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Behavior of Reinforced Concrete Beams Exposed to Fire with Adding Basalt Fibres to the Mix

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ملخص البحث

يقدم هذا البحث دراسة عن الخرسانة المسلحة بالألياف البازلتية والتي تعتبر نسبيًا طريقة جديدة لتحسين سلوك الخرسانة المسلحة وذلك للحصول على المزيد من الخصائص المرغوبة ، وتحسين العناصر الخرسانية لتحمل أحمال أكبر ولتعزيز أو تحويل السلوك الكلي إلى أكثر ليونة وقوة محسنة للخرسانة عند تعرضها للنار. و سيتم مناقشة سلوك الكمرات الخرسانية المسلحة المعرضة للحريق مع إضافة الألياف البازلتية عن طريق صب عشر عينات مقسمة إلى مجموعتين،تم صب عينتين دون إضافة ألياف البازلت ولم تتعرض للحريق و تم إضافة نسبة ألياف البازلت بنسبة (0.25٪) من حجم الخرسانة إلى ست عينات ، وست عينات تعرضت للحريق وتم إخمادها بالهواء والماء. تمت دراسة المتغيرات الحادثة علي سلوك الخرسانة باضافة نسبة 0.25٪ من ألياف البازلتية، ونسب التسليح المختلفة (انهيار الثني , انهيار القص) وطرق التبريد المختلفة.تم تسجيل العديد من النتائج: أحمال الشروخ ، نمط الشروخ ، منحنيات انحراف الحمل ، الصلابة وأحمال الانهيار لكل عينة. واستنتج من هذه الدراسة إلى أن استخدام ألياف البازلت بنسبة 0.25٪ من الحجم له تأثير إيجابي على سلوك الخرسانة المسلحة.

ABSTRACT

This paper present a study on basalt fibre reinforced concrete "BFRC" that considered relatively as a new method for reinforcing concrete, to gain more desired properties, confine the concrete members to sustain larger loads and to enhance or may convert the total behavior of the member into more ductile one and enhanced the character of concrete when exposed to fire. The parameters studied were percentage of 0.25 % basalt fibres, reinforced ratio (flexural failure and shear failure) and put out system for burned beams. Ten specimens were casted to study the behavior of reinforced concrete beams exposed to fire with adding basalt fibres to the mix, two control specimens were casted without adding basalt fibre and not exposed to fire, Basalt fibre ratio (0.25%) of the concrete volume were added to six specimens and six specimens exposed to fire and put out by air and water. Several results were recorded: Crack loads, crack pattern, load deflection curves, stiffness and failure loads were investigated for each specimen. Its concluded from this study that using basalt fibers with 0.25% of volume has positive effect on the behavior of under reinforced beams(flexural failure), can change the behavior of over reinforced beams(shear failure) to semi ductile one and has a positive effect on failure load, cracking load and stiffness for under reinforced beams that exposed to fire and put out with air, has a positive effect on ductility and cracking load for (flexural failure) beams that exposed to fire and put out by water and has a positive effect on failure load, cracking load, ductility and stiffness on (shear failure) beams that exposed to fire and put out with air or water.

Keywords: *Basalt Fibre, Exposed Fire, Under Reinforced Beams (Flexural failure), Over Reinforced Beams (Shear failure).*

1. Introduction

Reinforced concrete is not closed to its traditional component. A lot of additive had been discovered with chemical or natural reference that has large effective on behavior of reinforced concrete and added a lot of applications and these additives belong to fibre family. A lot of scientific researchers had done by using these additives and appears fantastic results and a large improvement on reinforced concrete like compressive strength, tensile strength, fire resistance and these additives are actually being used in different constructions. One of disadvantage of concrete is that it has no fire resistance, many cases of buildings failure was accrued because of fire or wrong trials to put out the fire. Examples of fibre family are: glass fibre, carbon fibre and basalt fibre. In this research study the effect of fire on concrete with various ratio of reinforced and behavior of it by using basalt fibre to concrete mix by casting ten beams and exposed some of it to fire with various types of put out fire by using water and air and recheck it by loaded and examine stresses on it and find difference by examine control beam without any additives. This research includes also the effect of different variables on crack loads, crack patterns, failure modes, loads deflection curves, initial stiffness, measurement of ductility and energy absorption on all beams.

2. Previous Research

Thaar Saud S. Al-Gasham (2015)[1] study research basalt fibre are produced from basalt rocks, which are melted at 1400 ˚C. Basalt fibres are environmentally safe, non-toxic, and possess high stability and insulating characteristics. Basalt rock is a volcanic rock and can be divided into small particles then formed into continues or chopped fibre. Basalt fibre has a higher working temperature and has a good resistance to chemical attack, impact load, and fire with less poisonous fumes. Basalt fibres are manufactured by melting basaltrock. There are two production methods: short fibres are produced using the Junkers method and continuous fibre using the Spinneret method Basalt's properties and behavior in concrete .Basalt has good mechanical properties – a high elastic modulus and strength. Tests had shown that basalt fibre, independent of the dosage, does not affect concretes' compressive strength. However, basalt does affect the flexural tensile strength and toughness, allowing bigger deformations and making it less sensitive to cracking**.** **Tumadhir M. Borhan (2013)[2],**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**.** **Nayan Rathod, Mukund Gonbare , Mallikarjun Pujari [3]** presents an experimental investigation that was carried out to evaluate the performance characteristics of basalt fibre reinforced concrete beams. The basalt fibre was supplied by Muktagiri industrial corporation Borivali, Mumbai. The primary objective of this investigation was to determine the strength of the basalt fibre in concrete, and to compare the experimentally determined ultimate moment capacity of basalt fibre reinforced concrete beams, and their calculated ultimate moment capacities according to IS 516:1959 (13) methods of tests for strength of concrete. The chemical tests are also carried on the basalt fibre to check their strength and stability with effect on their physical properties**.** **(Gabriel Alexander Khoury in.2008) [4]** said that Concrete is considered fireproof on account of its incombustibility and low thermal diffusivity. This is an advantage although concrete can also experience explosive spalling and deterioration of properties during heating which need to be understood and designed against either at the materials level and/or at

