flexure failure
	B-A-2	25.9	0.553	101.60	44.14	Flexure failure
	B-A-3	66.5	1.238	240.20	8.81	Shear failure
B	B-B-1	29.2	1.195	92.80	49	Flexure failure
	B-B-2	29.8	1.204	99.00	46.85	Flexure failure
	B-B-3	99.6	2.25	252.20	27.17	Compression failure
C	B-C-1	26.3	0.713	93.50	37.28	Flexure failure
	B-C-2	29.3	0.7175	101.90	58	Flexure failure
	B-C-3	99	2.623	222.70	14.47	Shear failure

A. Results of Under Reinforced Beams

1. First Crack Load:

All beams with basalt fibers in the lower third and the lower half shows higher cracking load than the control beam as in Figure 5, this can be due to the bridging action of fibers and its role in delaying the appearance of cracks.

2. Deflection

The deflection of all beams increased proportional to the load increase until the first crack occur, the deflection then continued to increase in a linear way with the increase of the load but with decrease in the slope till the end of the elasto plastic zone. Then the rate of increase in load decreased until reaching the failure load. The relation between the applied load and mid-span deflection for under reinforced beams are as shown in Figure 6 and Figure 7. There is a different manner between beams with and without basalt fibers; Basalt fibers beams showed a uniform increase in the deflection while control beam experienced a steep deflection. Because sudden drop in deflection from 19.152 mm to 34.926 mm occurred in the control beam during loading, so it recorded the maximum value of deflection. Consequently, it does not mean that it is the most ductile beam, the change in the beam behavior from a steep deflection due to the sudden drop to a uniform deflection considered a general enhancement in the beams performance recorded for the use of basalt fibers.

3. Failure Mode

All beams failed in a flexure failure mode. An increase in the failure load for beams with lower half dispersion than that of lower third dispersion, this shows that adding basalt fibers in wider area in tension zone contributed with the reinforcing steel in carrying the tension stresses induced in the tension zone consequently, increases the failure load and the flexure capacity of under reinforced beams.

Although concrete with higher basalt fiber percentages gives lower compressive strength values in the compression test of cubes, beams with the same percentages gives higher failure load in bending test than the control, especially in beams with lower half dispersion of fibers.

Because compressive strength of concrete is one of different factors that influence the flexure strength of beams in addition to other factors. For example, the interaction between reinforcement and fibers in carrying the tensile stresses induced in the tension zone, fiber orientation whether vertical, horizontal or inclined and the non-uniform distribution of fibers in different cross sections inside the tension zone. The last two factors could not be handled in this research. So if the in hand factor which is the compressive strength of concrete can be controlled, better flexure strength for beams may be achieved. Values of failure load for under reinforced beams are as in Figure 8.

