SHEAR STRENGTH OF FERROCEMENT COMPOSITE BOX SECTION CONCRETE BEAMS

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ABSTRACT

This paper presents an experimental and analytical study of the shear strength of ferrocement composite box section concrete beams. Two groups of ferrocement box beams were used. The experimental program includes seven box section concrete beams were tested using two-point loading system. Beams with expanded wire mesh showed an improvement in ultimate failure load, shear capacity and deflection with respect to beams with reference & welded wire mesh. The experimental data were used for validation of finite element models which had been developed using the Ansys 14.5 software. The analytical results showed an accepted agreement with the experimental results. Also, beams with wire mesh showed lower number of crack patterns than the reference.

KEY WORDS

Box beams, shear stress, welded wire mesh, expanded wire mesh, nonlinear finite element analysis (NLFEA), Ansys 14.5.

1. INTRODUCTION

The ACI committee 549 had realized ferrocement as “thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced small diameter wire mesh” [1]. Naaman [2] indicated utilizing the ACI 318 [3] for shear design. In the ACI “Guide for Design, Construction, and Repair of Ferrocement” [4], a fewer input was existed on designing ferrocement under shear stresses. Ordinary Portland Cement was usually applied for the ferrocement matrix [4]. The generality usually used additives were silica fume and superplasticizer [5, 6].

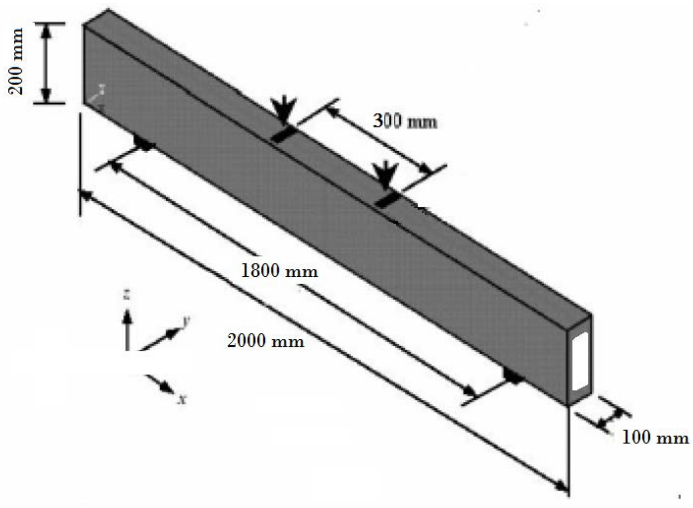
Shear behaviour of ferrocement composite beams were improved by El-Sayed & Erfan [7]. Results showed that the shear capacity of expanded wire mesh beams was greater than beams with reference & welded wire mesh.

2.EXPERIMENTAL PROGRAM

The experimental work was undertaken to investigate the general behaviour, cracks pattern, and the ultimate capacity of the reinforced concrete box beam reinforced using ferrocement composite fabrics. The experimental program consisted of seven composite box beam section having the dimensions of dimensions of 100 mm x200 mm and 1800 mm long were cast and tested until failure. All specimens were reinforced with the same longitudinal bars in tension and compression. The specimens were tested using two-point loading. The reinforcing bars were designed and detailed, and the bearing pad was proportioned such that the flexural, anchorage and bearing modes of failure were avoided. The concrete mix for the test specimens was designed to obtain compressive strength at 28 days age of 30 MPa. The mix proportions were 2 sand: 1 cement, water cement ratio was 0.3 and 1.5% super plasticizer by weight of cement. The concrete slump was found to be 130 mm and a density of 2300 Kg/m3. All specimens were tested under central compression axial compression loadings by using Compression Testing Machine of capacity 2000 KN.

2.1 Preparation of Specimens and samples description

The experimental program consists of seven concrete box beams, having the same geometry and steel reinforcement details as shown in Fig. 1, were prepared for testing under concentric loads. The control specimen was box section beam reinforced using 2Ø 12 in tensions and 2 Ø 10 in compression and 12 Ø 8/2m as stirrups. The other sixth box beams haven't stirrups but using ferrocement composite instead of stirrups. The first group consists of three beams B1-1, B2-1 and B3-1 which reinforced using one, two and three layers of expanded wire mesh respectively. Second group for B1-2, B2-2 and B3-2 which reinforced using one, two and three welded wire mesh instead of stirrups respectively as described in Table 1.



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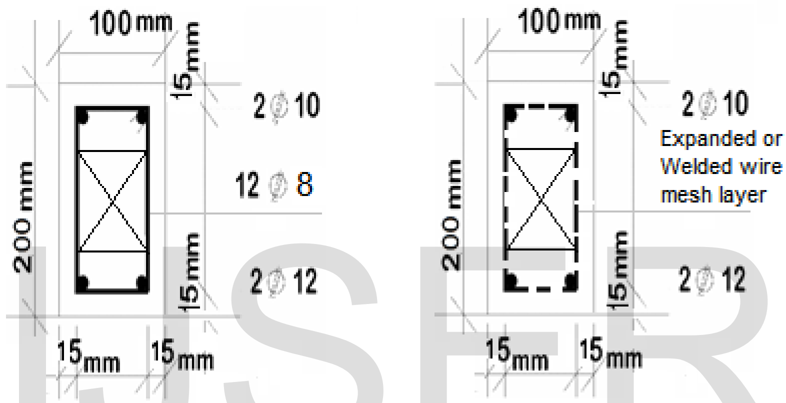

b) c)

Fig.1: a) Beams geometric shape and reinforcement details, b) control specimen; c) sample of beam with expanded or welded layer mesh.

Table 1: Box beams specimen's descriptions and notations

Series	Specimen No.	Specimens description	Reinf. Ten-sion	Horizontal stirrups	Vr. Stir-rups
Control	**BOX 1**	**Control specimen**	**2φ12**	**2 φ10**	**12φ8**
Group 1 "Expanded wire mesh"	**BOX 1-1**	**one layer expanded**	**2 φ12**	**2 φ10**	**-**
	BOX 2-1	**two layer expanded**	**2 φ12**	**2 φ10**	**-**
	BOX 3-1	**three layer expanded**	**2 φ12**	**2 φ10**	**-**
Group 2 "Welded wire mesh"	**BOX 1-2**	**one layer welded**	**2φ12**	**2 φ10**	**-**
	BOX 2-2	**two layer welded**	**2 φ12**	**2 φ10**	**-**
	BOX 3-2	**three layer welded**	**2 φ12**	**2 φ10**	**-**

2.2 Characteristics of Materials

The concrete mix contents utilized for the experimental program was summarized in Table 1 which gives concrete characteristic strength of 30 MPa. The yield strength of the used reinforced steel was 360 MPa. The characteristics of used composite layers either expanded or welded were summarized in Table 3 and shown in Fig.2. The beams were casted in a horizontal position and the vibrated concrete placed compacted in wooden molds.