the structural level. Decades of research have produced a considerable amount of materials data which could lead to confusion if not properly analyzed and sorted. Despite the abundance of data, there still remain areas than need further studies and also clarification such as the design of fireproof concrete and also the cost effective design of structures to withstand fires. There does not exists a universally agreed upon definition of fireproof concrete and the author recommends that an effort in that direction should be made. Numerical methods have made significant advances recently, especially with many authorities accepting performance based engineering design, but sadly numerical methods are still developing faster than the production of materials data that is required for their input. As a result, the outputs of computer models need to be carefully and critically examined to ensure their validity for the application in question.
Concrete structures are frequently exposed to fire. Examples include buildings and tunnels. The nature of the fire varies not only from application to another but also from fire to fire depending upon the fire load (fuel), the geometric configuration and the availability of oxygen.

3. Experimental Programme

3.1. 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 25 kN/m^2 after 28 days.

Coarse Aggregate: Dolomite used from natural sources with nominal maximum size of 10 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).

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 Fibres: The basalt fibers used was purchased from "Basaltex" Company [8], in Belgium with properties as listed in Table 1.

Table (1): Properties of Chopped Basalt Fibre.

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

3.2. Mixing

The proportions of these mixes are listed in the Table 2. Sand, coarse aggregate and half amount of fibres added to the mechanical mixer and mixed for about one minute. Cement and the rest amount of fibres 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 fibres content was less workable than those without fibres, this may be due to the absorption of certain amount of moisture by the fibres. Therefore, super Plastizer additive was added to the mix to enhance with 0.3 by water volume for enhancing the workability of the mix.

Table (2): Quantities by Weight for 1m^3 Concrete.

Mix No.	% of Basalt fibre	Cement Content (kg/m^3)	Coarse Aggregates (kg/m^3)	Fine Aggregates (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)
1	0.0%	350	1320	660	0.0	175
2	0.25%	350	1320	660	6.7	175

3.3. Test Specimens

Experimental work consists of ten beams, six cubes and six cylinders. The beams with dimensions 150 mm width, 300 mm depth, 2000 mm length and 1850 mm centre-right support to centre-left support. The ten beams classified into two groups as listed in Table 3. First group consists of five concrete beams classified as under reinforced (flexural failure) beam with 2Y12 bottom, 2Y10 top reinforcement and 5Φ8 stirrups, first beam is control beam, the second beam is with adding 0.25 % of concrete volume basalt fibre , the third beam is with adding 0.25 % of concrete volume basalt fibre and exposed to fire then put out with air, the fourth beam is with adding 0.25 % of concrete volume basalt fibre and exposed to fire then put out with water and the fifth beam is exposed to fire then put out with air as shown in Fig. (1). while the second group consists of five concrete beams classified as over reinforced (shear failure) beam with 5Y16 bottom, 2Y12 top reinforcement and 7Φ8 stirrups, first beam is control beam, the second beam is with adding 0.25 % of concrete volume basalt fibre , the third beam is with adding 0.25 % of concrete volume basalt fibre and exposed to fire then put out with air, the fourth beam is with adding 0.25 % of concrete volume basalt fibre and exposed to fire then put out with water ,the fifth beam is exposed to fire then put out with air as shown in Fig. (2). All beams tested under one point bending test after exposed six beams to fire on 400 ° C then put out with air for three and water for other three as shown in Fig. (3).

Table (3): Specimens Details.

Group	Beams	As	As\	Stirrups	Type of Section	Fibre Ratio %	Fire	Put out Type
Group (1)	B1UF	2Y12	2Y10	5 ϕ8/m\	Flexural failure	0	-	-
	B3UB	2Y12	2Y10	5 ϕ8/m\	Flexural failure.	0.25		
	B5UB	2Y12	2Y10	5ϕ8/m\	Flexural failure	0.25	Burned	Air
	B7UB	2Y12	2Y10	5ϕ8/m\	Flexural failure	0.25	Burned	Water
	B9UF	2Y12	2Y10	5ϕ8/m\	Flexural failure	0	Burned	Air
Group (2)	B2OB	5Y16	2Y12	7ϕ8/m\	Shear failure.	0	-	-
	B4OB	5Y16	2Y12	7ϕ8/m\	Shear failure.	0.25	-	-
	B6OB	5Y16	2Y12	7ϕ8/m\	Shear failure.	0.25	Burned	Air
	B8OB	5Y16	2Y12	7 ϕ 8/m	Shear failure	0.25	Burned	Water
	B10OB	5Y16	2Y12	7ϕ8/m\	Shear failure.	0	Burned	Air