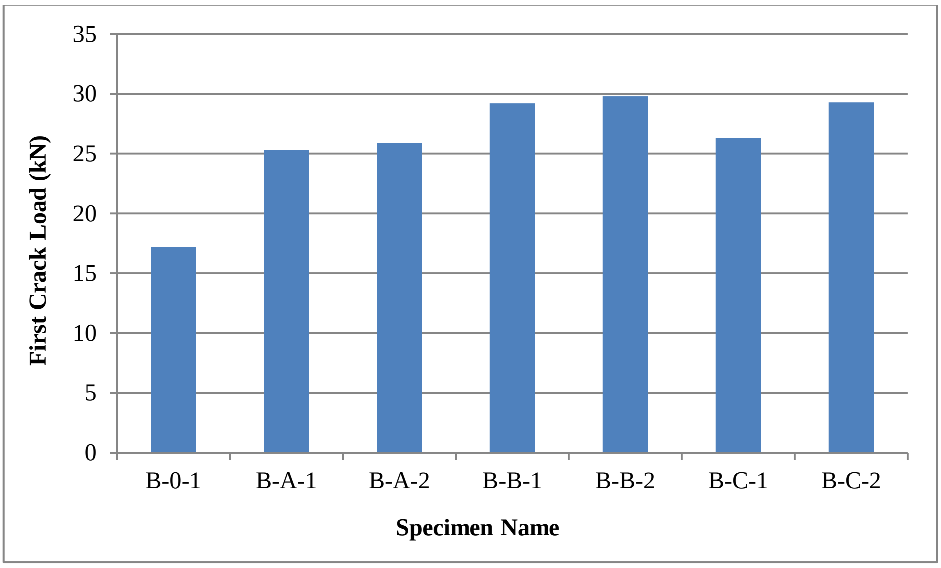

Figure 5: First Crack Load For Under Reinforced Beams

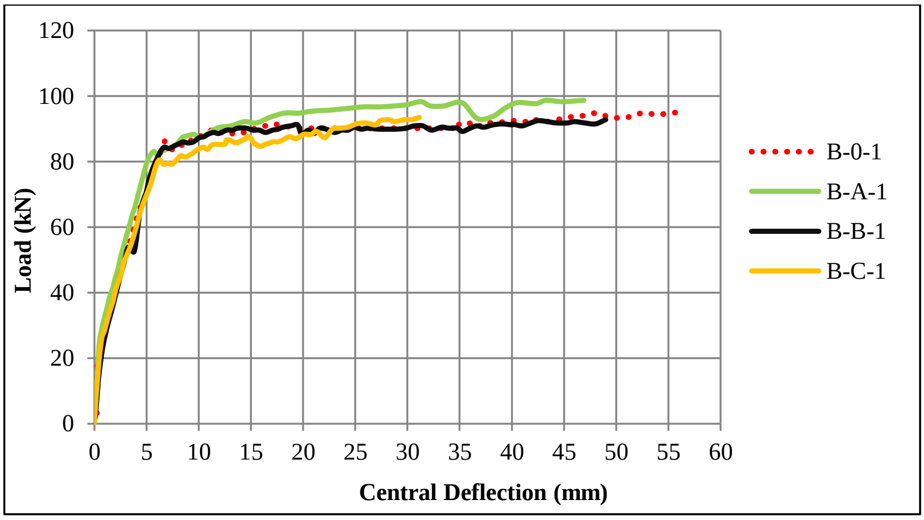

Figure 6: Load-Deflection Curves for Under Reinforced Beams with Lower Third Dispersion of Fibers

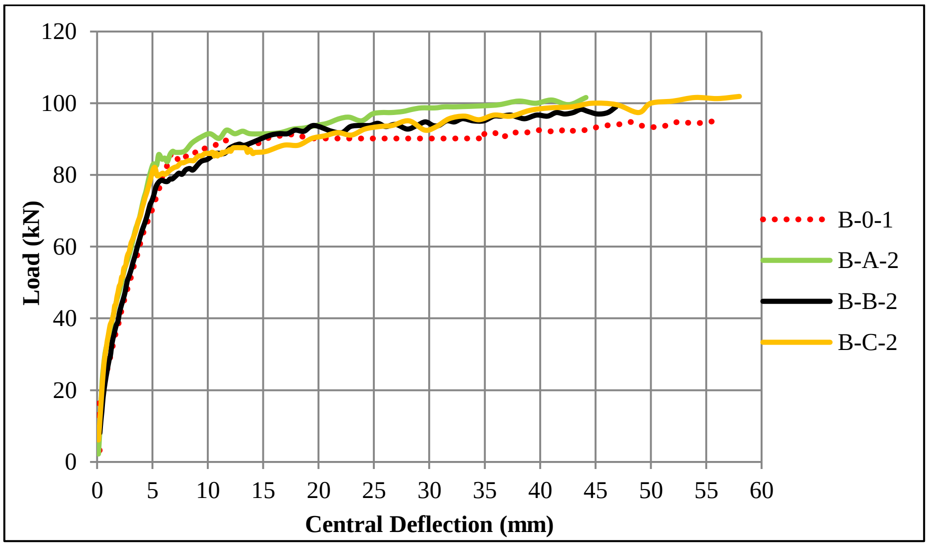

Figure 7: Load-Deflection Curves for Under Reinforced Beams with Lower Half Dispersion of Fibers