Table 2: The Contents of Concrete Mixture

Contents	Amount
Cement	350 K_g/m^3
Sand	700 K_g/m^3
Aggregate (1)	540 K_g/m^3
Aggregate (2)	620 K_g/m^3
Water	162.5 L/m^3
Admix	2 L/m^3

Table 3: Mechanical properties of expanded and welded wire mesh

Expanded wire mesh		**Welded wire mesh**	
Dimensions size	16.5x31 mm	**Dimensions size**	12.5x12.5 mm
Weight	1660 gm/m^2	**Weight**	600 gm/m^2
Sheet Thickness	1.25 mm	**Sheet Thickness**	0.7 mm
Yield Stress	250 N/mm^2	**Yield Stress**	400 N/mm^2
Ultimate Strain	59.2×10^{-3}	**Ultimate Strain**	1.17×10^{-3}
Ultimate Strength	380 N/mm^2	**Ultimate Strength**	600 N/mm^2

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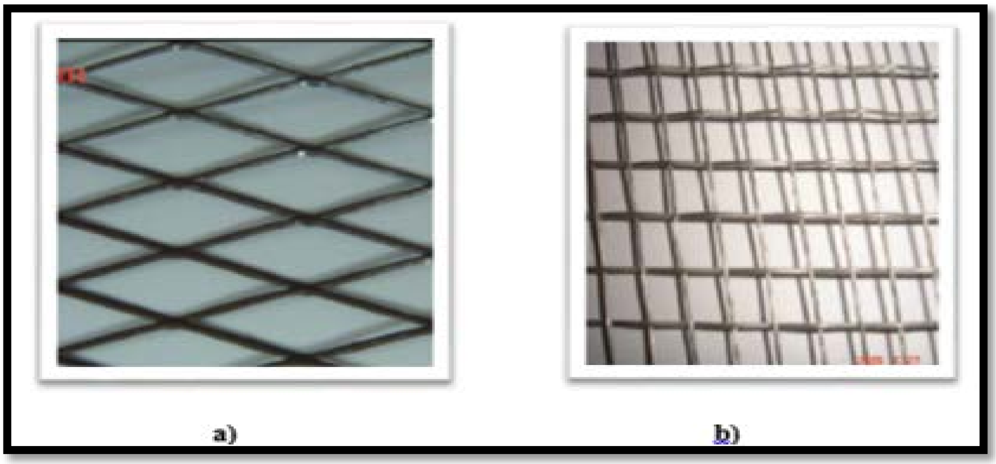


Fig.2: Ferrocement composite; a) Expanded wire mesh, b) welded wire mesh

2.3 Test setup

The tested box beam sections were tested under two-point load testing machine of maximum capacity of 600 KN with 1800 mm effective span and 750mm shear span and 300 mm load distance as shown in Fig. 3. Load was affective at 20 KN increments on the tested specimens. The LVDT and dial gages were used of high accuracy to measure the deflections and strains for steel and concrete. The load still increased till failure load and maximum displacements.

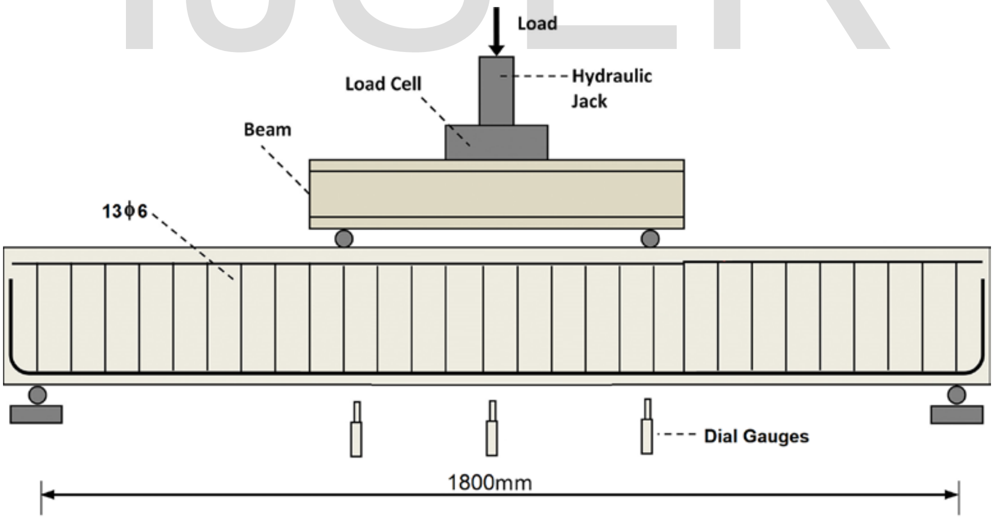


Fig. 3: Test set up schematic

3. TEST RESULTS AND DISCUSSION

Test results include the load carrying capacity and displacement in concrete box beams. The cracks propagation during the tests was recorded. The crack initialization in the specimens reinforced using wire meshes was developed however, at later stages with respect to the control specimen. Besides, the cracks lengths and widths decreased in the specimens reinforced with either expanded or welded wire mesh as compared to the control specimen.

3.1 Cracking

The first crack in all the tested box beam was inclined horizontal crack developed under the load pint in the mid span. This crack in the control specimen observed at a load of 7.5 KN. For specimens BOX1-1, BOX2-1 and BOX3-1, it was recorded at a higher load being 1.05, 1.2 and 1.35 times that of the Control Specimen; BOX1, respectively. The diagonal cracking initiated in the Control Specimen; BOX1 increased in length and width until failure at load of 42.5 KN. For specimens BOX1-2, BOX2-2 and BOX3-2, it was recorded at a higher load with respect to control specimen being 1.02, 1.12 and 1.18 times that of the Control Specimen; BOX1, respectively. Using the expanded wire mesh and welded wire mesh instead of stirrups enhance the crack pattern for box section beam as shown in Fig. 4.

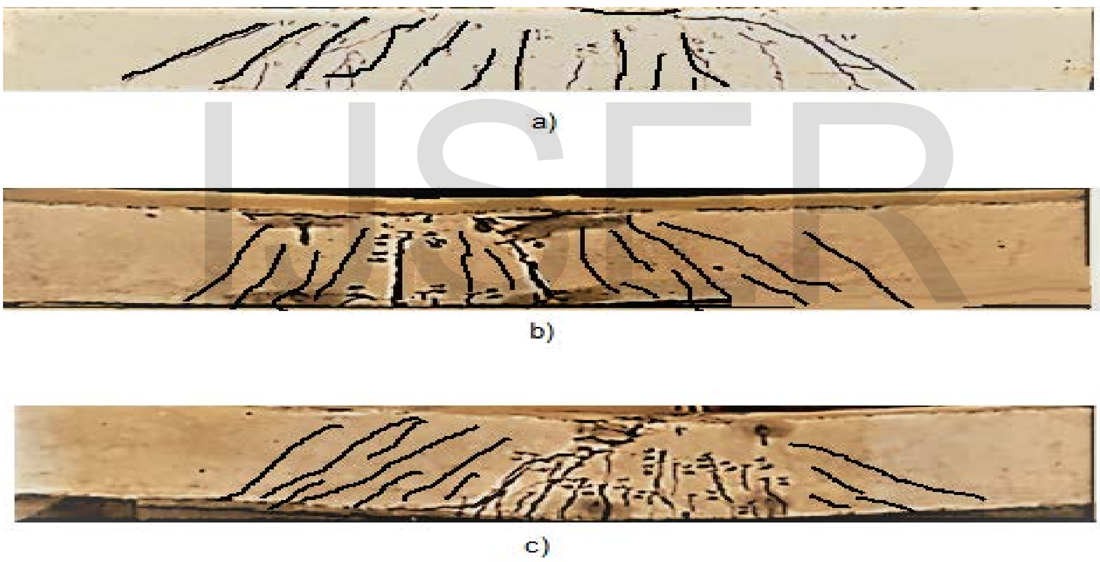


Fig.4: Sample of crack pattern; a) control specimen; b) expanded group; c) welded group.

