KUFA JOURNAL
OF ENGINEERING
ISSN 2071-5528
PRINTED IN IRAQ

Volume 1, Number 2, pp.61 - 71, June 2010

Investigation Strength Of One Way Slab Panel Using Steel Fibers And Wire Mesh (Ferro Cement)

Assistant lecturer : Ahmed Abdul Jaleel Almadany
Civil engineering department, College of engineering, Kufa university
(Received:25/8/2009 ;Accepted :6/4/2010)

Abstract :

This paper presents a study of the flexural behavior of the reinforced mortar slabs using both of steel fiber concept and ferrocement layer in tension zone cover as an additional reinforcement to the main steel bars .The concept of steel fibers mean that substitution the common types of steel fibers by alternative material exhibit the same action that produced by the tradition fibers. This material represented by short length of steel nails (SLSN) ,which is cheapest and more available than the first type in the local markets .The efficiency of this material have been checked using seven samples of beam prototypes tested under flexural behavior and reinforced with the nails. Results produced that the nails will improve ultimate flexural strength of mortar noticeably .The increasing ratio in flexural strength of mortar was in the range of (400-1200)% related with these seven beams .Therefore, and according to this advantage, eight one way reinforced slab panel have tested under flexural loading. They reinforced with the nails ,one layer of wire mesh to produce ferrocement cover, and the both material . After testing these eight panels ,the once reinforced with SLSN as an additional reinforcement exhibit the best performance in resisting flexural stresses by increasing flexural load capacity from 17.25kN to about 20kN. Furthermore, maximum central deflection was also reduced by this material from 24.75mm for non fiber reinforced panels to 4.9mm for reinforced once.

Although the action of ferrocement was less than the results produced by the fibers ,ferrocement cover increases the ultimate flexural load capacity for panels reinforced with single layer of wire mesh as well as decreasing in the maximum central deflection for these panels in comparison with the control specimens .

فحص تقوية ألواح السقوف المسلحة باتجاه واحد باستخدام كلا من الألياف الحديدية والمشبك الحديدي (الفيروسمنت)

الخلاصة :

تتناول الدراسة الحالية إمكانية استخدام كل من الفيروسمنت كطبقة واحدة من المشبك الحديدي المغطى بمونة السمنت \الرمل في منطقة اجهادات الشد بالإضافة إلى مبدأ الألياف الحديدية القصيرة الطول ذات نسبة الطول إلى القطر المساوية إلى ٢٥ ، كتسليح إضافي لعينات السقوف المسلحة بقضبان حديد التسليح الطولي ذات الاتجاه الواحد .إن القول بمبدأ استخدام الألياف الحديدية نعني به استخدام مادة تؤدي نفس سلوك الألياف الحديدية في العمل مع المونة أو الخرسانة مع مراعاة الكلف الاقتصادية . ومن خلال تواجد الألياف الحديدية الشائعة الاستخدام في البحوث العلمية بصورة غير متوفرة في الأسواق المحلية بشكل يؤهلها للاستخدام في الأعمال الإنشائية الاعتيادية ، فقد دعت الحاجة لاستخدام واختبار البديل المقترح عنها والمتمثل بالمسامير الحديدية القصيرة ذات نسبة الطول \ القطر ٢٥ المشابهة لأحد أنواع الألياف الحديدية .ولأجل ذلك ،فقد تم صب واختبار سبعة عينات من النماذج المصغرة للأعتاب الإسمنتية بحيث تسلح بعضها بالمسامير المختبرة وإبقاء البعض الأخر بدون تسليح لبيان مدى زيادة مقاومة اجهادات الانثناء لتلك الأعتاب بفعل وجود المسامير (الألياف) .إن نتائج الفحص أظهرت زيادة في مقاومة مونه السمنت لاجهادات الشد مما يؤدي الى زيادة مقاومة الأعتاب للاجهادات الانثنائية وبشكل جيد يتمثل بزيادة حمل الفشل الأقصى بنسبة (٤٠٠-١٢٠٠)% .وكنتيجة لذلك ،فقد تم صب وفحص ثمانية عينات من ألواح السقوف المسلحة بالاتجاه الواحد سُلّحَ بعضها بطبقة من المشبك الحديدي لعمل الفيروسمنت وتم تسليح أخرى بالألياف الحديدية المقترحة وأخرى لم يضاف إليها أي تسليح إضافي بالإضافة إلى العينات التي أضيف لها كلا نوعي التسليح الإضافي للحديد الطولي .لقد أظهرت نتائج الفحص إن الألياف الحديدية المقترحة عملت على زيادة حمل الفشل ألانثنائي الأقصى بنسبة ١٦% مقارنة بالعينات الخالية من التسليح الإضافي ،كما وإنها قللت مقدار الهطول الأقصى للعينات بنسبة ٨٠% وبصورة تفوق أداء التسليح باستخدام الفيروسمنت .ان استخدام الفيروسمنت عمل أيضا على زيادة حمل الانثناء الأقصى لعينات السقوف وتقليل مقدار الهطول المركزي لها ولكن بشكل اقل من تأثير الألياف الحديدية.

