Advanced

Technologies Journal of

Advanced Sciences

Journal of

Technologies

ournal of



ISSN: 2617-2070 (Print)

Journal of Advanced Sciences and Engineering Technologies

available online at: http://www.jaset.isnra.org

Journal of Advanced Sciences and Eng. Technologies

JASET

Aziz I. Abdulla*

Othman Majeed Abdullah

Department of Civil Engineering, College of Engineering, Tikrit University, Iraq

Keywords:

Composite beam

Ferro cement

Skeletal bar

Wire Mesh

ARTICLE INFO

Article history:

Received 01 Oct. 2019 Accepted 25 Nov. 2019 Available online 25 Dec. 2019

DOI: http://doi.org/10.32441/jaset.02.01.07

Copyright © 2018 by author(s) and This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

http://creativecommons.org/licenses/by/4.0





BEHAVIOR OF COMPOSITE FERROCEMENT REINFORCED CONCRETE BEAMS

ABSTRACT

The Ferrocement is a type of thin reinforcement concrete made of cement- sand mortar mixture with closely spaced of relatively small diameter wire meshes with or without bars of small diameter called skeletal bar. The purpose of the current study is to identify the behavior of the composite fibrocement and reinforced concrete beams. The main variables of the current study are the number of layers of wire mesh, the casting time for the second layer (Normal concrete), and the effect of the presence or absence of the skeletal bars. The current study included the casting of two reference beams with a different reinforcing ratio ($2\varphi 8$ mm), and ($3\varphi 8$ mm). The study also included the casting of eight composite beams of fibrocement and reinforced concrete. The results show that the use of fibrocement layer, with (4,6,8) layers of wire meshes, skeletal bar, and the first casting period (1.5 hr) leads to increase the ultimate load by (17.142%, 21.42%, and 22.85%) also the cracking load increased by (31.57%, 47.36%, and 68.42%). The results show that the use of fibrocement layer, with (4,6,8) layers of wire meshes, skeletal bar, and the second casting period (24 hr) leads to increase the ultimate load by (32.85%, 40%, and 42.85%) also the cracking load increased by (36.84%, 84.21%,and 89.47%). When using the fibrocement layer containing on the skeletal bar the maximum load increased (6.96%, 17.64%) for the first and second casting, respectively, also for cracking load, it increased by (6.67%,16.12%) respectively, this is due to that the skeletal bar leads to increase reinforcement area and increase restriction in compared with ferrocement layer without the skeletal bar.

© 2019 JASET, International Scholars and Researchers Association

^{*}Corresponding Author: Aziz Ibrahim Abdulla, E-mail: lan914@gmail.com

Introduction

Ferrocement is a type of thin-wall reinforced concrete. It is commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh is made of metallic or other suitable materials [1].Ferrocement has taken a noteworthy position among segments utilized construction development. It has strength, durability, and little thickness, which makes it is a segment appropriate for building some lightweight structures [2]. Over the past few decades, there has been a growing interest in research and studies for the development of construction materials. Many attempts have been made to succeed and improve the properties of concrete mix and increase the effectiveness of steel used in the reinforced parts, and such attempts led to the emergence of synthetic material which has good qualities in terms of tensile strength and resistance to cracking this material has been called the ferrocement [3].

Mahmoud and Kimio [4], presented the details of an experimental study conducted for studying the characteristics of 24 samples of simply supported ferrocement composite elements of (520*40*10mm) and loaded with two symmetrical point loads, the parameters considered in their investigation were, the effect of different types of reinforcement meshes, number of mesh laminates and different mesh diameter with opening size also different types of mortar materials. For testing, the Universal machine of capacity 500 kN was used. the authors observed that the used of stainless steel meshes as reinforcement leads to the improvement of bending characteristics from where of bending stiffness, fracture energy, ductility, and crack pattern also the bending properties of the thin composite elements of ferrocement made of different mortar materials show similar behavior, in

spite of using different number of mesh laminates or reinforcement meshes.

P.Paramasivam [5] presented a study on the flexural behavior of reinforced T- beams strengthened with ferrocement layers. Tests were conducted on 12 specimens simply supported and loaded with concentrated loads at mid-span. These beams were designed depending on BS8110:Part1:1985, O.P.C. Sand and cursed coarse aggregates with a maximum size of 20mm were used the mix with proportions of (1:2.8:3.5) by weight. The water/cement ratio was 0.6. The main parameters considered were the volume of the fraction, the spacing of the shear connectors and method of preparation of the surface. The performance of beams also compared with a focus on cracking patterns, ultimate strength, and mid-span deflection. Loads of 500 kN were applied by a hydraulic jack at increments of 5kN until the appearance of the first crack. This study showed that when the ferrocement layer was added to the soffit face (tension face), it led to improved performance of the beams and increased the rigidity of the strengthened beams. It also led to an increase in the flexural capacity, which depended on the amount of additional reinforcement.