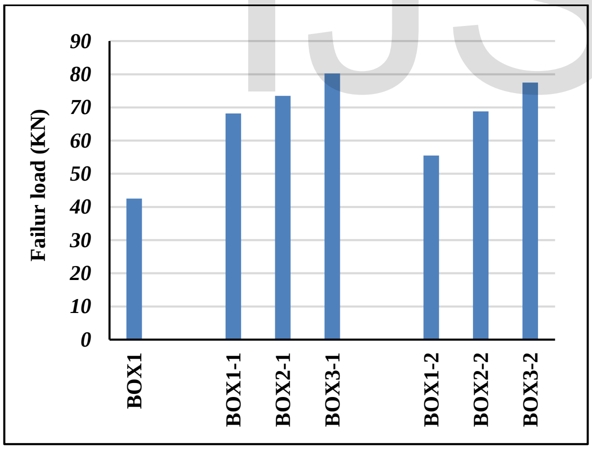
3.2 Ultimate load Capacity

The load carrying capacity is differing from one box section to another according to its reinforcement and using expanded and welded wire mesh instead of steel stirrups. For the control specimen BOX, the ultimate failure load was 42.5 KN. The first group which reinforced using expanded wire mesh recorded failure loads of 68.2, 73.5 and 88.7 KN for BOX1-1, BOX2-1 and BOX3-1 respectively with enhancement ratio with respect to the control beam of 60.4%, 72.9% and 88.8% respectively. This enhancement related to number of expanded wire mesh used in reinforcement as shown in Table 4.

For the second group which reinforced using welded wire mesh of different layers number of BOX1-2, BOX2-2 and BOX3-2. The experimental failure loads were 55.5, 68.8 and 77.5 KN with enhancement ratio of 30.5%, 61.8% and 77.5% for BOX1-2, BOX2-2 and BOX3-2 respectively. Observing that using three layers of either expanded or welded wire mesh recorded the highest load and enhancement in carrying capacity. It is noticed that the effect of using expanded wire mesh has the major effect in load carrying capacity as shown in table 4 and fig. 5.

Table 4: Experimental testing results

Series	Specimen No.	Failure load (KN)	% Of enhancement in load	Deflection (mm) at failure load
Control	BOX1	42.5	----	0.52
Group 1 “Expanded wire mesh”	BOX1-1	68.2	60.4	0.25
	BOX2-1	73.5	72.9	0.24
	BOX3-1	80.25	88.8	0.23
Group 2 “Welded wire mesh”	BOX1-2	55.5	30.5	0.31
	BOX2-2	68.8	61.8	0.27
	BOX3-2	77.5	82.3	0.25



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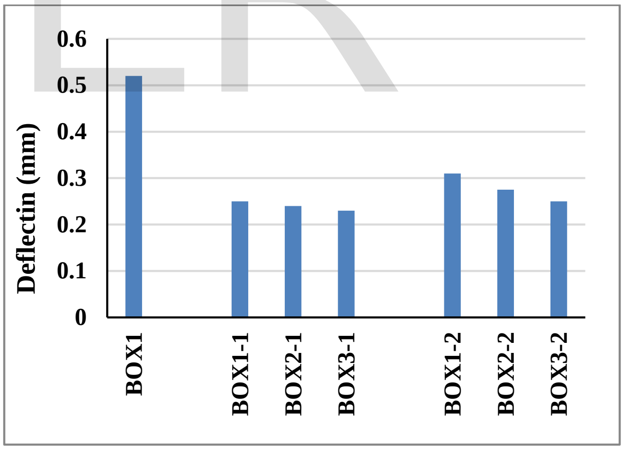

b)

Fig. 5: comparison between experimental results; a) maximum load (KN); b) deflection (mm) at ultimate load

3.3 Experimental ultimate deflection

As shown in Table 4 and Fig. 5.b and Fig. 6 the experimental deflection recorded for different specimens with different reinforcement types. The deflection recorded for the control specimen was 0.52 mm at failure load. For group one which reinforced with expanded wire mesh, the maximum deflection at failure load was 0.53, 0.62 and 0.68 mm but at the same load it was 0.25, 0.24 and 0.23mm respectively which is lower than the control specimen. This indicates the effect of expanded wire mesh in decreasing the deflection with average ratio of 53.7%.

For group two which reinforced with welded wire mesh, the maximum deflection at failure load was 0.54, 0.69 and 0.72 mm which is higher than the control specimen but if the deflection recorded at specimens BOX1-2, BOX2-2 and BOX3-2 at failure load of control specimen which was 0.31, 0.275 and 0.25 mm respectively. This indicates the effect of welded wire mesh in decreasing the deflection with average ratio of 46.4%. This ratio indicates that the expanded wire mesh has the best effect in decrease the deflection.

The decrease in ultimate deflection of group one and two is mainly due to increase in number of expanded or welded wire mesh layers used in reinforcement which lead to increase in its volume fraction in specimens.