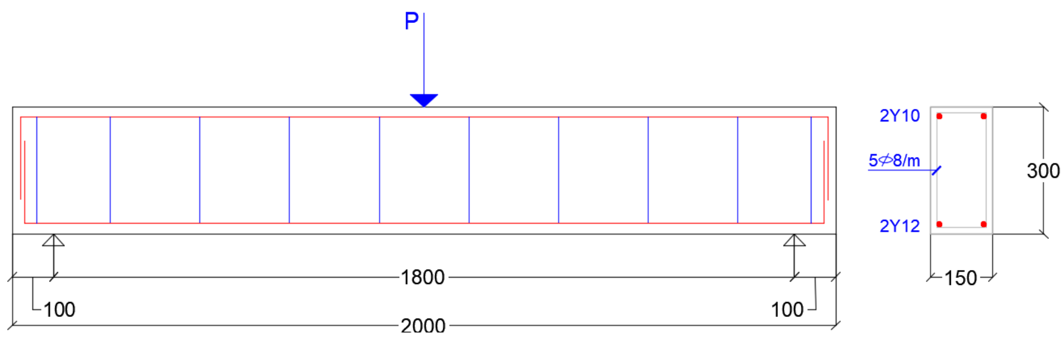

Fig. (1): Details of tested Beams Group 1 (Flexural failure beams) in mm.

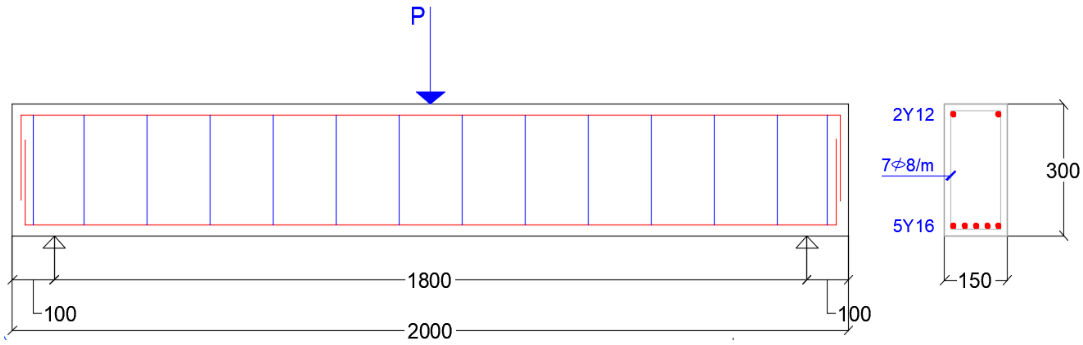

Fig. (2): Details of tested Beams Group 2 (Shear failure beams) in mm.

Fig. (3): Burning Beams on 400c.

3.4. TEST SETUP

Specimen setup is as shown in Fig.4, 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 300 mm from the right support, the second followed by 300 mm and the third was at the mid span.

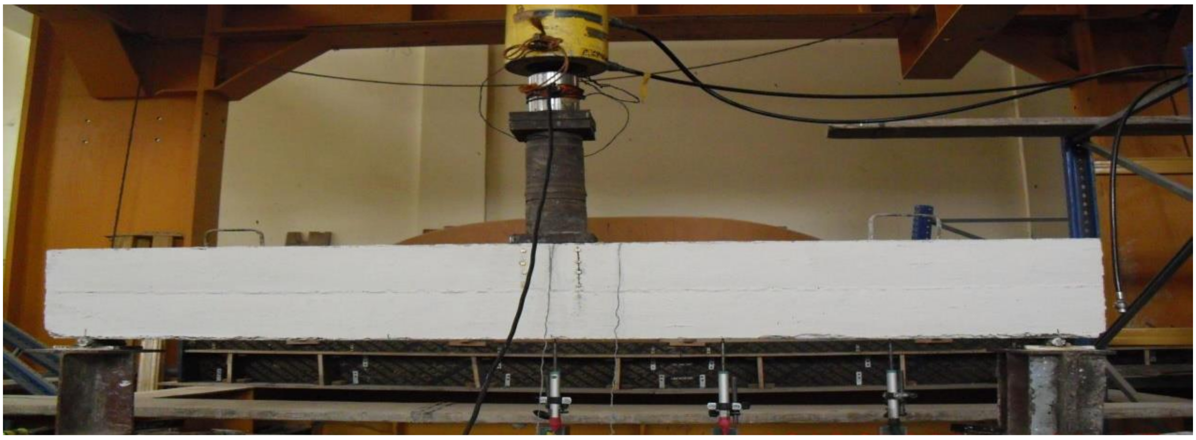

Fig. (4): Beam under One Point Load.

4. RESULTS OF EXPERMENTAL PROGREM

Test values for beams are summarized in Table 4 and will be discussed below.

4.1. Results of Under Reinforced Beams (Flexural Failure)

4.1.1. First Crack Load

All beams with basalt fibers higher cracking load than the control beam this can be due to the bridging action of fibers and its role in delaying the appearance of cracks , beam without basalt fiber and exposed to fire has a lower cracking load due to the negative effect of fire on concrete beams. As shown in Fig. (5).

