Journal of Engineering and Applied Sciences 13 (18): 7612-7617, 2018
ISSN: 1816-949X
© Medwell Journals, 2018

Influence of Near Surface Fiber Nets Reinforcement on the Behavior of Solid and Voided Reinforced Concrete Beams

Rafea Flaih Hassan, Muna H. Jaber Nabeel and Hasan Ali Al-Salim
Department of Civil Engineering, College of Engineering, University of Babylon, Babylon, Iraq

Abstract: Using deferent number of fibre reinforcement nets near to surface of Reinforcement Concrete (RC) beams was studied experimentally in this research. In addition to discuss the effect of the conic voids that added inside RC beam as a 10% of a tested beam volume. The total sample number was six reinforced concrete beams with these specific dimensions 0.1×20.18×1.22 m which tested under two points load. And to strengthen the beams two methods of applying the fibre net were used: the first one was used four separate layers of net around the beam section (one for each beam side) while the second method used five layers of net around the beam section (one for each beam side) and added another layer of net in the beam base to be two layers. Whereas the tests results indicated an increasing in the strength about 5.8 and 27.7% for solid beam after adding one and two layers of fibre nets in beams base as a near surface reinforcement for RC beams, respectively while the increasing about 12.5-45% for the voided beam after adding one and two layers of fibre nets in beams base as a near surface reinforcement for RC beams, respectively. Thus, using two layers of fibre nets in the base of beam changed failure criteria of beams from flexural failure to shear failure in both cases of solid and voided beam.

Key words: Cracks, fibre net, flexural, reinforcement concrete beams, solid and voided

INTRODUCTION

Recently, Reinforced Concrete (RC) structures are used widely in many engineering structures either tall or short building and it used to build any types of buildings due to strength, easy applied and cost as well as it has the ability to behave depending on the assumptions designer when controlling the applications conditions in situ. Generally, RC beams are designed to support shear forces and bending moments.

Improving behaviour of RC beams is very important especially with increasing the development of construction materials and techniques. This approach is used to enhance properties of concrete beams along with increasing the cost. Xing *et al*. (2010) studied the effect of strengthening the RC beams with steel nets that embedded in polymer mortar overlay in five RC (T section) beams. And the test results show an evidence for successful steel nets composites in strengthening RC beams in flexure.

Qeshta *et al*. (2014) investigated the performance of concrete beams strengthen with mesh-epoxy specially the flexural performance. They were used four beams to test them and discuss the effect of different composite width on supporting the flexural behaviour of plain concrete beams bonded with wire mesh-epoxy composite. The results showed that the large composite width specimen indicated an improvement in its behaviour with respect to energy absorption capability. Mohamad *et al*. (2017) studied the structural behaviour of the concrete beams that reinforced with High Density Polyethylene Balls (HDPE) that undergone to flexural load where the (HDPE) balls used to produce spherical voids that lead to decrease the beam self-weight. The result indicated a reduction in the load capacity of beams with polyethylene balls by 32% compared to control beam (the general beam without any change). Also, the maximum deflection at mid span was increased about 4%. However, beams with polyethylene balls is more ductile compared to control beam.

On the other hand, Hassan (2018) examined the effect of using fibre wire mesh on the flexural and shear behaviour of solid RC beams by testing six simply supported beams. The tests results referred to a significant influence for fibre wire mesh which is more clearly in shear behaviour than the flexural behaviour of RC beams.

Moreover, Al-Salim (2018) studied the effect of voids shape (spherical and conic voids) on the flexural behaviour of RC beams and the enhancement of the

Corresponding Author: Rafea Flaih Hassan, Department of Civil Engineering, College of Engineering, University of Babylon, Babylon, Iraq

behaviour of voided beams by using Polyvinyl Alcohol (PVA). Where the tests result's referred to reduce the capacities of normal concrete voided beam about -6.4 and -18.3% for spherical voids and conic voids, respectively but increasing ultimate load for PVA concrete beams (13.8, 5.4 and 3.1%) for solid, spherical voided and conic voided beams, respectively.