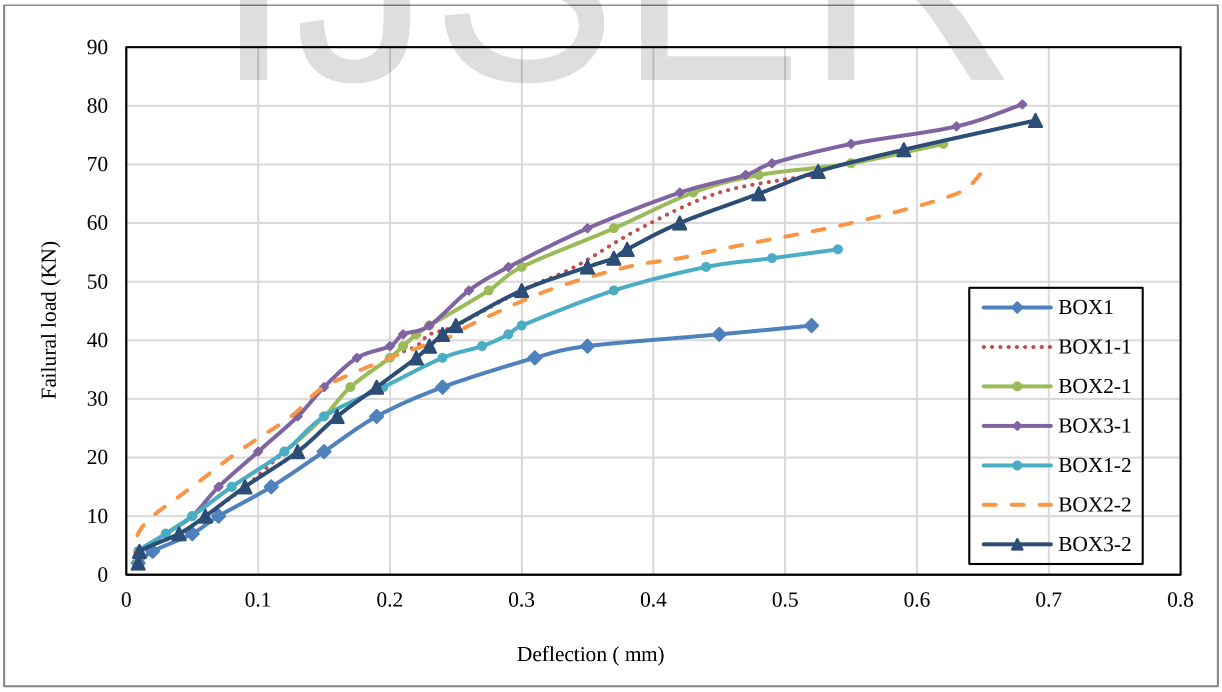

Fig. 6: Experimental load deflection curve

3.4 Ductility and energy absorption

Ductility is defined as the ratio between the deflections at ultimate load to the deflection at the first crack load but the energy absorption is the total area under the load deflection curve. The ductility recorded an average ratio for different specimens of 5.66. A progressive increase of energy absorption which represents the specimen toughness with volume friction percentage and ductility was observed. For the control specimen BOX1 the energy absorption recorded 285.6 KN.mm, compared this value with the recorded for different series it shows good enhancement. For all series the enhancement percentage varies between 99.6% and 129%. The smallest enhancement was at specimen BOX1-2 which use one welded layer instead of stirrups due to the weak properties of the used type of layer but the highest enhancement was in BOX3-1 which used three expanded layers wire mesh. Finally using reinforced with various types of metallic materials were developed with high ultimate loads, crack resistance, better deformation characteristics, high durability and energy absorption properties, which are very useful for dynamic effect.

3.5 Shear stress

The obtained shear stresses are obtained according to the ECP203/207 [8]. For the control specimen BOX1 the shear stress was 1.20 MPa. For the first group box beams BOX1-1, BOX2-1 and BOX3-1 the shear stresses were 1.89, 2.04 and 2.23 MPa respectively with an enhancement ratio of 57.5%, 70.0% and 85.8% respectively with respect to the control specimen. The second group which used the welded wire mesh instead of stirrups, the shear stresses was 1.54 MPa, 1.91 MPa and 2.15 MPa for BOX1-2, BOX2-2 and BOX3-2 respectively. The enhancement in this group with respect to the control specimen was 28.3%, 59.2% and 79.2% respectively which is relatively less than the group used the expanded wire mesh.

4. FINITE ELEMENT ANALYSIS STUDY

This study was done to verify the obtained experimental results. The groups studied were as shown in table 1 which divided in to control specimen and other two groups. Group one which used expanded wire mesh instead of steel stirrups with different number of layers. The second group used welded wire mesh instead of steel stirrups. these specimens were modeled and analyzed using ANSYS 14.5 program [9].

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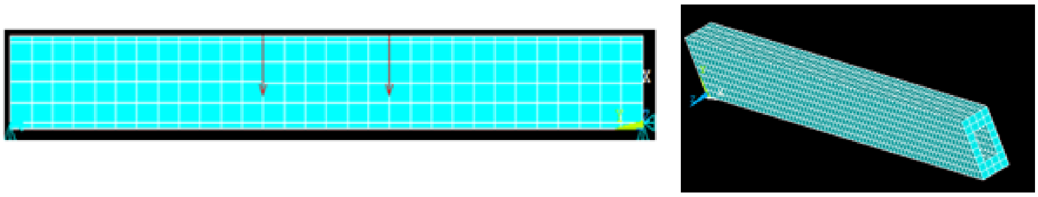
4.1 specimens modeling

NLFEA was carried out to estimate the behavior of ferrocement composite box beams as shown in Fig. 7. The discussed behavior included the ultimate capacity, deflection and crack pattern for each specimen.

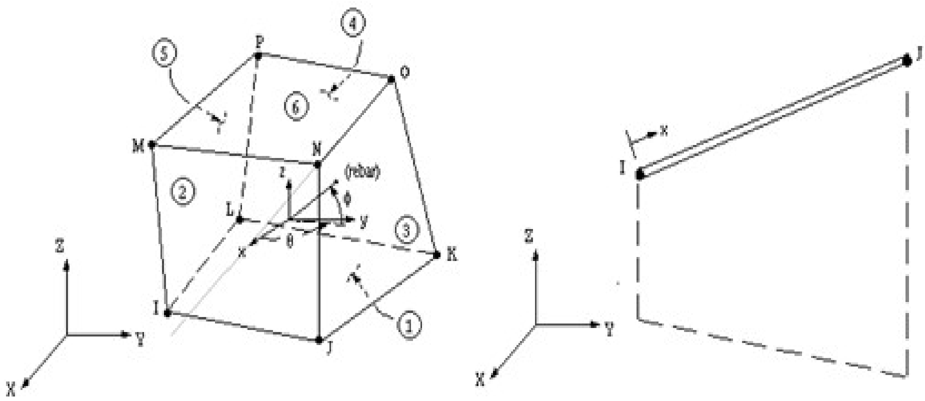


a) Model of box beam under loads b) model of box beam

Fig. 7: NLFEA model of examined box beams

4.1.1 Model Elements Types

Solid 65 represent the concrete element which represents the stress strain curve for concrete in compression and the other properties of it represent the concrete strength in tension. The other used element was LINK 8 3-D to represent the steel bars with its strength and steel stirrups. the composite materials of expanded or welded wire mesh was represented by calculating the volumetric ratio of it in the concrete element using its properties by calculating the ratio of steel to concrete in each element as shown in figure 8. Each material has its X, Y and Z coordinates and has its orientation angle and its reinforcement in ferrocement smeared element.



a) Solid65 b) Link8

Figure 8: Geometry and node locations for element types

4.1.2 Modelling Material properties

The mechanical properties for element SOLID 65 and LINK 8 which represent concrete and steel reinforcement respectively was Elastic modulus of elasticity (Ec = 4400√fcu=24100 N/mm^2) and Poisson's ratio (ν=0.3), but Yield stress (fy=360 N/mm^2 & fy_{st}=240 N/mm^2) with Poisson's ratio (ν=0.2).

For the specimens which represents the ferrocement properties for expanded wire mesh are shown in Table 3. For the expanded wire mesh which has diamond size is 16.5 x 31mm with thickness of 1.25mm, its volumetric ratio of one layer of expanded mesh (V1=0.0093), two-layer was (V1=0.0186) but for the three layers the volumetric ratio of three layer of expanded mesh (V1=0.0279). For the welded layers the size of opening is 12.5x12.5mm with wires of diameter 0.7mm. Its volumetric ratio of one layer of expanded mesh (V1=0.0031), two-layer was (V1=0.0062) but for the three layers the volumetric ratio of three-layer of expanded mesh (V1=0.0093). For the welded layers.

4.2 Analytical Results and Discussion

The finite element program presents the nonlinear response of the box beams specimens. Loading was incrementally increased until failure and divergence occurs which lead to failure. The finite element results represent the cracks patterns, failure load, deflection and yielding of steel as shown in Table 5.