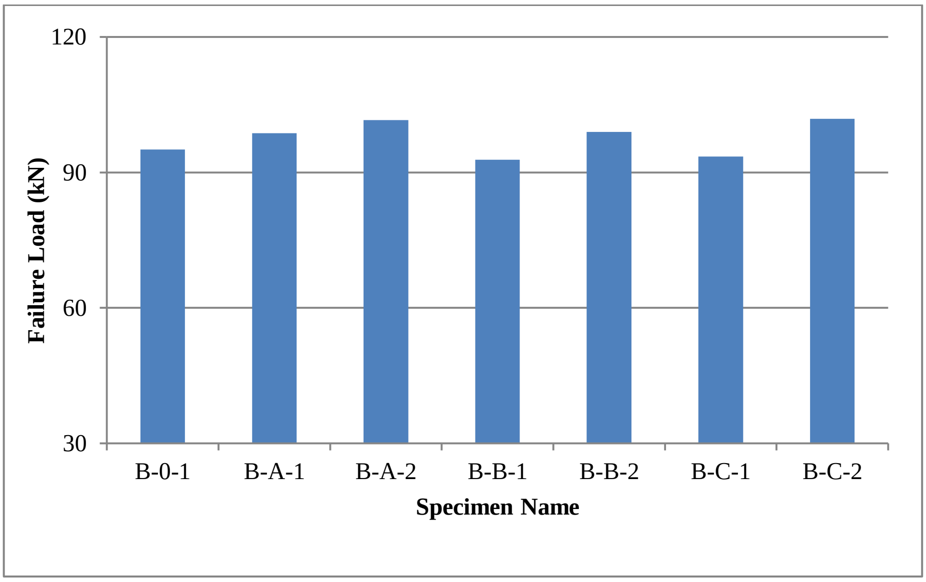

Figure 8: Failure Load for Under Reinforced Beams

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B. Results of Over Reinforced Beams

1. First Crack Load

The first crack load was not influenced with the presence of basalt fiber, because the fibers are located at upper half of the beam and the cracks initiated in the bottom flexure zone.

2. Crack Pattern

Figure 9 to Figure 12 shows the crack pattern for all over reinforced beams. In specimens (B-0-2) 0% B.F and (B-A-3) 0.25% B.F, flexure and shear cracks propagate, ended with a shear crack connects between the compression zone and the right support which appeared wider in (B-0-2).

Specimen (B-B-3) 0.625% B.F, several flexure cracks appeared in the tension zone this can be due to the confinement of the basalt fibers to the compression zone and its contribution in carrying compression strains induced in the compression zone during the test. The flexure cracks then were accompanied by few shear cracks near the support and finally deterioration of concrete cover in the compression zone.

Specimen (B-C-3) with 1% B.F showed the positive effect of adding B.F in the upper half. A propagation of flexure cracks in the tension zone without extension to the compression zone (no flexure cracks crossed the centre line of the beam depth). Therefore, it can be concluded that; 1% B.F stiffened or totally confined the compression zone without any cracks, working with the stirrups hangers (top steel) as a compression steel, no crushing caused at the top zone and finally the failure was governed by shear.

3. Deflection

All beams performed larger deflection at failure than the control beam as shown in Figure 13 and Figure 14. An extreme increase in the ultimate deflection showed for beam (B-B-3) equal to 261.8 % compared with the control beam.

So basalt fibers are able to increase the deflection of the over reinforced beams and convert it to less brittle or semi ductile.

4. Failure Mode

The control specimen (B-0-2) reached its maximum load can sustain then the load decreased gradually until it dropped suddenly with shear failure, the same in specimens (B-A-3) and (B-C-3), but without sudden drop in the load after reaching the maximum capacity.

While specimen (B-B-3) reached the failure load and remains constant for several load increments then beam loading was stopped after a small decrease in load was reached in a compression failure mode.