Hani and Husam [6], present the details of an experimental study conducted for studying the behavior of 24 composite beams under twopoint loading system until the failure. All specimens' dimensions were (152*152*914mm). Ferrocement layer thickness was 25.4mm with steel wire mesh as a reinforcement (welded and hexagonal) with different layers (4, 6, and 8). The composite beam is classified into two groups. Group 1 possesses four beams, three beams having (4, 6, and 8) welded layers of wire meshes in 12.7 mm thick ferrocement laminate and one control beam. Group 2 possesses four beams

three beams having (4,6, and 8) hexagonal layers of wire meshes in 12.7 mm thick ferrocement laminate, and one control beam. Different types of studs are used as shear connectors. From the results, the authors observed that the load-deflection curve goes through three stages, a linear to yield, a continuous yield stage, and a stage of full plastic deformation until the point of failure. Also from the result, the first crack loading of composite beam increased by 81.716% in compared with the control beam, and the ultimate load also increased by 25% in compared with the control beam.

Ehsan Ahmed [7], experimental investigation of 2 Grad 30 concrete beams, one beam was strengthened with ferrocement layers in tension zone while the other was without ferrocement layer. Every one of the specimens was tested under four-point flexural loading over a range of 1400mm and instrumented for the estimation of the quarter and mid-length redirections. It is empiric from the curves that the load-deflection curve at the first stage was linear and with increasing load, the behavior of the load-deflection curve goes to the non-linear behavior until the final failure of the beam. From the experimental investigation, it is seen that the ultimate load was increased by 21% compared with that of the control beam. The strengthening effect was additionally powerful in deferring the development of the first crack and the cracking load was increased by 65% for the beam strengthened with ferrocement layer. Also, the three layers of wire mesh used in ferrocement layer in soffit layer of the beam led to improvement of the first crack loading and increased the flexural stiffness and loadcarrying capacity of the strengthened beam.

Alaa Abdwl Tawab[8] presented the details of an experimental study conducted for studying the characteristics of three control reinforced concrete beams of dimensions (300, 150, 2000 mm) and eighteen beams with dimensions of

(300, 150, 2000 mm), consisting of reinforced concrete cores cast in 25 mm U-shaped precast ferrocement laminates. The control beam was reinforced with two steel bars of 12 mm diameter at the top and bottom of the beam and stirrups of 10 mm diameter placed at 200 mm. parameters were the types of mesh layers (woven wire mesh, expanded wire mesh). The single and double layers of each type of the steel mesh were utilized. All the beams were examined under three-point flexural loadings. The results showed that the ultimate load, crack resistance control, and good energy absorption properties were achieved by using the ferrocement layers. The increase in the ultimate load for the beams could be attributed to the presence of larger area of steel, steel mesh, and steel bars, on the tension face of the beams as compared to the control beams which had steel bars only, The energy absorption of the beams incorporating the ferrocement permanent forms was significantly higher than that of the control beams. The level of increment of the energy absorption relative to the control beams was around (15.6%, 37.6%, and 1.6%) when a single layer of steel mesh was utilized and(46.7%, 66.4%, and 44.4%) when a double layer of steel mesh was utilized for woven wire mesh, and expanded wire mesh, respectively.

Hamza Al Saadi [9], studied four elements of (100*150*750mm) materials used in this study were O.P.C, sand, coarse aggregate, and water also steel mesh and rebars as reinforcement. The mix proportional was (1, 2.03, 2.492) based on BS code [10], and w/c ratio was 0.45. The elements tested under two-point loads by using 100T (U T M). This study includes the theoretical analysis and experimental study on the flexural strengthening of reinforced concrete beams by using steel mesh. From experimental study and theoretical analysis, the authors observed that the use of wire mesh leads to enhance load carry capacity. From the experimental study, the failure load of element

strengthened with wire mesh was increased by (18.3%) and from theoretical analysis, failure load was increased by (5.14 kN) compared with the control element.

Wen-Jie Ge [11], studied the flexural behavior of ECC – concrete composite beam. The parameters of the study were the reinforcement ratio, ECC thickness. The results of these study show that in the case of tensile failure increasing reinforcement ratio and

increasing EEC ratio led to increasing yield and ultimate moment. In compressive failure when increasing ECC replacement ratio and reinforcement ratio led to decreasing the ductility also the curvature and energy dissipation increasing in case of tensile failure but decreased in the case of compressive failure.