Table 4: Results of Tested Specimens

Beam No.	Cracking Stage		Failure Stage		Initial Stiffness	Ductility	Absorbed Energy (kN.mm)
	P_{CR} (Kn)	Δ_{cr} (mm)	P_F (Kn)	Δ_f (mm)	K_i		
B1UF	41.1	0.93	94.27	16.53	44.29	2.9	2100
B2OF	81	1.52	235.34	8.96	54	4.1	1340
B3UB	50.9	1.12	99.67	17.46	62.8	4.1	4040
B4OB	197.87	5	258.6	9.45	49.4	4.4	1500
B5UB	44.63	1.81	103.79	32.86	24.6	3.1	2885
B6OB	129.68	2.32	294.4	10.88	55.28	4.6	2360
B7UB	55.52	2.43	94.68	37.7	22.83	2.8	4020
B8OB	175.9	5.49	280.66	13.47	32	6	2500
B9UF	37.69	2.49	87.41	21.34	27.71	3.73	1650
B10OF	91.82	2.47	203.95	7.31	29.8	4.6	890

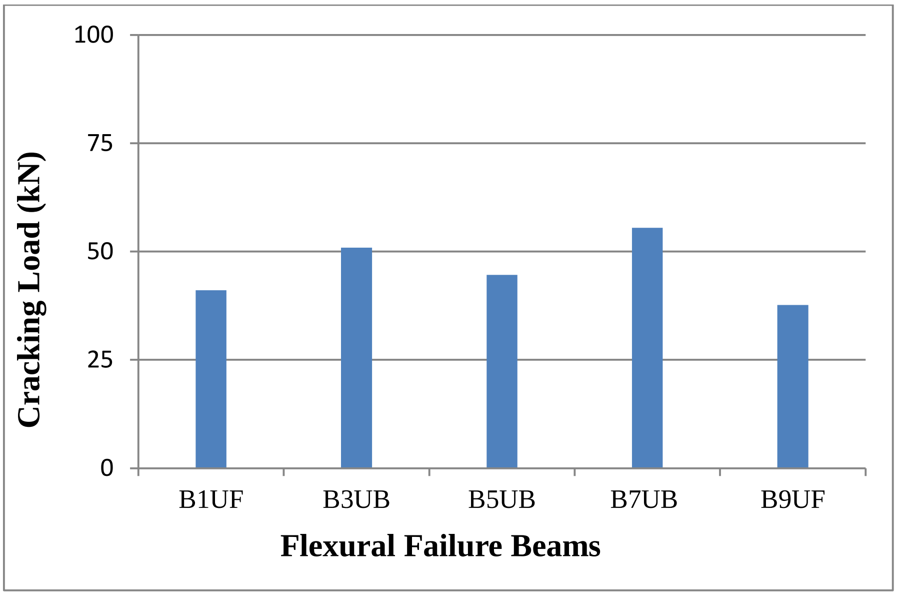

Fig. (5): First Crack Load for Flexural Failure Beams.

4.1.2. Cracking Pattern

Cracks begin to occur with one crack in the middle of beam (B3UB) with the first drop in strain bar reading otherwise the cracks is to start with one crack in the middle of beam (B3UB) but without drop in bar strain. Number of cracks had done in beam B3UB is more than beam B1UF.There is a different between two beams in shape of cracks at the end of loading at failure, beam (B1UF) had shape of one crack in the middle between two bows but beam (B3UB) had two cracks from the bottom connected to each other in the middle to be one crack at the end of the beam and Cracks with smaller crack width were observed) due to the effect of basalt fibers in bonding the cracks. The crack pattern for beams (B1UF and B9UF).begin to occur with two cracks in the middle of beam then started to widen and extend until connected to each other and failure occurred. Number of cracks had done in beam (B9UF) is more than beam (B1UF).There is different between two beams in shape of cracks at the end of loading at failure; beam (B1UF) had shape of one crack in the middle between two bows but beam (B9UF) had a three main cracks in the middle with a clearance distance widen and extended together until the middle crack had a large widen before a failure, shear cracks observed in beam (B9UF) in order to the beam designed to flexural failure this must because the effect of fire on concrete .The crack patterns for beams (B5UB and B7UB) begin to occur with two cracks in the middle of beam then started to widen and extend until connected to each other and failure occurred. Number of cracks had done in beam (B3UB) is more than beams (B5UB and B7UB) and number of cracks in beam (B7UB) is more than (B5UB).There is a different between 3 beams in shape of cracks at the end of loading at failure; beam (B3UB) had two cracks from the bottom connected to each other in the middle to be one crack at the end of the beam but beam (B5UB) had a two main cracks in the middle with a clearance distance widen and extended together until connected to each other just before failure and beam (B7UB) had a three main cracks which in the middle third of the beam the first two cracks connected to each other in the middle of beam line but the third still alone extending in diagonal shape to the other and the two cracks extended and widen together but the failure occurred from the first crackas shown in Fig (6,7,8,9 and 10).

Fig. (6).Cracking Pattern for Beam (B1UF).

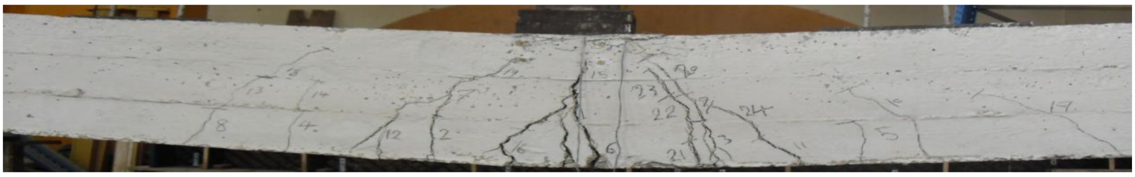

Fig. (7).Cracking Pattern for Beam (B3UB).