An increase in failure load than the control for specimens (B-A-3) and (B-B-3), while slightly decrease in failure load observed for specimen (B-C-3) as shown in Figure15

Figure 9: Crack Pattern for Specimen (B-0-2)

Figure 10: Crack Pattern for Specimen (B-A-3)

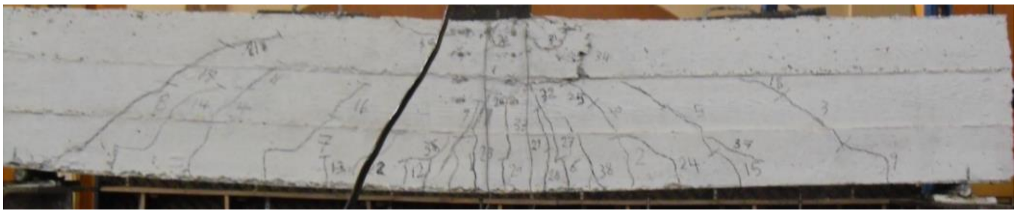

Figure 11: Crack Pattern for Specimen (B-B-3)

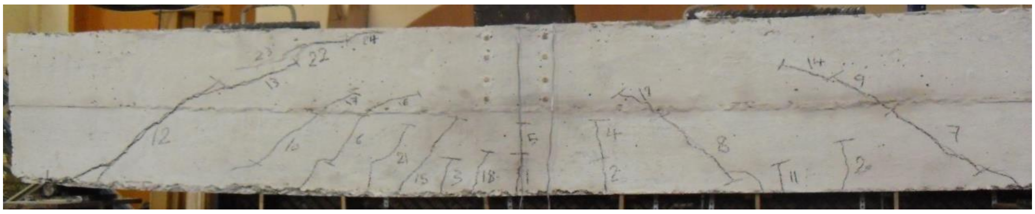

Figure 12: Crack Pattern for Specimen (B-C-3)