Notation :

As :cross sectional area for steel bar
Asw: cross sectional area for wire mesh .
fc: concrete compressive strength
fcf : fibrous concrete compressive strength
fy: yield strength of bar reinforcement
fyw: yield strength of wire mesh reinforcement
ϕ :diameter of bar
L/D :(aspect ratio) length of fiber divided by the diameter of it
USD :American dollar
vf: fiber volume fraction (volume of fiber in the mortar mix with respect to the volume of total mix).
SLSF : short length of steel fibers
SLSN : short length of steel nails

1.Introduction:

Fibers appear to be an economical alternative or auxiliary material for construction . Fibrous construction material can be factory mass- produced in prefabricated form , a process best suited to the concentrated demands of urban area , or it can also be a fabricated in situe in a village .

Although adequate design information and field experience have been acquired for many types of fibrous structures , the future extent of fibrous construction will mainly depend on economic construction . Research into the properties of fibrous roof panels is urgently needed , and the literature on the behavior of roofs made from fibers is scanty [(1)].

2.Test program:

Eight simply supported one – way main reinforcement action panels were tested . All panels were rectangular with 300 mm width , 80 mm thick (providing 65mm effective depth) and a total length of 650 mm given a free span of 610 mm . The specimen were arranged in four groups , A – D with two specimens for each . All specimens reinforced with two ϕ 6 mm bars with fy equal to 250 MPa , as main reinforcement . Group A have no any additional reinforcement otherwise the main one , which are considered to be as the control specimens. Group B was designed to investigate the effect of one layer wire mesh as an additional reinforcement . Specimens in group C consist of 1% fiber volume fraction to investigate the action of short length steel nails instead of the wire mesh in the panel as a fiber reinforcement . Finally , both of the wire mesh and the short length steel nails (fibers) are gathered in group D as an additional reinforcement to the panels .

3.Materials:

Portland cement (obtained from Kufa cement Plant)and natural sand were used for the mortar to give 23.52 MPa mortar compressive strength . This result obtained after testing three mixes with cement / sand ratios of 1:1.5 , 1:2 and 1:2.4 by weight , to give a 28 day compressive strength of 32.13 , 23.52 and 17.20 MPa, respectively .The water cement ratio was 0.5 for all mixes. Present study adopt the middle value which is 23.52 MPa .All the previous mixes were caste in 50x50x50 mm square cube molds with electrical vibrator and similar curing conditions in order to investigate their compressive strength . Electrical concrete mixer used to mix mortar and fibers with about 5 minutes mixing time for all the cubs , beams prototypes and the slab panels .The ferrocement (wire mesh) reinforcement was a galvanized welded square wire mesh of 1mm diameter and 10 mm openings. Hand compaction was used for the panels specimens , while an electrical compactor used for the beams prototypes . The required wire mesh placed under the main reinforcement as a single layer for panels of groups B and D . Short length of small nails (about 25mm length and 1mm diameter) used as steel fibers . This materials has been adopted after checking its efficiency in strengthening tensile strength of mortar as what will be explained later . The main steel bar reinforcement were 2ϕ6mm non deformed bars hooked at their end in order to coincide with the ACI- 2008 [2] code requirements . Another 2ϕ6mm similar bars used as shrinkage and temperature reinforcement welded perpendicularly with main groups . These bars were assemblaged using 4ϕ6mm bolts welded perpendicularly to the bars groups . These bolts provides two advantages , a constant cover for the panels and act as a shear connecters . Full the instruction details can be seen in Fig.1 .