Fig. (8).Cracking Pattern for Beam (B5UB).

Fig. (9).Cracking Pattern for Beam (B7UB).

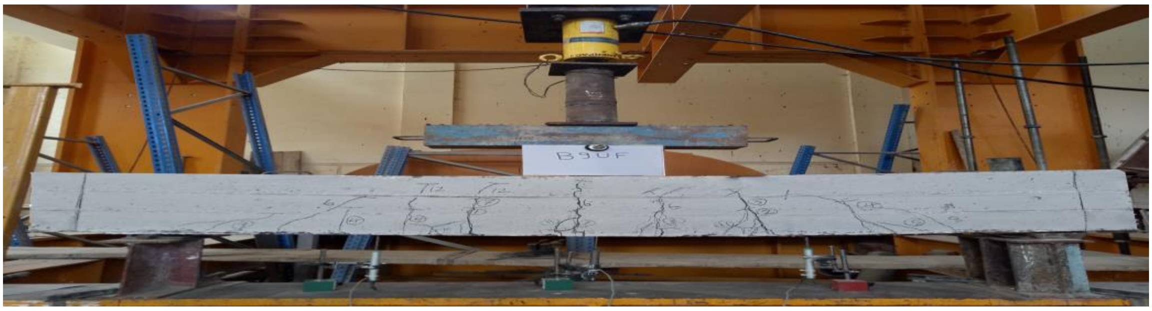

Fig. (10).Cracking Pattern for Beam (B9UB).

4.1.3. Load Deflection Curve

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 Fig. (11).

4.1.4. Failure Mode

Beam B3UB showed an increase in failure load while beam B1UF gives slightly lower failure load. It was concluded that, specimen basalt fibre shows highest in failure load , this means that if we can improve the concrete properties of high percentage of BFRC mainly adding 0.25% of concrete volume basalt fibre we can reach a failure load up to 1.12 times. An increase in the failure load for beam (B5UB) compared with beam (B3UB) this showed that adding basalt fibers for burned beam and pot out with air increased the failure load and so the flexural strength of the beams.it may because the homogenous that made from melting basalt fibers in voids of concrete that made it elastic unite. But in beam (B7UB) showed the lowest result in failure load it may because shock that occurred to the concrete after put out with water after fire suddenly that may lead to a small explosion in the bond between concrete and reinforcement bars. Beam B9UF gives lower failure load than control beam (B1UF) this means that fire had a negative effect on properties of concrete.as shown in Fig.(12).

4.2. Results of Over Reinforced Beams (Shear Failure)

4.2.1. 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 as shown in Fig.(13).

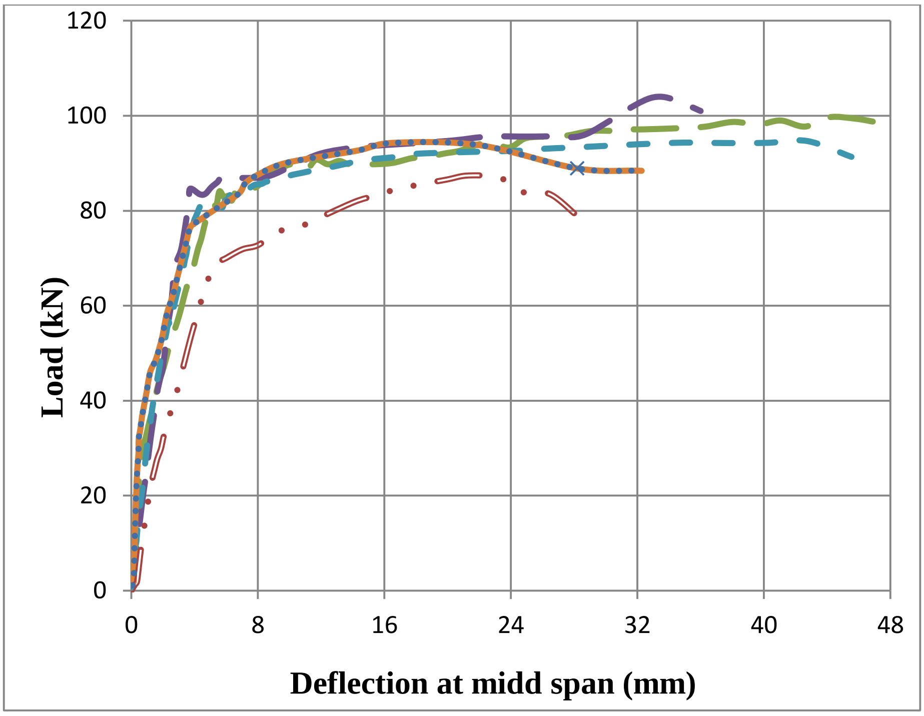

Fig.(11):Load Deflection Curve for Flexural Failure Beams.