According to Fantilli *et al*. (2016) the mechanical behaviours of concrete beams affected by the amount of steel fibres which changes the beams behaviours under bending stress from brittle to ductile behaviours depending on the volume fibres ratio. And this amount approximately equal to the minimum steel bars amount in RC beams, known as Ductility Index (DI). And theoretically and experimentally, have proven that there is a linear relationship between (DI) and the fibre ratio.

The specified purpose of this piece of work is to examine different approaches to enhance the behaviours of RC beams by using low cost materials and the possibility of adding impeded conic voids inside the concrete beams after finishing steel cage work.

MATERIALS AND METHODS

Experimental plan: To gain the goals of this piece of work, six Reinforcement Concrete (RC) beams were used (three samples were containing voids and the others were solid). And these samples were prepared and tested by using two points load. Table 1 shown the information of each beam.

Tested beams details: The tested beams dimensions were 1.22 m as a total length and 1 m the length of net span with 0.12×0.18 m cross sectional area as shown in Fig. 1. All samples were reinforced with two reinforcement the top one with ϕ = 8 mm diameter and the bottom longitudinal reinforcement were located at spacing of 76 mm C/C using (ϕ = 6 mm diameter).

Voids distribution: Voids were represented by conic cork cups with these dimension (40 mm top diameter, 70mm

Table 1: Beams code

Beams details	Beams ID
Solid beams	
Control beam	N
Four layers of fibre nets one layer on each side	N1
Five layers of fibre nets two in the base and one layer on each side	N2
Conic voids beams	
Control beam	C
Four layers of fibre nets one layer on each side	C1
Five layers of fibre nets two in the base and one layer on each side	C2