4.2.1 Cracking

The first crack in the entire tested box beam was slightly inclined crack developed under the load pint in the mid span. This first crack in the control specimen observed at a load of 4.0 KN. For specimens BOX1-1, BOX2-1 and BOX3-1, it was recorded at a higher load being 1.2, 1.15 and 1.05 times that of the Control Specimen; BOX1, respectively. The cracking initiated in the Control Specimen; BOX1 increased in numbers until failure at load of 37.5 KN. For specimens BOX1-2, BOX2-2 and BOX3-2, it was recorded at a higher load with respect to control specimen being 0.95, 1.05 and 1.12 times that of the Control Specimen; BOX1, respectively. Using the expanded wire mesh and welded wire mesh instead of stirrups enhance the crack pattern for box section beam as shown in figure 9.c.

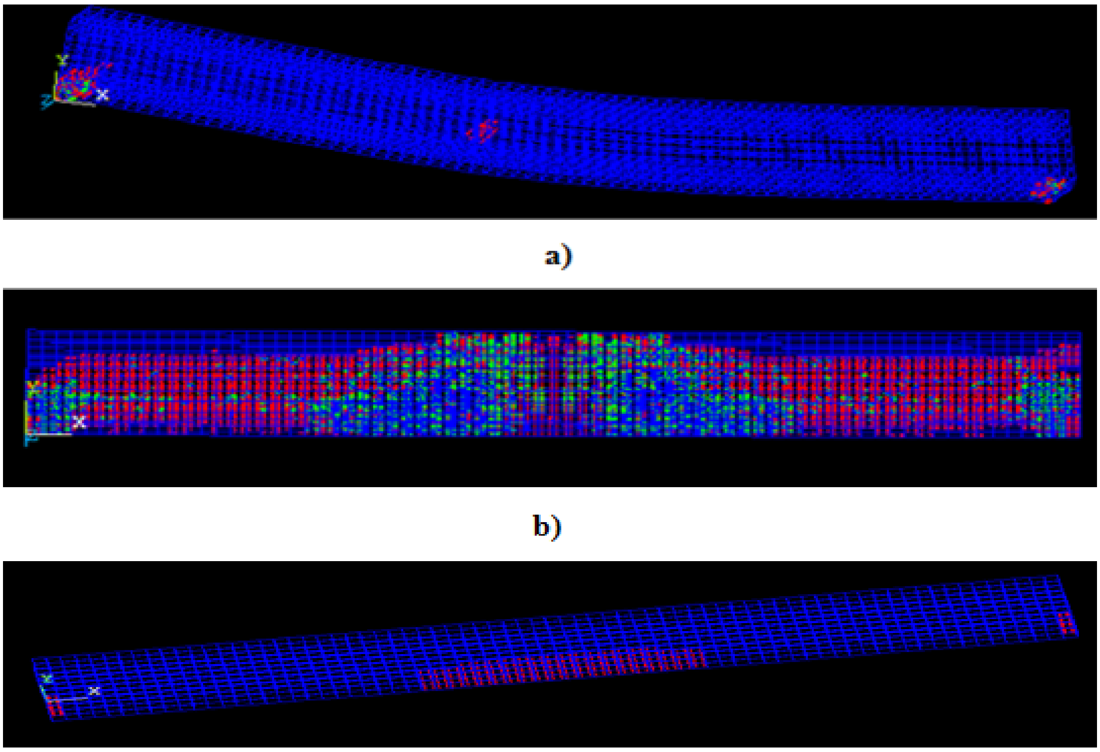


Fig.9: Sample of crack pattern for control specimen; a) first cracks; b) cracks at failure; c) sample of cracks for specimens in group 1.

4.2.2 Ultimate Failure Load

The load carrying capacity is differing from one box section to another according to its reinforcement and using expanded and welded wire mesh instead of steel stirrups. For the control specimen BOX, the ultimate failure load was 37.5 KN. The first group which reinforced using expanded wire mesh recorded failure loads of 60.5, 65.7 and 72.4 KN for BOX1-1, BOX2-1 and BOX3-1 respectively with enhancement ratio with respect to the control beam of 61.3%, 75.2% and 93.0% respectively. This enhancement related to number of expanded wire mesh used in reinforcement as shown in Table 5. For the second group which reinforced using welded wire mesh of different layers number of BOX1-2, BOX2-2 and BOX3-2. The experimental failure loads were 50.0, 62.5 and 70.2 KN with enhancement ratio of 33.3%, 66.6% and 87.2% for BOX1-2, BOX2-2 and BOX3-2 respectively. Observing that using three layers of either expanded or welded wire mesh recorded the highest load and enhancement in carrying capacity. It is noticed that the effect of using expanded wire mesh has the major effect in load carrying capacity as shown in table 5 and Fig. 10.

Table 5: NLFEA Analytical Results

Series	Specimen No.	Failure load (KN)	% Of enhancement in load	Deflection (mm) at failure load
Control	**BOX1**	**37.5**	**---**	**0.49**
Group 1 "Expanded wire mesh"	**BOX1-1**	**60.5**	**61.3**	**0.266**
	BOX2-1	**65.7**	**75.2**	**0.260**
	BOX3-1	**72.4**	**93.0**	**0.250**
Group 2 "Welded wire mesh"	**BOX1-2**	**50.0**	**33.3**	**0.275**
	BOX2-2	**62.5**	**66.6**	**0.270**
	BOX3-2	**70.2**	**70.2**	**0.265**

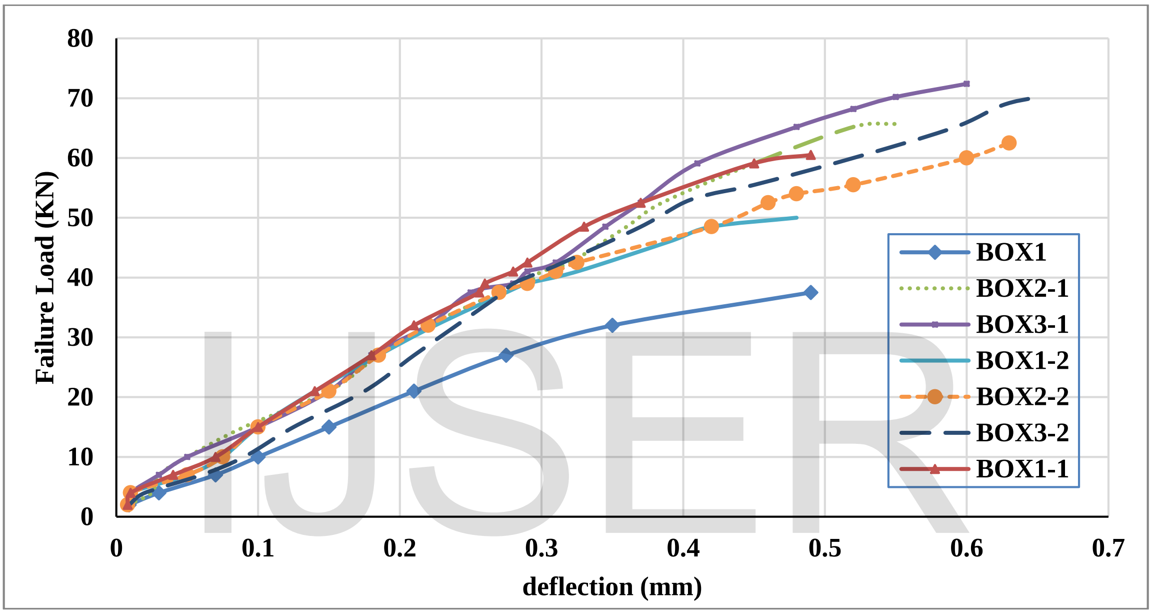


Fig. 10: NLFE load deflection curve

4.2.3 Analytical Ultimate deflection

The analytical deflection recorded for different specimens with different reinforcement types is recorded as in table 5 and Fig. 10 and Fig. 11. The deflection of the control specimen was 0.49 mm at failure load. For group one which reinforced with expanded wire mesh, the maximum deflection at failure load was 0.495, 0.55 and 0.59 mm but at the same load of the control specimen it was 0.266, 0.26 and 0.25mm respectively which is lower than the control specimen. This indicates the effect of expanded wire mesh in decreasing the deflection with average ratio of 47.8%.