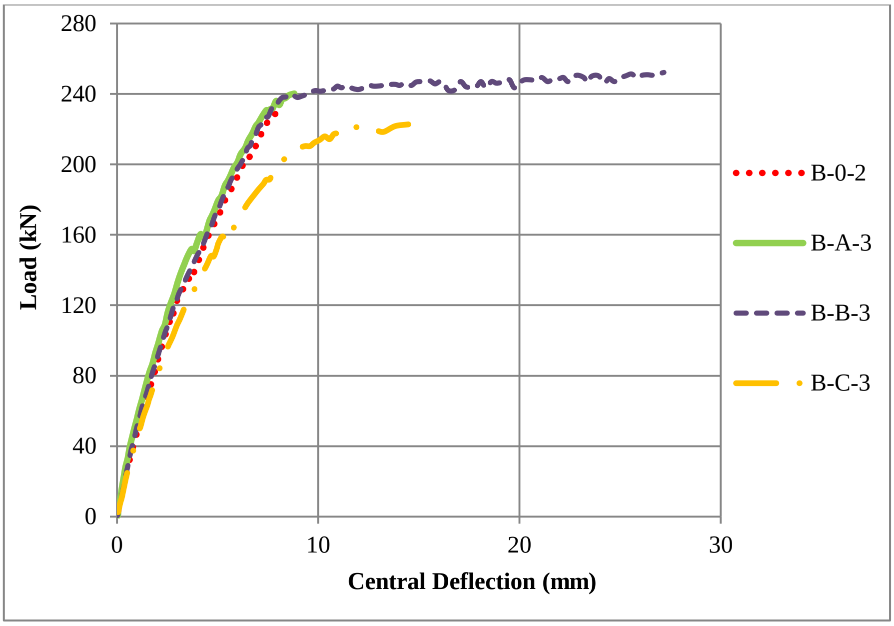

Figure 13: Load Deflection Curves for Over Reinforced Beams

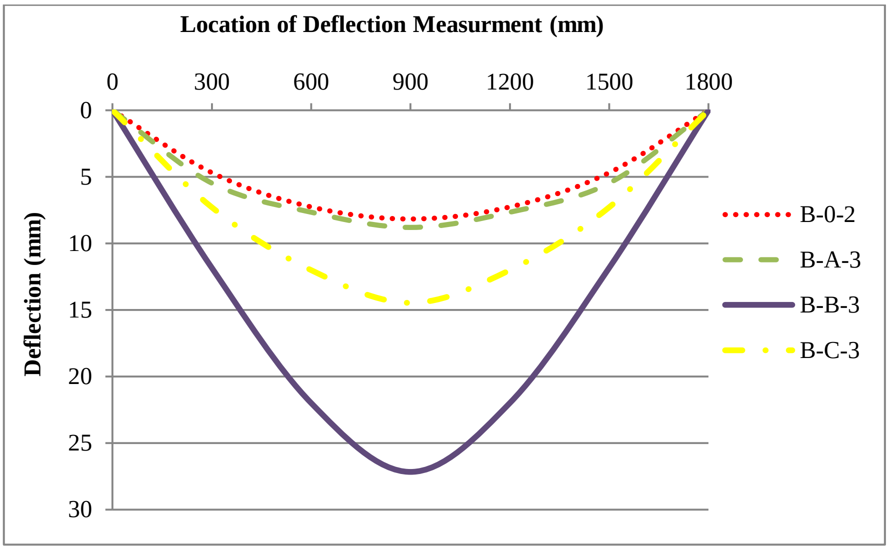

Figure 14: Deflection Profile for Over Reinforced Beams

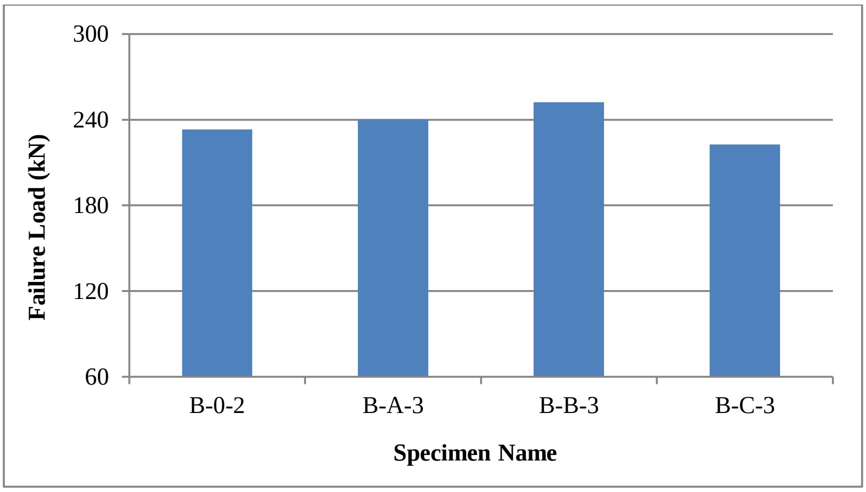

Figure 15: Failure Load for Over Reinforced Beams

9. CONCLUSION

From this present study, the following conclusions are obtained:

1. An increase in the first crack load for all beams with basalt fibers than the control beam in both cases lower third and lower half fiber dispersion.

2. Basalt fibers change the deflection performance for beams from steep deflection to more uniform deflection.

3. Higher failure loads recorded for beams with lower half dispersion of fibers, 6.83%,4.10% and 7.15% for 0.25%, 0.625% and 1% basalt fibers respectively.

4. Beams with lower half dispersion shows higher cracking load and failure load than beams with lower third dispersion, which is a result of B.F presence in larger area in the tension zone.

5. All beams with basalt fibers show higher deflection than the control beam, which is a sign of ductility.

6. Beams with basalt fibers showed more cracks in the tension zone than the control beam due to the confining effect of basalt fibers in the compression zone and their contribution in carrying the compression strains induced in the compression zone.

7. Higher percentage of basalt fibers can work with the stirrups hanger as compression steel stiffening and confining the compression zone without cracks.

8. Basalt fibers can change the performance of over reinforced beams to less brittle or semi ductile.

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