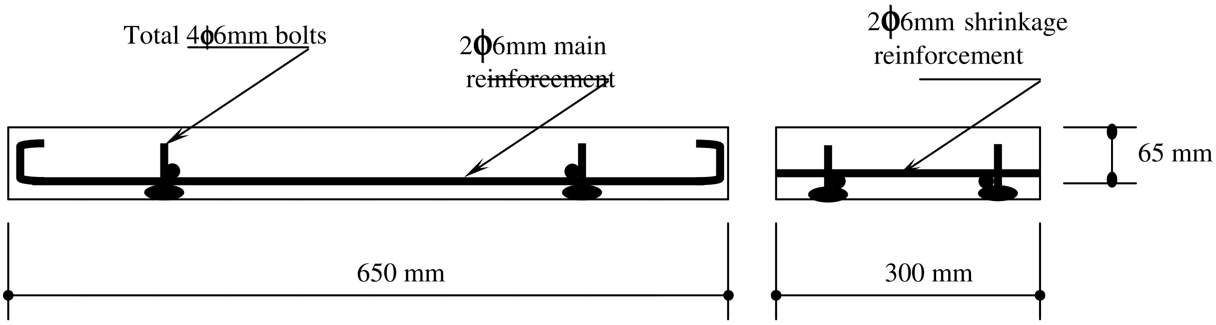

Fig. 1. Slabs panels with main reinforcement, shrinkage reinforcement and shear connecters details

4.Efficiency of nails as fiber reinforcement :

In order to insure that the use of short length steel nails (SLSN) will give the same action obtained by the use of short length steel fibers (SLSF) (25mm length and 1mm diameter) with a constant aspect ratio (L/D) equal to 25 for both materials , the following test was used :

1- Seven specimens of beams prototypes (100x100x400 mm length) dimensions were casted . Two of them(specimens 1and 2in Table(1)) have no any reinforcement in order to obtain the pure tensile strength of the mortar (Photo1*c*) , while the other five specimens were reinforced with 1% volume fraction of (SLSN) randomly distributed throughout the mortar mix (Photo 1*b*). The obtained increasing in tensile strength existed in these specimens is due only to the applied fiber reinforcement .

2- A flexural test had been adopts to all these seven specimens as indirect tensile test of the mortar mix by using two point load digital ELE testing machine .Results of testing these specimens are listed in Table 1 .The instrumentations and illustrating photos can be shown below.

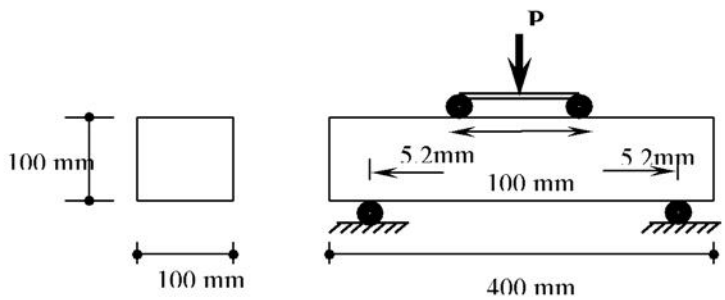

Fig. 2. Schematic diagram of the test setup for the beams prototypes during flexural investigation

(a) *(b)* *(c)*

Photo 1, (*a*) Fibrous mortar beams at failure (no complete separation) ,(*b*) Randomly distributed fibers throughout the beam section, and (*c*) Plain mortar beam at failure (completely separation)

3- Results obtained after testing these seven specimens (Table 1) reflects the perfect increasing behavior related with the tensile strength of mortar using SLSN . An increasing range of about (400 – 1200) % of mortar tensile strength occurred when using SLSN in the mix .The tensile strength increased from about 0.284 MPa for the plain specimens to about 2.825 MPa (average of five specimens) for the fibrous mortar. The failure mode accompanied with the plain mortar beams was sudden and brittle with a loud crushing voice , and there is no any precaution signs exhibit in the extreme body just before failure occurred. Alternatively, a perfect ductile performance existed in the fibrous beams with noticeable marks appears gradually during the load propagation with no sudden failure located, so that, the beams still stand with no complete separation after failure (graph (1*a*)). Literature researches [3,4] showed that the use of SLSF with a fiber volume fraction (*vf*) equal to 1% will increase the flexural and tensile strength of both concrete and mortars significantly . However , present study try to prove that the use of SLSN will give an alternative best results than the use of SLSF .