Table (1) Materials proportions and compressive strength of the cube samples

Trail Mix No	W/C	C/S	S.P (Mega	fcu Compressive	fcu Compressive
			flow 500)%	Strength (MPa)	Strength (Mpa) at
				7days	28 day
Trail -n-1	0.32	1:1.5	1.5	37.194	51.7
Trail -n-2	0.32	1:1.5	1.25	37.6	52.2
Trail-n-3	0.3	1:2	1.5	37.88	53.9
Trail -n-4	0.3	1:1.5	1.25	39.1	55.8
Trail -n-5	0.28	1:1.5	1.25	41.6	57.34
Trail -n-6	0.28	1:1.5	1.5	42.41	60.03

The Aim of Study

The choice of the study (Behavior of Composite Ferro cement Reinforced Concrete Beams) is to present the effect of the fibrocement layer on the tensile zone of the concrete beams.

This study includes the casting of composite beams of concrete and fibrocement, these are examined under static loads and compared with normal beams and reinforced with different percentages of reinforcing.

3.Materials

Cement, sand and coarse aggregates are used to get a suitable concrete mixture The mix proportional was (1:2.13:2.41) and with w/c

ratio (0.505). Also the mortar mixture proportion for fibrocement was as shown in table below. The highest compressive strength was for the trail mix named (Trail –n-6), which was 42.41Mpa at the age of 7 days and 60.03 Mpa at the age of 28 days.

Cement

For casting Samples during the experimental program, Ordinary Portland cement used locally known (MASS). Bogue's equations are used to calculate. The chemical composition and physical properties of cement are conformed the Iraqi Specification No.5/1984 [12].

Table (2) Physical properties of cement

Physical Properties	Test Results	Limit of Iraqi specification No. (5/1984)
Setting time by, (Vicat apparatus)		
The initial setting, (hrs: min)	1:30	Not less than 45 min
The final setting, (hrs: min)	7:10	Not more than 10 hrs
Compressive strength (MPa)		
For 3 day	34.2	15 MPa lower limit
For 7 day	36.15	23 MPa lower limit

^(*) Tests were carried out at Civil Engineering Lab at University of Tikrit.

Coarse Aggregates

The natural gravel obtained from the ALzwyah city at the north of Tikrit was used to casting specimen. The maximum nominal size was 12.5

mm. The coarse aggregates were cleaned with water. The classification of rough aggregates corresponds to the requirements of (Iraqi Classification No. 45/1984) [13].

Table (3) Grading of coarse aggregate

Sieve size	Pass %	Iraqi classification	
		(No.45 / 1984 with the adjustment, No.20 / 2010)	
20	100 %	100%	
14	100 %	90%-100%	
10	70 %	50%-85%	
5	0.2%	0%-10%	
2.36	-	0%	

 $[\]hbox{*Conducted at Civil Engineering Department laboratory / Tikrit University}$

Table (4) Physical properties of coarse aggregate

Properties	Test result	Specification
Specific gravity	2.59	ASTM C127-88
Absorption %	0.45 %	ASTM C127-88
Oven-dry density	1600 kg/m ³	ASTM C29 / C29M
Moisture content	0.3%	ASTM C566-97

3.3. Fine Aggregate

As fine aggregate river sand from ALzwyah city at the north of Tikrit was used to casting

specimen. Based on the Iraqi standard, (I.Q.S., No. 45-1984)[13]

Table (5)Sieve analysis of fine aggregates

Sieve size	Cumulative passing (%)	Limit of <i>IQS No. 45/1984 - zone No.</i> (2)
4.75 mm (No. 4)	100	90 - 100
2.36 mm (No. 8)	81	75 - 100
1.18 mm (No. 16)	67.6	55 - 90
600 μm (No. 30)	54.8	35 - 59
300 μm (No. 50)	24.7	8 - 30
150 μm (No. 100)	4.7	0 - 10

^(*) Tests were carried out at Civil Engineering Lab at University of Tikrit.

Table (6) Physical and chemical properties of sand

Properties	Specification	Test Results	Limits of specification
Specific gravity	ASTM C128-01\04	2.69	-
Absorption (%)	ASTM C128-01\04	1%	-
Finess modulus	ASTM C33-01	2.17	
Dry loose unit weight (kg/m³)	ASTM C29/C29M-10	1565	-
Sulfate content (as SO ₃) (%)	(IQS) No. 45-84	0.028	0.5 (max. value)
Gypsum material %	(IQS) No. 45-84	0.06	< 0 · 5
Soluble salts %	(IQS) No. 45-84	0.13	< 0 · 5
Material finer than 0.075 mm (%)	(IQS) No. 45-84	1.3	5 (max. value)

(*) Tests were carried out at Civil Engineering Lab at University of Tikrit.