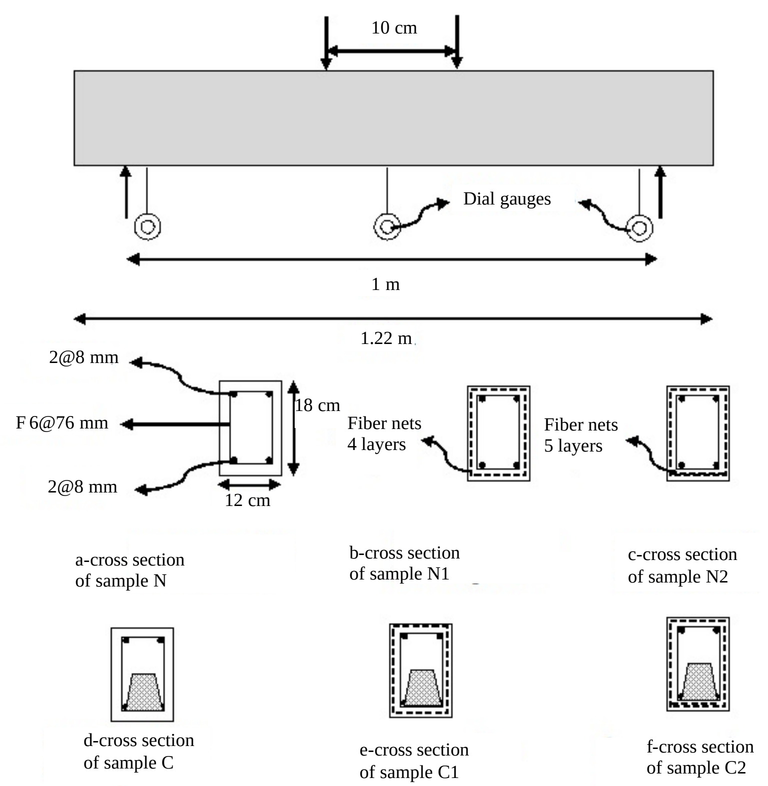

Fig. 1: Tested beams reinforcement details

Fig. 2: Conic voids inside steel cage

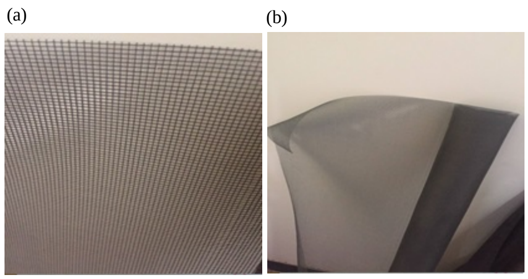

Fig. 3: Fibre nets

base diameter and 70mm height). And during the samples preparing the voids ratio is still constant which was about 10% of the effective volume of the tested beam (1*0.12*0.18 mm). Thirteen conic voids were arranged depending on these dimensions where located at 2 cm from the base of beam along one line at 76 mm c/c spacing as shown in Fig. 2.

Properties of materials

Steel reinforcement: Two steel bars diameters were used in reinforcing the beam one is ϕ = 8 mm and the other one is ϕ = 6 mm. And the average yield stress of these bars was obtained from testing three specimens for each diameter which about 530 MPa for ϕ = 8 mm and 510 MPa for ϕ = 6 mm diameter.

Fibre nets properties: Fibre nets is small grey wires with 0.15 mm diameter and the grid size about 2×2 mm as shown in Fig. 3. As well as the tensile strength of this net is 1120 MPa were accomplished according to ASTM D412 (Anonymous, 1998).

Other materials: The other materials such as water, cement, fine aggregate and coarse aggregate were used the materials that available locally which found in the laboratories of civil engineering, Babylon University, Iraq. And the proportion of these materials as shown in Table 2.

Compressive strength (f/c): Compressive strength test was done according (ASTM C496-96) (Anonymous, 2001, 2003) and the mixture that used with proportions are mentioned in Table 2, the compressive strength obtained by testing three standard cylinders 100×200 mm at 28 days age was 27.2 MPa.

Fig. 4: Testing machine

Table 2: Concrete mix

Parameter	Amount
Water/cement ratio	0.45
Water (kg/m^3)	202.5
Cement (kg/m^3)	450
Fine aggregate (kg/m^3)	670
Coarse aggregate (kg/m^3)	1040

Test set-up and measurements: All beams were prepared as mentioned previously, then tested by using a hydraulic machine with 150 kN capacity. As well as the net vertical displacements were measured at mid-span by using three dial gauges as shown in Fig. 4.

RESULTS AND DISCUSSION

The test results will be discuss the two beams type (solid and voided) in different aspects such as first crack load, ultimate load, ductility and failure modes of all test specimens as listed in Table 3. As well as Table 3 shows that the first cracking load (kN) and ultimate load (kN) were increased with increasing the fibre nets layers also the voided beams give higher load than solid beams. So, the maximum first cracking load (kN) had been recorded for sample (N2) about (32 kN) and the maximum ultimate load (kN) had been recorded for sample (N2) about (61.3 kN) (Fig. 5).

Solid beams: In this research, three solid beams were tested to study the effect of fibre nets on behaviours of beams (N, N1 and N2). The load-displacement curves of these tests are shown in Fig. 6. This figure indicated a little changes in the behaviour of beams N and N1 as well as it shows the stiffer behaviour for beam N2. And the failure shape for this type of beams are shown in Fig. 5.