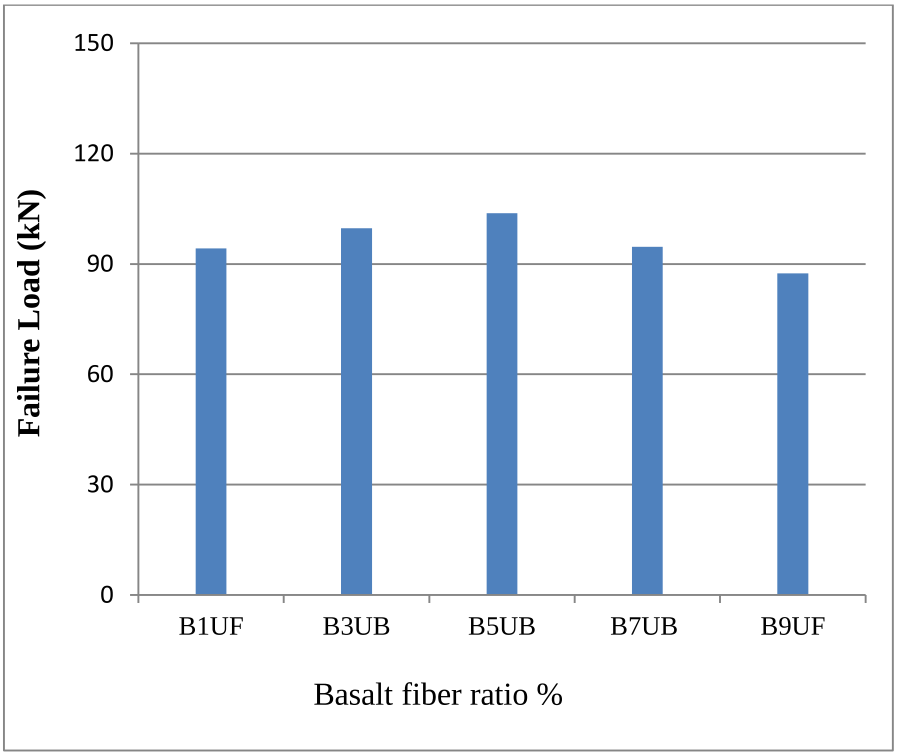

Fig.(12).Failure Load for Flexural Failure Beams.

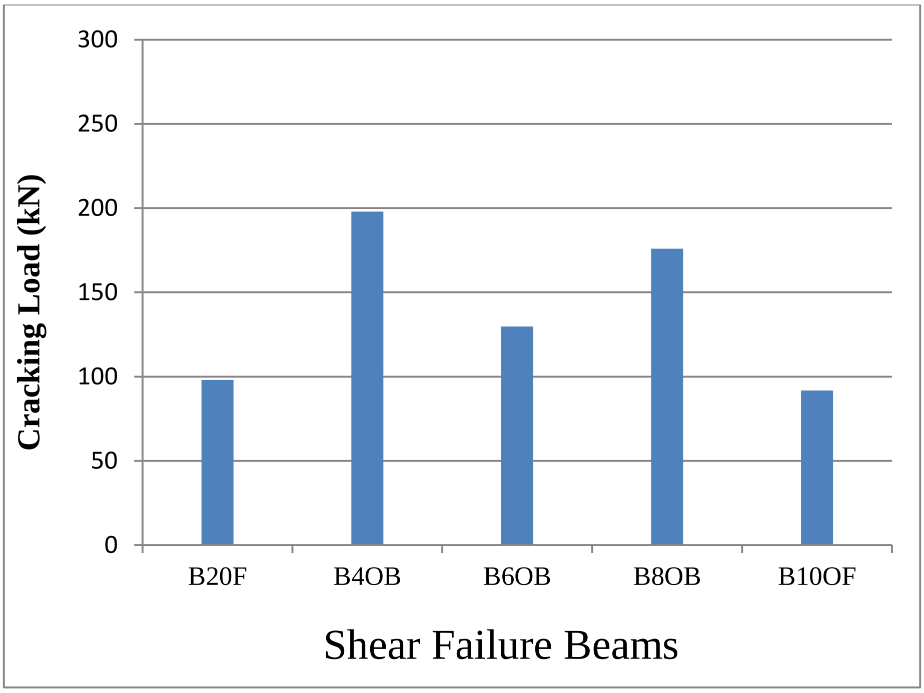

Fig.(13):First Crack Load for Shear Failure Beams.

4.2.2. Cracking Pattern

Cracks pattern for beams (B2OF) Cracks begin to occur with one flexural crack in the middle of beam (B2OF) otherwise the cracks is to start with one shear crack in the right of beam (B4OB).Number of cracks had done in beam (B2OF) is more than beam (B4OB).There is a different between two beams in shape of cracks at the end of loading at failure, beam (B2OF) had a large number of shear cracks in one side beam without symmetric shape along the span and it had a large number of flexural crack in the middle of the span but (B4OB) had asymmetric shape of shear cracks along the span and had just one flexural crack in mid span before failure load directly That means the flexural cracks delayed in appearance in basalt fibre beams with the presence of fibre in the beam because of the bridging action of the fibers and its role in controlling and carrying tension stresses induced in the flexure zone. The crack pattern for beams (B4OB ,B6Oband B8OB).begin to occur with one crack in the middle of beam1 with the first drop in strain bar reading otherwise the cracks is to start with one crack in the middle of beam3 but without drop in bar strain. Number of cracks had done in beam (B8OB) is more than beam (B4OB).There is a different between two beams in shape of cracks at the end of loading at failure, beaa(B4OB) had shape of on crack in the middle between two bows but beam(B8OB) had two cracks from the bottom connected to each other in the middle to be one crack at the end of the beam. The crack pattern for beams (B2OF and B10OF).begin to occur with two flexural cracks in the middle of beam then shear cracks started and widen and extend until connected from support to loading point surface and failure occurred suddenly. Number of cracks had done in beam (B10OF) is more than beam (B2OF).There is a different between two beams in shape of cracks at the end of loading at failure, beam (B2OF) had a large number of shear cracks in one side beam without symmetric shape along the span and it had a large number of flexural crack in the middle of the span but (B10OF) had asymmetric shape of shear cracks along the span and had a large number of flexural cracks and shear cracks in mid span during loading the beam. As shown in Fig. (14, 15, 16, 17 and 18).