For group two which reinforced with welded wire mesh, the maximum deflection at failure load was 0.48, 0.62 and 0.65 mm which is higher than the control specimen but if the deflection recorded at specimens BOX1-2, BOX2-2 andBOX3-2 at failure load of control specimen which was 0.275, 0.270 and 0.265 mm respectively. This indicates the effect of welded wire mesh in decreasing the deflection with average ratio of 44.8%. This ratio indicates that the expanded wire mesh has the best effect in decrease the deflection.

The decrease in ultimate deflection of group one and two is mainly due to increase in number of expanded or welded wire mesh layers used in reinforcement which lead to increase in its volume fraction in specimens.

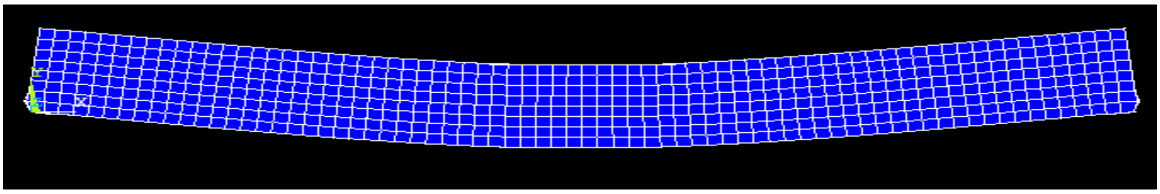


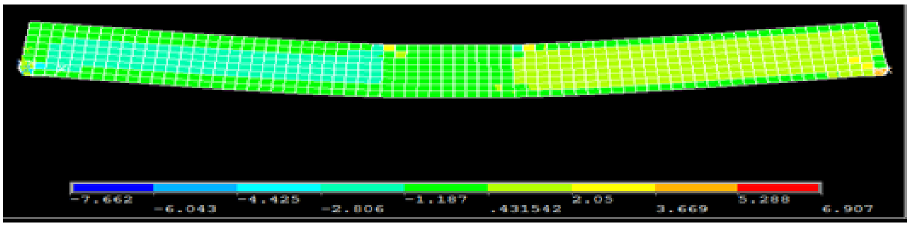
Fig.11 Typical deformation of NLFEA deflection for box beams

4.2.4 Ductility and energy absorption

A progressive increase of energy absorption which represents the specimen toughness with volume friction percentage and ductility was observed. For the control specimen BOX1 the energy absorption recorded 249.9 KN.mm, compared this value with the recorded for different series it shows good enhancement. For all series the enhancement percentage varies between 45.1% and 159%. The smallest enhancement was at specimen BOX1-2 which use one welded layer instead of stirrups due to the weak properties of the used type of layer but the highest enhancement was in BOX3-1 which used three expanded layers wire mesh which agreed with the results. Finally using metallic materials were developed with high ultimate loads, crack resistance, better deformation characteristics, high durability and energy absorption properties, which are very useful for dynamic effect.

4.2.5 Shear stresses

The obtained shear stresses are obtained according to the obtained results from the NLFEA as shown in Fig.12. For the control specimen BOX1 the shear stress was 1.10 MPa. For the first group box beams BOX1-1, BOX2-1 and BOX3-1 the shear stresses were 1.68, 1.75 and 2.01 MPa respectively with an enhancement ratio of 52.7%, 59.1% and 82.7% respectively with respect to the control specimen. The second group which used the welded wire mesh instead of stirrups, the shear stresses was 1.31 MPa, 1.62 MPa and 1.90 MPa for BOX1-2, BOX2-2 and BOX3-2 respectively. The enhancement in this group with respect to the control specimen was 19.1%, 47.3% and 72.7% respectively which is relatively less than the group used the expanded wire mesh.



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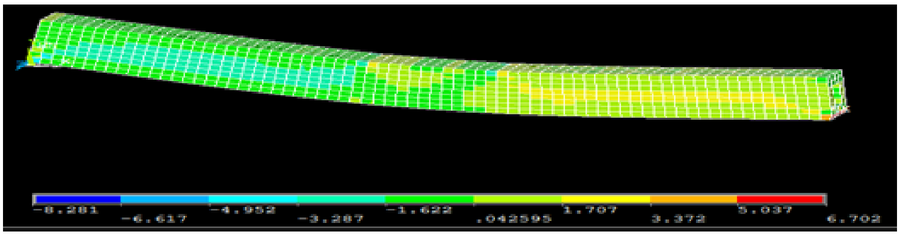

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Fig.12 NLFEA Shear Stresses; a) Shear stresses for BOX1;
b) Sample of shear stresses for different specimens

5. COMPARISON BETWEEN EXPERIMENTAL AND NLFEA RESULTS

This comparison aims to ensure the NLFEA models are available and suitable to exhibit the response of Ferrocement box beams. There are seven finite element models were compared with seven experimental specimens in term of ultimate load, ultimate deflection and crack patterns.

5.1 Ultimate failure load

There is an acceptable agreement between the experimental failure load and the analytical failure load obtained from NLFE program as shown in table 6 and Fig.13. The ratio between the NLFE failure loads to the experimental failure load varies between 0.88 to 0.91 with an average ratio of 0.89. The ratio of Pu NLFE/ Pu Exp, for control specimen was 0.88 but for the specimens in group one, it was 0.88, 0.89 and 0.90 for BOX 1-1, BOX2-1 and BOX3-1 respectively.

For the second group this ratio was 0.901, 0.908 and 0.905 for BOX 1-2, BOX2-2 and BOX3-2 respectively. This shows that the NLFEA gives the object of the studied parameters in face of load carrying capacity.