Table 3: Results of the test

Sample ID	First cracking load (kN)	Ultimate load (kN)	Failure mode
N	10	48	Gradual, flexural
N1	22	50.8	Gradual (with slightly crushing at compression zone), flexural
N2	32	61.3	Gradual (with slightly cracking at shear zone), shear
C	8	40	Gradual, flexural
C1	18	45	Gradual (with slightly crushing at compression zone), flexural
C2	25	58	Gradual (with slightly cracking at shear zone), shear

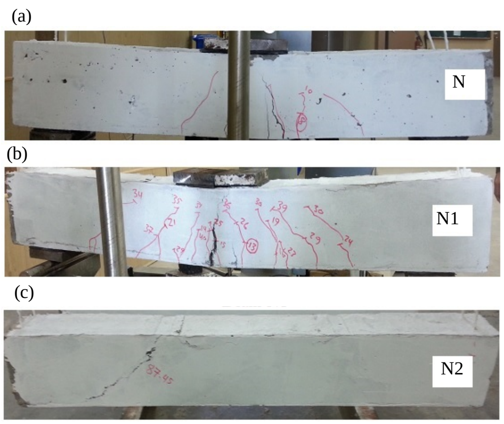

Fig. 5: Crack patterns for voided beams: a) N; b) N1 and c) N2 at ultimate loads

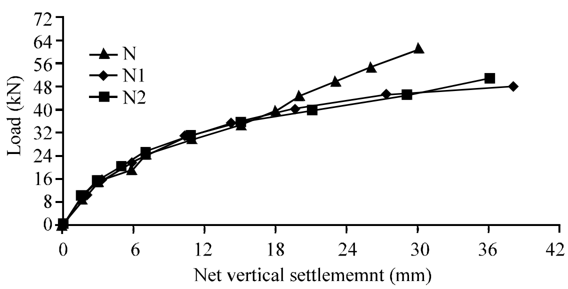

Fig. 6: Load vs net displacement of RC beams N, N1 and N2

Voided beams: On the other hands, three voided beams were tested to study the effect of fibre nets on behaviours of beams (C, C1 and C2). And then compared with solid beam to find the effect of fibre nets on each beams type. The results of the voided beams are shown in Fig. 8. And the failure shape for this type of beams are shown in Fig. 7.

Crack pattern and modes of failure: The crack pattern and modes of failure for voided and solid beams with (0, 4 and 5) fibres nets layers shows in Fig. 5 and 7, respectively. These two Fig. 5 and 7 shows that the cracks pattern and modes failure are different between voided and solid beams as well as they are differing depending on the fibre net layers. Beams (N and C) failed due to rupture of the beams in the mid-span in tension zone at the bottom face of each beams and as shown in Fig. 5 and 7 and the failure modes in both of them are gradual and flexural. Also, beams (N) has less cracks than beam (C) due to presence of voids in beams (N) and devoid of beams (C) from these voids which make it weaker in tension zone (concrete has good resistance for compression but it brittle in tension). While beams (N1 and C1) less cracks than beams (N and C) and the failure modes in solid and voided beams are gradual (with slightly crushing at compression zone) and flexural. Due to adding four fibre nets layers in all beams sides which enhance the beam against tension and increase the ductility of them but still beams (N1) has less cracks than beam (C1) due to presence of voids in beams (N1) and