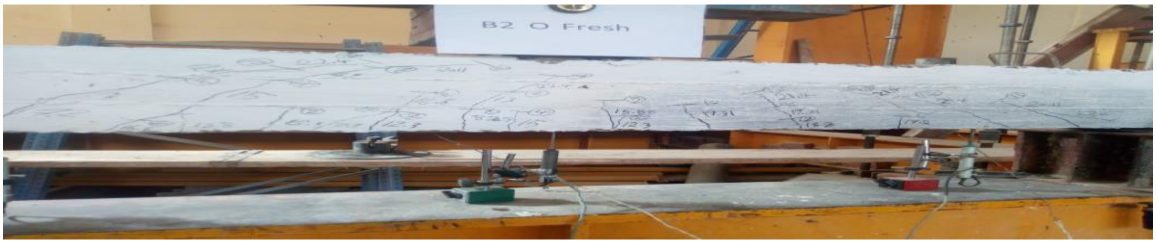

Fig.(14).Cracking Pattern for Beam (B2OF).

Fig.(15).Cracking Pattern for Beam (B4OB).

Fig.(16).Cracking Pattern for Beam (B6OB).

Fig.(17).Cracking Pattern for Beam (B8OB).

Fig.(18).Cracking Pattern for Beam (B10OF).

4.2.3. Load Deflection Curve

All beams performed larger deflection at failure than the control beam .So basalt fibers are able to increase the deflection of the over reinforced beams and converts it to less brittle or semi ductile. As shown in Fig.(19).

4.2.4. Failure Mode

Beam B4OB showed an increase in failure load while beam B2OF gives slightly lower failure load. It was concluded that, specimen basalt fibre shows highest in failure load , this means that if we can improve the concrete properties of high percentage of BFRC mainly adding 0.25% of concrete volume basalt fibre we can reach a failure load up to 1.12 times. An increase in the failure load for beam (B6OB) compared with beam (B4OB) this showed that adding basalt fibers for burned beam and put out with air increased the failure load and so the flexural strength of the beams.it may because the homogenous that made from melting basalt fibers in voids of concrete that made it elastic unite. But in beam (B8OB) showed the lowest result in failure load it may because shock that occurred to the concrete after put out with water after fire suddenly that may lead to a small explosion in the bond between concrete and reinforcement bars. Beam (B10OF) gives lower failure load than control beam (B2OF) this means that fire had a negative effect on properties of concrete.as shown in Fig.(20).

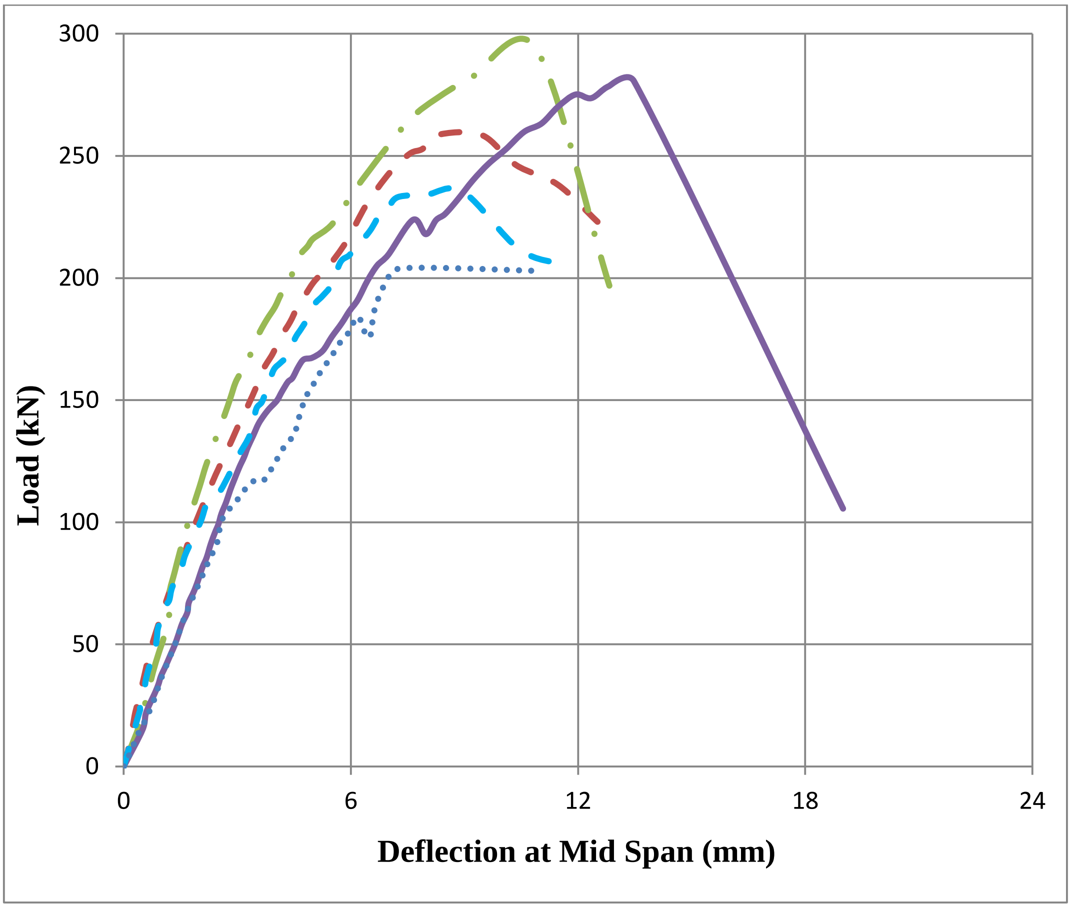

Fig.(19): Load Deflection Curve for Flexural Failure Beams.