Water

In all mixtures and curing tap water was used.

Reinforcement

Welded Wire Mesh

In the reinforcement, the square-welded wire mesh, known locally as the chicken wire mesh, was used. These meshes are produced in the form of 1.25m width rolls. The wire mesh was cut in the form of strips of 11 cm width, and 96 cm length to suit the measurement of molds. The average diameter of the grids is 0.5 mm and the size of the hole 12.7 mm is mounted on the skeletal bar according to the number of

Shear Reinforcement

The shearing reinforcement was used with a diameter of 6 mm and a circumference of 640 mm. The shear designed depending on (ACI Code 318) [14]. The direct tensile test was performed and the results are shown in **Table** (7).

Flexural Reinforcement

layers required. The yield stress, final tensile strength, and elasticity modulus were measured by the direct tensile strength of the sample. The test was performed in accordance with ACI 549[14]. **Table(7)** shows the yield strength, the absolute tensile strength, and the elastic coefficient.

Skeletal Bar

The Skeletal bar is made using steel grids with a diameter of 4 mm and a distance between 60 mm bars. The wire mesh was installed with the skeletal bar. Direct tensile testing of the steel bars was performed in accordance with (ASTM A 615 / A615M-09)[13] and the results are shown in **Table (7)**.

The flexural reinforcement was used with a diameter of 8 mm and a length of 940 mm. The flexural design depends on (ACI code 318).[14]. At some beams, reinforced with $(2 \ \varphi \ 8 \ mm)$ and in the other reinforced $(3 \ \varphi \ 8 \ mm)$ by design, the direct tensile test was performed. Results are shown in **Table (1)**.

Table (7) Test results of wire mesh and steel bar reinforcement Error! Not a valid link.(*)
Tests were carried out at Mechanical Engineering Lab at Tikrit University

(**) Tests were carried out at Mechanical Engineering Lab at Baghdad University.

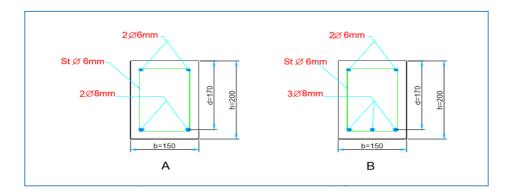
Super plasticizers

As a superplasticizer, Mega Flow 500 was used. The main purpose of using this admixture was

to improve the workability of the mixture and to get high strength of the concrete mixture. Mega Flow 500 depended on (ASTM C 494)[15]

4. Beams Details

The dimensions of the composite beam length were 1000 mm, the effective span of the beam was 900 mm, the width was 150 mm, and the depth of the beam was 200mm, Fig. (1), and Fig (2) Shown the details of reinforcement



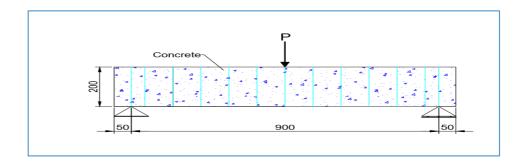


Fig.(1):Normal Concrete Beams Reinforcement

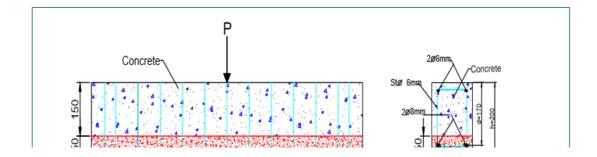


Fig. (2): Composite Beam Reinforcement

Table (8) Details of study models

Name of beam	Number of wire mesh layers	Rebar	The thickness of Ferrocement layers (mm)	Beam dimensions (mm)
B1		2¢8mm		(150*200*1000)
B2		3¢8mm		(150*200*1000)
BCW4SD1	4	2¢8mm	50	(150*200*1000)
BCW4SD2	4	2¢8mm	50	(150*200*1000)
BCW6SD1	6	2¢8mm	50	(150*200*1000)
BCW6SD2	6	2¢8mm	50	(150*200*1000)
BCW8SD1	8	2¢8mm	50	(150*200*1000)
BCW8SD2	8	2¢8mm	50	(150*200*1000)
BCW8D1	8	2¢8mm	50	(150*200*1000)
BCW8D2	8	2¢8mm	50	(150*200*1000)

^{*}Wire mesh type: welded wire mesh with (12.7mm spacing and 0.5mm diameter)

Where:-

 B_1 :- Control Beam Number 1 with ($2\phi 8mm$), B_2 :- Control Beam Number 2 with ($3\phi 8mm$), C:- Composite symbol, W:- Wire Mesh symbol, S:- Skeletal bar symbol, D:- Duration symbol

Experimental Program

The main purpose of the study is to investigate the behavior of the composite beams of the ferrocement and concrete under static loads. The current study examines the effect of the number of layers of the wire meshes, the casting period as well as the skeletal bar effect on the properties of the beams such as flexural strength, toughness, ductility, and stiffness, as discussed and compared to the control beams.