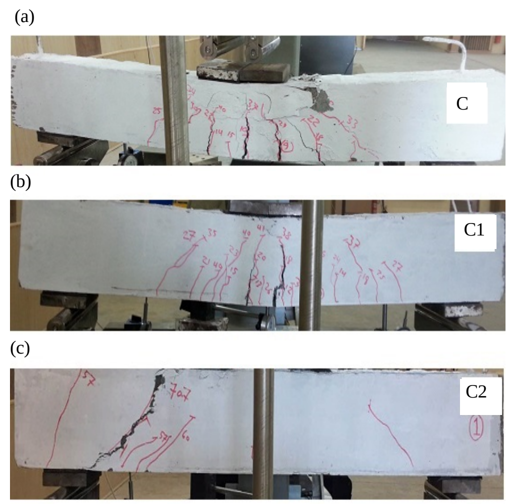

Fig. 7: Crack patterns for Solid beams C, C1 and C2 at ultimate loads

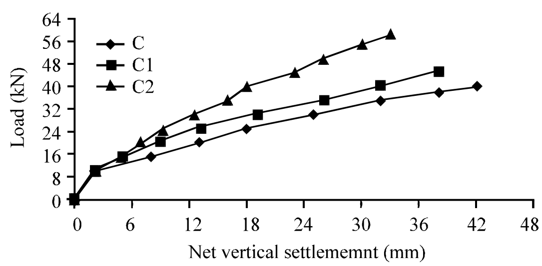

Fig. 8: Load vs net displacement of RC beams C, C1 and C2

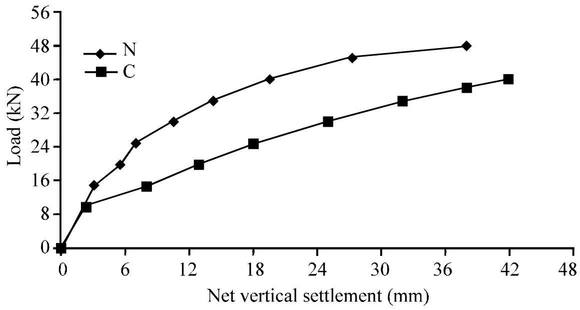

Fig. 9: Effect of voids on beams without fibre nets reinforcement

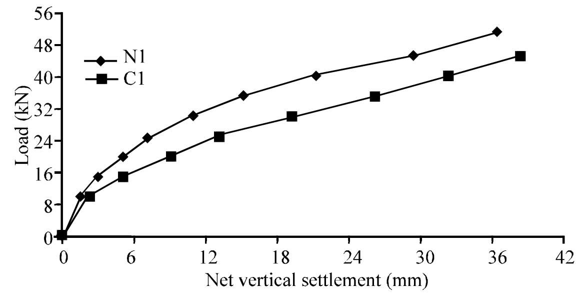

Fig. 10: Effect of voids on beams with four layers of fibre nets reinforcement

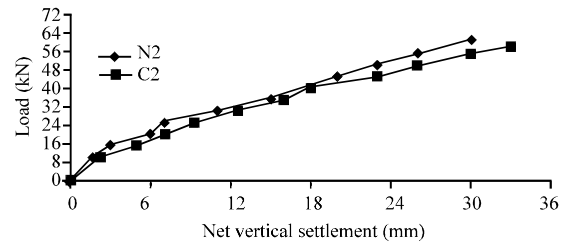

Fig. 11: Effect of voids on beams with five layers of fibre nets reinforcement

devoid of beams (C1) from these voids. And finally, beams (N2 and C2) less cracks than beams (N, C, N1 and C1) and the failure modes in solid and voided beams are gradual (with slightly cracking at shear zone) and shear failure. Due to adding five fibre nets layers in all beams sides and two in the beam base which enhance the beam against tension and increase the serviceability but decreasing the ductility of the beams. As well as beams (N2) still has less cracks than beam (C2) due to presence of voids in beams (N2) and devoid of beams (C2) from these voids. Gradual (with slightly cracking at shear zone), shear.

Load-deflection behaviour: Figure 6 and 8 show the relationship between the vertical displacement (deflection) and the load for voided beams (N, N1 and N2) and solid beams (C, C1 and C2). The benefits of the relationship between the load and deflection is to investigate and describe the behaviours of the RC beams under load. Generally, the first part in the curves (sharp) increasing refer to the ability of beams to resist the loads without cracks. And the change of the graph from linear to curve with an increasing refer to beginning of the cracks while the decreasing in the curve refer to failure. In addition to that the reinforcement ratio effect on the stiffness of the beam and then effect on load behaviour. In Fig. 6 and 8, the voided and solid beams show significant increasing in the load-deflection curve in condition of using five fibre nets layers. And overall the voided beams have higher load-deflection than solid beams.