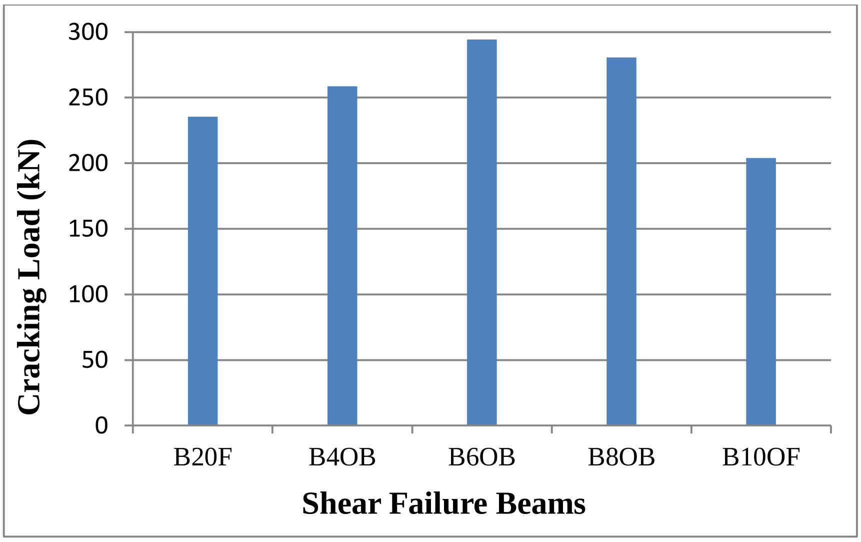

Fig.(20): Failure Load for Shear Failure Beams.

5. CONCLUSION

5.1. Effect of Basalt Fibre on Flexural Failure Beams

1-An increase in cracking load for basalt fibre beam comparing with the control beam that means the crack delayed in appearance with the presence of fibres in the beam.
2-Basalt fibres change the deflection performance for beam from steep deflection to more uniform deflection and gives value of deflection higher than control beam..
3-An increase in failure load for basalt fibres beam than control beam.
4-An increase in number of cracks and fallen concrete on failure for basalt fibre beam revers control that mean the basalt fibres beam gives severe alarm before failure.

5.2. Effect of Fire on Flexural Failure Basalt Fibre Beams.

1-Put Out by Air.

1-A decrease in cracking load for burned basalt fibres beam comparing with not burned basalt fibre beam that means the crack appearance quickly affected with changes in concrete characteristics.
2-Fire on basalt fibre beam not change the deflection performance but gives lower value of deflection.
3-Fire on Basalt fibre beam gives lower values of stiffness, absorbed energy and ductility.
4-Fire on basalt fibre beam gives lower number of cracks than not exposed to fire.

2-Put out by Water.

1- An increase in cracking load for burned basalt fibres beam comparing with not burned basalt fibres beam that means the crack appearance quickly affected with a changes in concrete characteristics.
2-Fire on basalt fibres beam not change the deflection performance but gives lower value of deflection.
3- A decrease in failure load for burned basalt fibres beam exposed to fire than not exposed to fire.
4-Fire on basalt fibres beam gives lower number of cracks than not exposed to fire.

5.3. Effect of Basalt Fibre on Shear Failure Beams.

1-A large increase in cracking load for basalt fibre beam comparing with the control beam that means the crack delayed in appearance with the presence of fibre in the beam.
2-Basalt fibre not changes the deflection performance for beam but gives higher failure load in the same value of deflection.
3-An increase in failure load for basalt fibre beam than control beam.
4-basalt fibre gives a little number of cracks on failure for basalt fibre beam.

5.4. Effect of Fire on Shear Failure Basalt Fibres Beams.

1-Put Out by Air.

1- A decrease in cracking load for burned basalt fibre beam comparing with not burned basalt fibre beam that means the crack appearance quickly affected with a changes in concrete characteristics.
2- Fire on basalt fibre beam not change the deflection performance but gives higher value of failure in the same value of deflection.
3-An increase in failure load for basalt fibre beam exposed to fire than not exposed to fire.

4-Fire on basalt fibre beam gives higher number of cracks than not exposed to fire and have more cracks in the tension zone.

2-Put Out by Water.

1- A decrease in cracking load for burned basalt fibre beam comparing with not burned basalt fibre beam that means the crack appearance quickly affected with a changes in concrete characteristics.

2-Fire on Basalt fibre beam changes the deflection performance for beam and higher value of deflection in failure than not burned beam.

3-An increase in failure load for basalt fibre beam exposed to fire than not exposed to fire.

4-Fire on basalt fibre beam gives lower number of cracks than not exposed to fire and have more cracks in the tension zone.

6. REFRENCES

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