The results of the tests were obtained on the basis of the load-deflection in the center of the beam, the crack pattern, the failure loads. The following parameters were adopted this study in:-

- 1- The number of wire meshes layers.
- 2- Duration of casting the second layer.
- 3- Presence or absence of skeletal bar.

Stages of Molding and Processing of Used Models.

The Samples used in the study were poured and processed by following these steps as shown in Fig (3, A-D) and described below:-

1. Preparing and cutting the wire meshes according to the required dimensions, and then

opened.

cutting the skeletal bar in the required dimensions, as appropriate to the dimensions of the mold.

- 2. After cutting the wire mesh and skeletal bar, they are installed and linked together
- 3. Preparing the metal mold, and lubrication of the inner surface using motor oil to facilitate the lifting of the model from the mold when

- each model, to allow the provision of concrete cover for the layers of reinforcement.
- 5. Mixing the cement mortar and putting it in the lower part of the mold (tensile area), with a thickness of 50 mm.
- 6. After finishing the casting of the ferrocement layer, the normal concrete layer is poured according to the time periods specified in the



Fig (3-A): Slicing the skeletal bar



Fig (3-B): Connecting the wired meshes with the skeletal bar



Fig (3-C): Connecting the ferrocement reinforcement with the flexural



- 7- The quality control samples (cubes and prisms) are poured from the mixture of ferrocement and normal concrete and then opened after 24 hours and put in the curing basin with water for 7, and 28 days.
- 8. After the casting process, the samples are left for 24 hours and then opened and transported to the treatment basins and treated with immersion in the treatment basins for 28 days.

9. After the processing has finished, the samples are uplifted from the treatment basins and are prepared for testing.

Tested Beams

All composite beams are cured for 28 days, and after this period beams coated by using white color. The beams were tested using a universal testing machine under static loads until failure. Adial gauge of 0.001mm was used at mid-span to measured deflection in beams. Beams with effective span (900mm) tested under one point load at center. Fig (4)



Fig. (4): Beams Under Testing

Results and Discussion

Crack Load

The results show the effect of the ferrocement layer on the first crack. Where it was noted that by increasing the number of wire mesh layers leads to an increase in the cracking load as shown in Fig.5. Also, the cracks have been confined to the loading area and decreased the number of cracks. As for the effect of the casting period, the results show that the beams that were cast at the second casting period have a higher crack load than the beams that were

poured in the first period and due to the cohesion of the ferrocement layer after 24 hours was greater. Also for the effect of containing or not containing the composite beam on the skeletal bar. The beams containing on the skeletal bar have a higher crack load than the beams without the skeletal bar. The reason for this because the beams that possess skeletal bar are more restricted than beams that do not contain a skeletal bar.

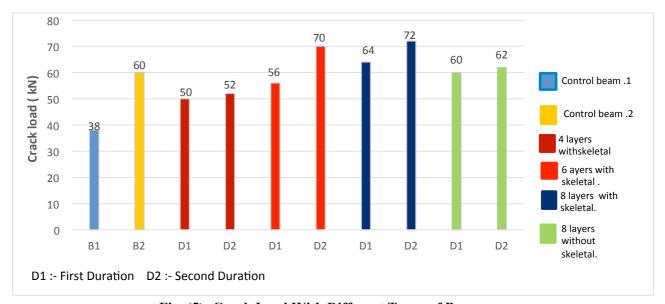
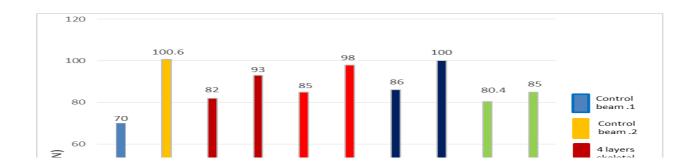


Fig. (5): Crack Load With Different Types of Beams

Ultimate Load

As shown in Fig. 6 the ultimate load of the composite beam has increased by the ratio of (17.142 %, 21.42 %, and 22.85%) when using 4,6, and 8 layers of wire meshes, and with the first duration. Also, the ultimate load of the composite beam has increased by the ratio of (32.857 %, 40%, and 42.85%) when using 4,6, and 8 layers of wire meshes,

and with the second duration. The composite beams that possess skeletal bar have an ultimate load more than composite beams without skeletal bar by a ratio of (17.64%). This is due to the fact that the composite beams with skeletal bar have reinforcement area higher than composite beam without the skeletal bar.