Table 6: Comparison between experimental and NLFE Analysis

Beam-Speci-men	Failure Load $P_{ult.}$ (KN)		Deflection $\Delta_{ult.}$ (mm)		Shear Stress V_u (MPa)		$P_{u\ NLFEA}$ / $P_{u\ exp.}$	$\Delta_{u\ NLFEA}$ / $\Delta_{u\ exp.}$	$V_{u\ NLFEA}$ / $V_{u\ exp.}$
---	NLFEA	EXP	NLFEA	EXP	NLFEA	EXP	---	---	---
BOX1	37.5	42.5	0.49	0.52	1.20	1.10	0.88	0.94	0.92
BOX1-1	60.5	68.2	0.50	0.53	1.89	1.68	0.88	0.93	0.89
BOX2-1	65.7	73.5	0.55	0.62	2.04	1.75	0.89	0.88	0.86
BOX3-1	72.4	80.2	0.59	0.68	2.23	2.01	0.90	0.86	0.90
BOX1-2	50.0	55.5	0.48	0.54	1.54	1.31	0.90	0.88	0.85
BOX2-2	62.5	68.8	0.62	0.69	1.91	1.62	0.90	0.89	0.85
BOX3-2	70.2	77.5	0.65	0.72	2.15	1.90	0.90	0.90	0.88

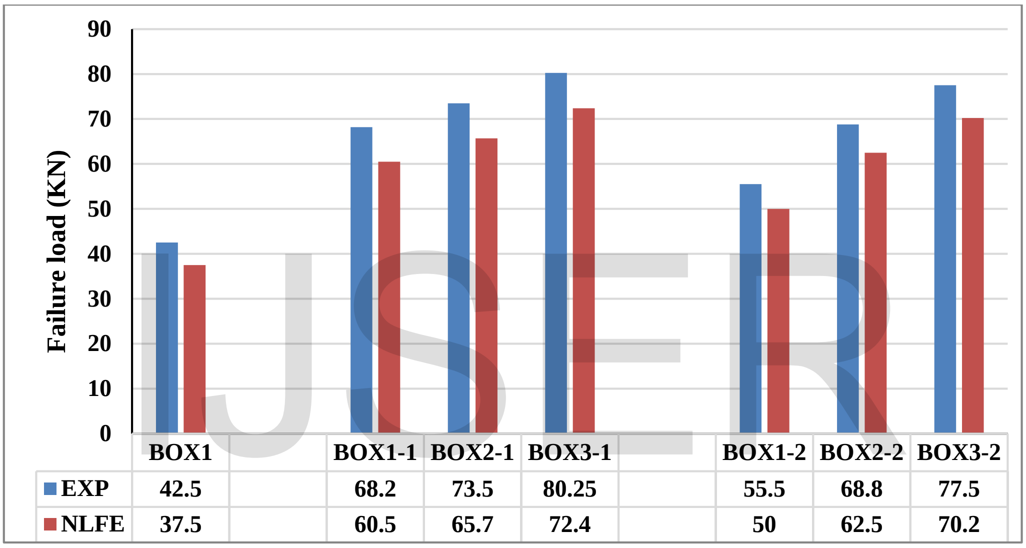


Fig. 13: Comparison between Exp. Failure load and NLFE failure load

5.2 Ultimate Deflection

Fig. 14 showed the load deflection curves for all box beams in phase of experimental and NLFE obtained results. The recorded deflection for experimental and NLFE analysis showed an agreement with respect to the deflection recorded for the control specimen as in Figure 15 and Table 6. The recorded ratio between ΔNLFE / ΔExp of 0.94 for the control specimen. For the first group this ratio recorded 1.02, 1.08 and 1.09 for BOX 1-1, BOX2-1 and BOX3-1 respectively but for BOX 1-2, BOX2-2 and BOX3-2, this ratio were 0.89, 1.02 and 1.06 respectively. These ratios showed that NLFE program provide an acceptable response in deflection as in Fig. 15.

5.3 Crack Patterns

The figure 16 indicate a comparison between the crack patterns experimentally and in NLFE analysis these cracks begins micro cracks and increased in length and width till failure

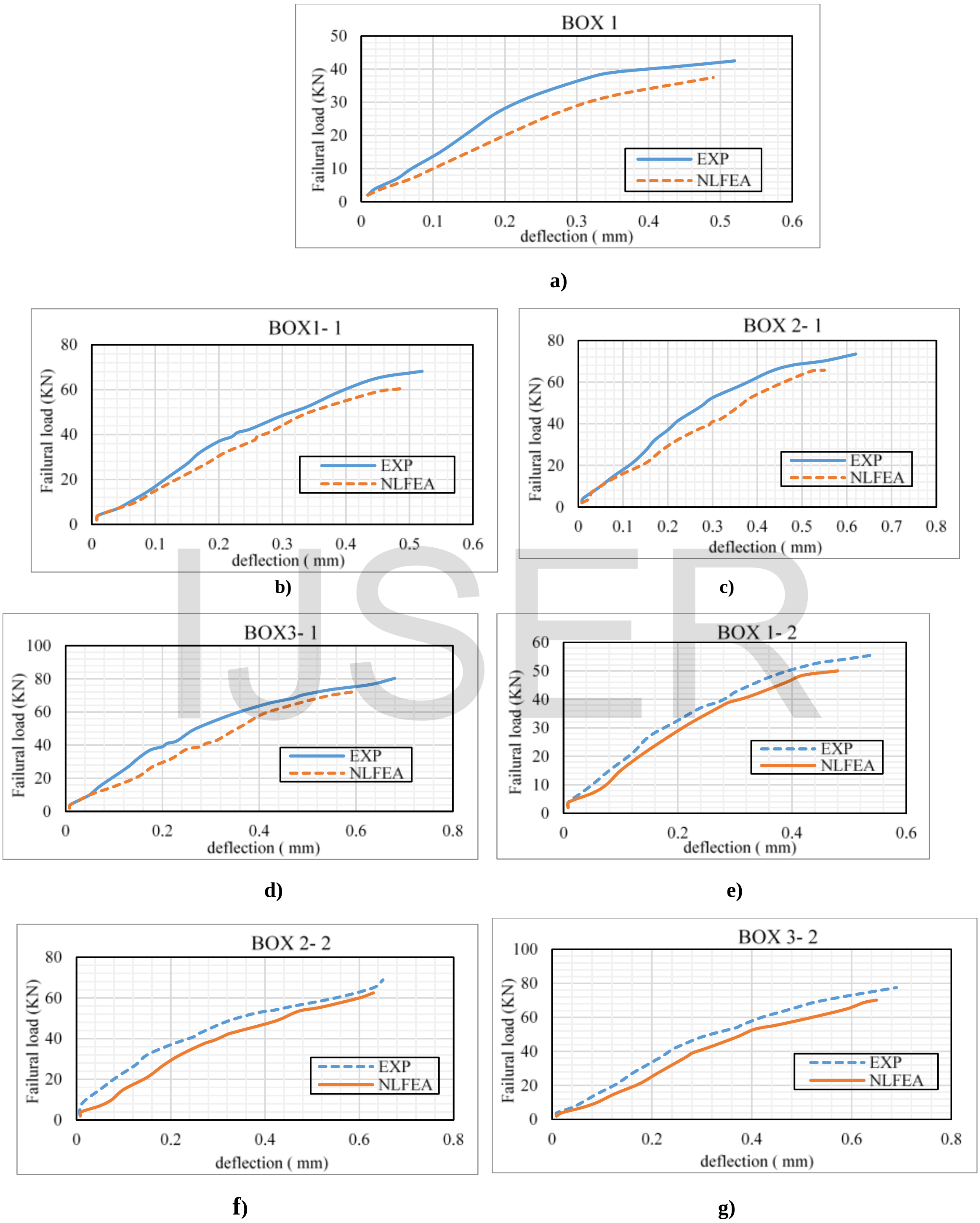
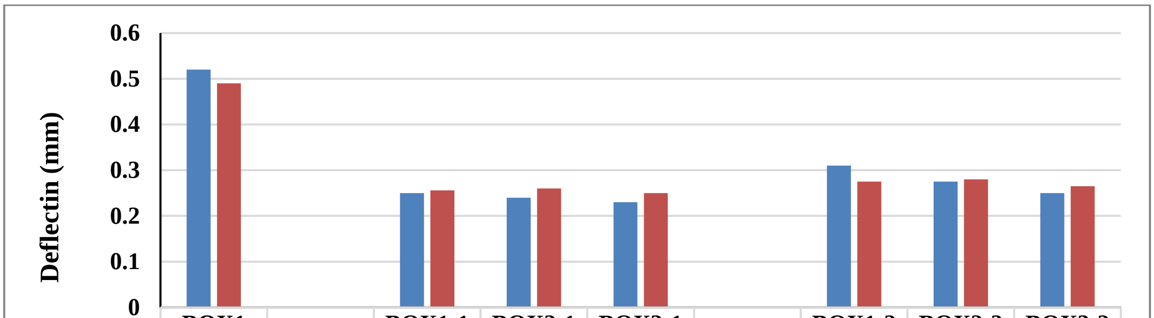
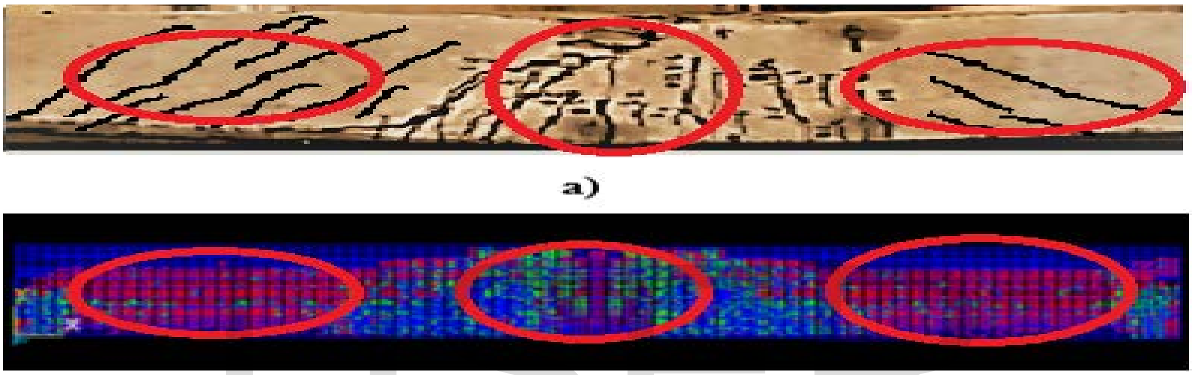