Effect of voids: Figure 9-11 shows the relationship between the load and the deflection for solid and voided beams reinforced by using different numbers of fibres net layers (0, 4 and 5) layers. And the void ratio of voided beams is 10%. Figure 9 shows the effect of voids on the ductility of the beams where the voided beams give good indication for load-deflection curve compared with solid beam that means the voided beams more ductile than the solid one. In addition to that the ductility has an effects on the serviceability deflection of RC beams where flexural cracking occurs. Thus, the 10% void ratio improved the behaviour of beams to be more ductile than the solid beam also the load resistance increased with decreasing the deflection.

Figure 10 indicate that the using of four fibres nets layer in both solid and voided beams improve the ductility index of the beams with increasing the serviceability of the beams. While Fig. 11 shows that increasing the fibre net layers to five layers will decrease the ductility of both solid and voided beams but it increase the service ability of these beams.

CONCLUSION

The most important points that can be noticed from the tests results as following: Fibre nets improve the concrete resistance against shrinkage to prevent the cracks caused by shrinkage. The fibre nets reinforcement reduced the damages in the compression zone of the beams with flexural failure while the shear zone in beams were suffering from shear failure. The using of the fibre net increased the ultimate strength for the solid beam about 5.8 and 27.7% depending on the number of net layer one and two layers, respectively and for voided beams about 12.5-45% for one layer and two layers, respectively. In case of solid and voided beams with one layer net the cracking load of the samples increased about 120-220% while the using of two net layers increased the cracking load of the samples about 125-210% for both solid and voided beams, respectively. Finally, the main influence of the voids are ultimate load reduction and the reduction about 17,11.4 and 5.4% for no fibre nets, four fibre nets layers and five fibre nets layers, respectively.

ACKNOWLEDGEMENTS

The Ministry of Higher Education and Babylon University in Iraq is gratefully acknowledged. The experimental part was performed in the laboratory of Babylon University.

REFERENCES

Al-Salim, N.H.A., 2018. Improving the voided reinforced concrete beams behavior by strenthining the compression zone concrete using polyvinyl alcohol. J. Univ. Babylon, 26: 307-317.

Anonymous, 1998. Standard test methods for vulcanized rubber and thermoplastic elastomers-tension. ASTM D412-98a, ASTM International, West Conshohocken, Pennsylvania. https://www.astm. org/DATABASE. CART/HISTORICAL/D412-98A.htm

Anonymous, 2001. Standard specification for deformed and plain billet-steel bars for concrete reinforcement. ASTM A615/A615M-01b, ASTM International, West Conshohocken, Pennsylvania. https://www. astm.org/DATABASE.CART/HISTORICAL/A615A 615M-01B.htm

Anonymous, 2003. Standard test method for splitting tensile strength of cylindrical concrete specimens. ASTM C496-96, ASTM International, West Conshohocken, Pennsylvania. https://www. astm.org/DATABASE.CART/HISTORICAL/C496-96.htm

Fantilli, A.P., B. Chiaia and A. Gorino, 2016. Fiber volume fraction and ductility index of concrete beams. Cem. Concr. Compos., 65: 139-149.

Hassan, R.F., 2018. Flexural and shear behavior of RC concrete beams reinforced with fiber wire mesh. J. Univ. Babylon, 26: 264-273.

Mohamad, N., W.I. Goh, A.A.A. Samad, A. Lockman and A. Alalwani, 2017. Structural behaviour of beam with HDPE plastic balls subjected to flexural load. Mater. Sci. Forum, 889: 270-274.

Qeshta, I.M.I., P. Shafigh, M.Z. Jumaat, A.I. Abdulla, U.J. Alengaram and Z. Ibrahim, 2014. Flexural behaviour of concrete beams bonded with wire Mesh-epoxy composite. Applied Mech. Mater., 567: 411-416.

Xing, G., T. Wu, B. Liu, H. Huang and S. Gu, 2010. Experimental investigation of reinforced concrete T-beams strengthened with steel wire mesh embedded in polymer mortar overlay. Adv. Struct. Eng., 13: 69-79.