7.2.1 Effect of Second Layer Casting Duration

In this study, two different periods were adopted, for the casting of the second layer (normal concrete layer), which is (1.5 hr and 24 hr). The results of the second casting period are the best with the different numbers of the layers of wire meshes. Where the results of the composite beam that were poured after 24 hr have the highest ultimate load.

The reason for this because the ferrocment layer after the first casting period 1.5 hr is fresh. When casting the second layer of concrete effect on ferrocement layer. It depends on the number of wire mesh layers in the beam. Where the increase of wire mesh layers led to increased ultimate load by (17.14% - 42.85%) as shown in Fig. 7.

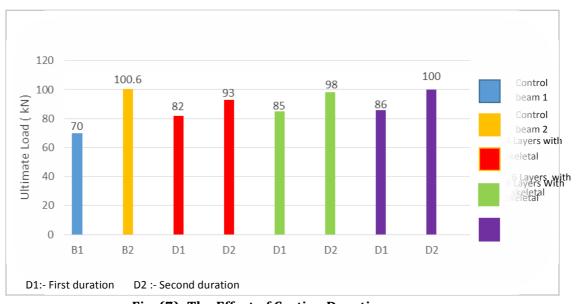


Fig. (7): The Effect of Casting Duration

Effect of Skeletal bar

In this study, the effect of containing or not containing the composite beam on skeletal bar, where the beams were carried out on models with the reinforcing of 8 layers of wire mesh, was found by studying the effect of the skeletal bar on the ultimate load, as the ultimate load of the beam with the skeletal bar was higher than

ultimate load of the beam without the skeletal bar with an increase of (17.64%). This is due to the fact that the composite beams with skeletal bar have reinforcement area higher than composite beam without the skeletal bar as shown in Fig. 8.

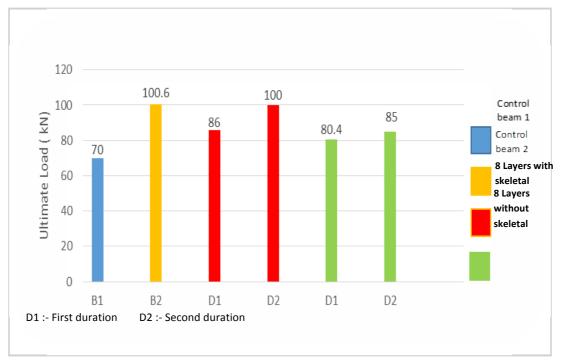
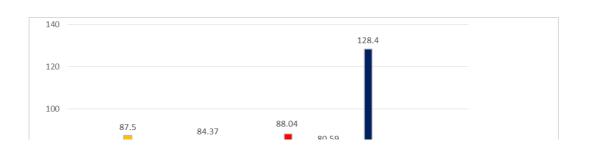


Fig. (8):Effect of Skeletal bars

The Stiffness

Taking the load at 45% of the yield load, and intersecting it on the load-deflection curve take then deflection at this point, and by dividing the load at 45% to this deflection, the stiffness can be calculated. The effect of the number of wire meshes was clearly related to the skeletal bar as well as the casting period. It has been observed that by increasing wire mesh from (4 to 6 and 8), stiffness increased. Due to the increase in the

wire mesh layers led to an increase in the rate of volume fraction and thus an increase in the restriction of the beam and this led to an increase in stiffness. Also, the beams cast at the second duration has higher stiffness compared with beams that cast at first duration. The reason for this is that the ferrocement layer after 1.5 hr is fresh and affected by the casting of the second layer (normal concrete) as shown in Fig. 9.



D1:- First duration D2:- Second duration

Fig.(9): The Stiffness of Tested Beams

Ductility

The ductility is the result of the division the deflection at the ultimate load to deflection at the yielding load. The effect of the number of wire meshes was clearly related to the type of skeletal bar as well as the casting period. In the case of the use of 4 layers of wire mesh with a skeletal bar and the first casting, period led to an increase of the ductility by (13.89%) for the first casting period and decrease by (21.24%) for the second casting period. The reason for that is due to the first period for casting with skeletal bar led to less restrictive for the composite beam, which led to increase ductility, as shown in Fig. 10.