Fig. 14: Comparison between experimental and NLFEA load deflection curve;
a) Control BOX1; b) BOX1-1; c) BOX2-1; d) BOX3-1; e) BOX1-2; f) BOX2-2; g) BOX3-1.



	BOX1		BOX1-1	BOX2-1	BOX3-1		BOX1-2	BOX2-2	BOX3-2
EXP	0.52		0.25	0.24	0.23		0.31	0.275	0.25
NLFE	0.49		0.256	0.26	0.25		0.275	0.28	0.265

Fig.15: Comparison between Exp. deflection and NLFE deflection at the failure load of control specimen.



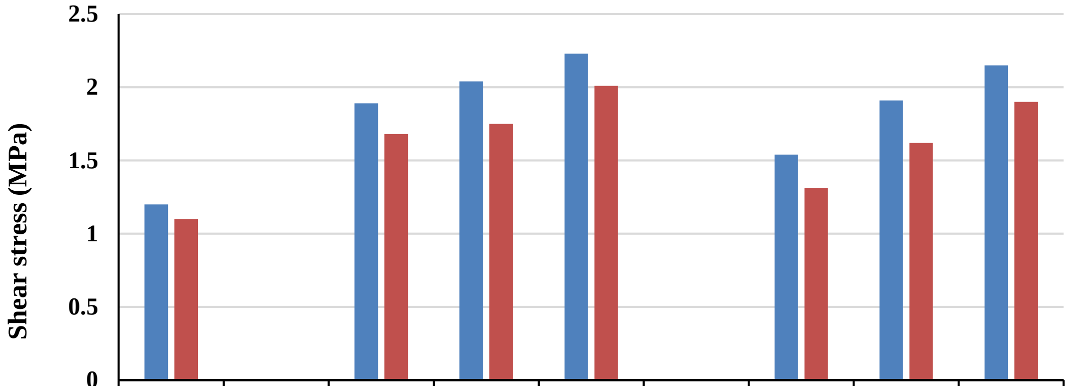
a)

b)

Fig.16: Crack pattern for box beams; a) Experimental crack pattern; b) NLFE crack pattern

5.4 Shear Stresses

From the porpoise of this study is to discuss the shear stresses and the effect of using wire meshes in resist shear and cracks propagates. The experimental and NLFEA showed agreement in the obtained results as shown in Figure 17 and Table 6. The ratio between the obtained shear stresses from NLFEA and experimentally was 0.91 for control specimen, but for the group one which used expanded wire mesh instead of steel stirrups this ratio was 0.89, 0.86 and 0.90 for BOX 1-1, BOX2-1 and BOX3-1 respectively. For the second group which used welded wire mesh, the ratios were 0.85, 0.84 and 0.88 for BOX 1-2, BOX2-2 and BOX3-2 respectively. So, the finite element analysis represents an acceptable presentation for shear stresses.



	BOX1		BOX1-1	BOX2-1	BOX3-1		BOX1-2	BOX2-2	BOX3-2
EXP.	1.2		1.89	2.04	2.23		1.54	1.91	2.15
NLFEA	1.1		1.68	1.75	2.01		1.31	1.62	1.9

Fig.17: Comparison between Exp. Shear stresses and NLFE Shear stresses.

6. CONCLUSIONS

Based on the results and observations of the experimental and the analytical study presented in this study and considering the relatively high variability and the statistical pattern of data, the following conclusions can be drawn:

1- Expanded and welded wire mesh exhibited features over normal reinforcement with reinforcing steel, epically in box beams such that, it has high strength, easy to be handling cutting and shaped also has light weight.

2- Using expanded or welded wire mesh instead of steel stirrups exhibit high ultimate failure load with respect to control specimen.

3- Expanded wire mesh has high effect in increasing load capacity, deflection, the shear stresses and cracks propagate.

4- The cracks propagation decreased and its number and width decreased by using expanded and welded wire mesh especially in specimens with two and three layers of wire mesh.

5- There an acceptable agreement between experimental and analytical results obtained in ultimate failure load, deflection and shear stresses.

6- This work gives an acceptable prediction for shear stresses of box beams reinforced with expanded or welded wire mesh where the obtained average ratio (Vu NLFEA/ Vu EXP) was 0.878.

At the end, the ferrocement composite either expanded or welded wire mesh in reinforcement of box sections instead of steel stirrups has a better effect in failure load, deflection, cracks propagation and shear stresses.

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