As for the increase in the number of wire meshes from 4 to 6 and 8 and in the same period of casting second duration and the second skeletal led to a decrease of the ductility and the reason for this is due to the increase the number of wire meshes led to a decrease in the cohesion between the mortar and the wire meshes. As for the effect of the presence and absence of the skeletal bar on the ductility, where the ductility of the beams that do not contain a skeletal bar increased and the reason in this is due to the presence of the skeletal bar increases the restriction of the beams in compared with the beams that do not contain the skeletal bar.

$$\mu = \frac{\Delta u}{\Delta v}$$

Where:

μ: ductility index

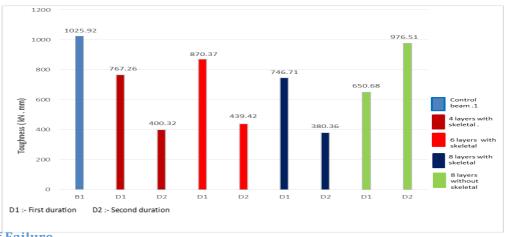
 Δu : ultimate load deflection Δy : yielding load deflection.



Toughness

Toughness is the resistance of the material to break when exposed to the stresses and known as the amount of energy that the material can absorb before refraction and its equal the area under the load-deflection curve. The test results showed that increasing the number of wire mesh increased the toughness at first crack layers from 4 to 6and 8 and that because of the increase in the ratio of volume fraction. The test results show that the toughness at yield load at 4 layers of wire mesh was decreased because of the wire mesh is yield to relatively little load. But toughness at first crack increases by increasing wire mesh from 6 to 8. And the test results showed that the toughness at ultimate load was decreased because of the increase in the number

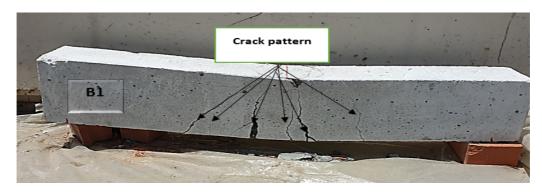
of wire mesh layers led to increasing the restriction of the composite beam so that the toughness decrease. As for the effect of the presence and absence of the skeletal bar on the toughness, The toughness at first crack and at yield load of the beams that do not contain a skeletal bar decreased and the reason in this is the beams without a skeletal bar it's yielding by the relative little load. The toughness at the ultimate load of beam possesses skeletal bar decreased. The reason in this is due to the presence of the skeletal bar increases the restriction of the beams in compared with the beams that do not contain the skeletal bar, as shown in Fig. 11.



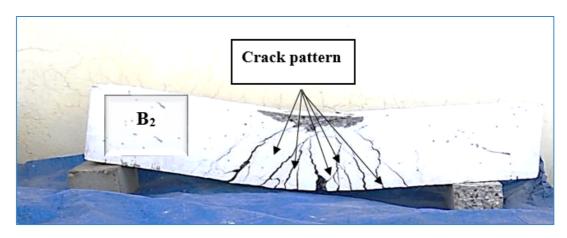
Modes of Failure Fig. (11): The Toughness (kN.mm)

All the composite beams tested under concentrated load show a similar failure mode. Also, the cracks concentrated in the loading area. Also, their number decreased as it was noted that the increase in the number of wire meshes led to

a decrease in the number of cracks. and confined in the loading area. Due to the increase of wire meshes, the restriction of the cracks has increased, reducing their number and confining them to the loading area, as shown in Fig. 12.



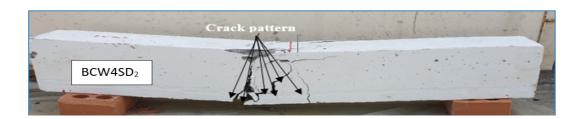
A- Control Beam B1



B- Control beam B2



C-BCWSD1





E-BCW6SD1



F-BCW6SD2



H-BCW8SD1



H-BCW8SD2



I-BCW8D1



J-BCW8D2

Fig.(12): The Mode of Failure and Crack Pattern of beams

Conclusions

From the experimental study carried out during this research, the following conclusions can be calculated:

- 1. The ultimate load of the composite beam has increased by the ratio of (17.142 %, 21.42 %, and 22.85%) when using 4,6, and 8 layers of wire meshes, skeletal bar, and with the first duration. Also, the ultimate load of the composite beam has increased by the ratio of (32.857 %, 40%, and 42.85%) when using 4,6, and 8 layers of wire meshes, skeletal bar No.2, and with the second duration.
- 2. By increasing the number of wire mesh layers, a load of cracks is increased by a ratio of (31.57%,47.36%, and 68.42), when using 4,6, and 8 layers of wire meshes, skeletal bar. Also, a load of cracks increased by a ratio of (36.84%,84.21%, and 89.47%) when using 4,6, and 8 layers of wire meshes, skeletal bar No.2, and with the second casting duration.
- 3. The stiffness of composite beams increased by a ratio (226.4% 436.58%) is compared with the control beam. This is due to the fact that the ferrocement layer increases the restriction of beams.
- 4. The ductility of composite beam with 4 layers of wire mesh, skeletal bar, and with

- the first duration was increased by a ratio of (13.89%) while the same beam casting in the second duration the ductility was decreased by a ratio (21.24%). This is due to the fact that the composite beam with the second poured duration was restricted more than composite beam with first poured duration.
- By increasing the number of wire mesh 5. layers from (4 to 6) layers with skeletal, and the first duration. The ductility increase (13.89% - 52.07%), while the same beam casting in the second duration the ductility was decreased by a ratio (21.24% -56.38%). This is due to the fact that the composite beams with the second poured duration were restricted more than composite beam with first poured duration. Also by increasing the number of wire mesh layers from (6 to 8), the ductility decreased by a ratio (7.82%) is compared with the control beam. This is due to the fact that the increasing number of wire meshes layers from (6 to 8) lead to a decrease in cohesion between the wire mesh and mortar.
- 6. The composite beam without skeletal bar has ductility more than composite beam with skeletal bar by a ratio of (93.93%) is compared with a composite beam with skeletal bar, and by a ratio of (78.75% and 115.65%) is compared with control beam. This is due to the fact that the composite beams with the skeletal bar were restricted more than composite beam without the skeletal bar.
- 7. The toughness of the composite beam has decreased by a ratio (4.81% 62 92 %). Depending on the number of wire meshes layers, skeletal type, and duration of the casting. This is due to the fact that the ferrocement layer leads to increases the restriction of the composite beam so that the toughness decrease

References

[1] International Ferrocement Society (IFS 10-01). (2001). Ferrocement Model Code.

- International Ferrocement Information Center, Thailand, pp. 1.2.
- [2] ACI 549R-97. State-of-the-Art Report on Ferrocement. Part 5, pp. 1-26.
- [3] Naaman, A. E. (2000). Ferrocement and laminated cementitious composites (Vol. 3000, No. 1). Ann Arbor: Techno press.
- [4] Wafa, M. A., & Fukuzawa, K. (2010). Characteristics of ferrocement thin composite elements using various reinforcement meshes in flexure. Journal of Reinforced Plastics and Composites, 29(23), 3530-3539.
- [5] Paramasivam, P., Ong, K. C. G., & Lim, C. T. E. (1994). Ferrocement laminates for strengthening RC T-beams. Cement and Concrete Composites, 16(2), 143-152.
- [6] Nassif, H. H., & Najm, H. (2004). Experimental and analytical investigation of ferrocement-concrete composite beams. Cement and Concrete Composites, 26(7), 787-796.
- [7] Ahmed, E., Sobuz, H. R., & Lee, J. B. H.(2011). Flexural and cracking performance of reinforced concrete beam strengthened with ferrocement laminates.
- [8] Tawab, A. A., Fahmy, E. H., & Shaheen, Y. B. (2012). Use of permanent ferrocement forms for concrete beam construction. Materials and Structures, 45(9), 1319-1329.
- [9] Al Saadi, H. S. M., Mohandas, H. P., & Namasivayam, A. (2017). An Experimental Study on Strengthening of Reinforced Concrete Flexural Members using Steel Wire Mesh. Curved and layered structures, 4(1), 31-37
- [10] British DOE (Department of Environment) Method, (1988). Design of normal concrete mixes. BSI, Chis wick High Road, London.
- [11] Ge, W. J., Ashour, A. F., Ji, X., Cai, C., & Cao, D. F. (2018). Flexural behavior of ECC-concrete composite beams reinforced with steel bars. Construction and Building Materials, 159, 175-188.

- [12] Meikandaan T, Hemapriya M.(2017). Study of damaged RC beams repaired by bonding of CFRP laminates. International Journal of Pure and Applied Mathematics
- [13] Iraqi classification (No.45 / 1984 with the adjustment, No.20 / 2010). Aggregate from natural sources for concrete and building construction.
- [14] ACI Committee 549- 93. (1993). Guide for the design construction, and repair of ferrocement. ACI 549 – 93, in manual of concrete practice, American concrete institute, 27 pages.
- [15] ASTMA615/615M-09.(2010).Standard test method for deformed and plain carbon steel bars for concrete reinforcement.