Table 1. Maximum flexural load and stress obtained after testing beams prototypes using SLSN

Specimen	*vf* (%) SLSN	Load at failure (KN)	Stress at failure (MPa)
1	0	0.94	0.283
2	0	0.95	0.286
3	1	4.54	1.363
4	1	13.78	4.133
5	1	5.81	1.740
6	1	11.89	3.567
7	1	11.08	3.325
Further samples obtained from literature[5]	0	0.93	0.282

5. Economic considerations:

The use of SLSN in the mortar or concrete mixes , being coincide with the economic consideration in comparison with the use of SLSF .However, the price of one kilogram of SLSF in the Iraqi markets is about 3.1 USD , while it is equal to 1.75 USD for the SLSN . This fact exhibit a suitable aim to use SLSN rather than SLSF , if we know that the same mixing and casting requirements being similar for both material .

6.Test results and discussion :

A schematic diagram of the test setup is shown in Fig.3 .The slab panels were simply supported on two sides and free at the other . A double point load was applied at the middle one third of each slab to insure that the flexural failure will exist . Each slab was instrumented for measuring central deflection . Tests were conducted in a 2000-KN testing machine with a displacement rate of 0.3mm/min , and the loading process was monitored via a data acquisition system . The load versus central deflection curves for the panels are presented in Fig (5,6,7 and 8) .

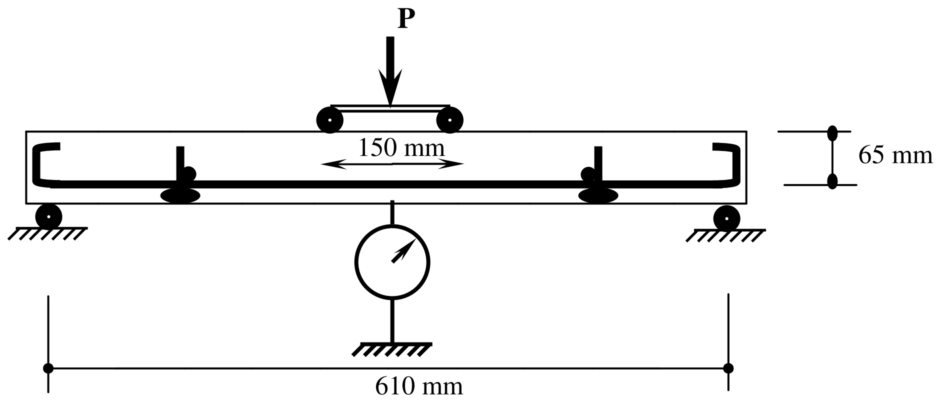

Fig 3. Schematic diagram of the test setup for the panels during flexural investigation

Tow parameters had been investigated during the present study : the addition of SLSN to the slab panels and the use of wire mesh as a ferrocement mortar .It can be seen that from the load – deflection graphs (Fig. 5,6,7 and 8), the relationship within the range of load equal to (0 – 5) KN, seems to be linearly for all the specimens ,then it will slightly start to decrease specially for panels in group A and B .However , the slope (P/Δ) for the panels reinforced with SLSN being relatively high ,and it is decreases for the other group panels. The slope rising value in the (P – Δ) curve (group C and D) represent the favorite resistant to the deflection related with these panels , so that , the other panels reinforced with only (2ϕ6mm) or those whom provided with the wire mesh only ,make no sufficient resistant to the total deflection .

The perfect case can be seen among all cases related with (P – Δ) curves is that of group C , which represent the use of SLSN as an additional reinforcement only. In this case ,maximum load capacity was achieved with about 20 KN as an average value for two specimens (providing an increase in total capacity equal to 15.9% with respect to the control specimens), and the deflection was also the minimum among all values which was 4.9 mm at the maximum load .The reduction amount in total deflection with respect to the control specimens was 80.2% (Table 2) .

Due to the absence of wire mesh in panels of group C ,fibers spreads throughout the whole depth of the panel section freely , so that, the effective depth of the mortar will increase and permit to a more tensile resistant provided for the section ,which is about 15mm of the fibrous mortar cover exists below the main reinforcement (Fig. 4*c*) .This case was not available in the panels of group D, because of the existent of the wire mesh whom prevent the fibers to be spread throughout the steel cover (Fig. 4*d*). However, this will reduce the total effective depth of the panel section that resist the tensile stresses..

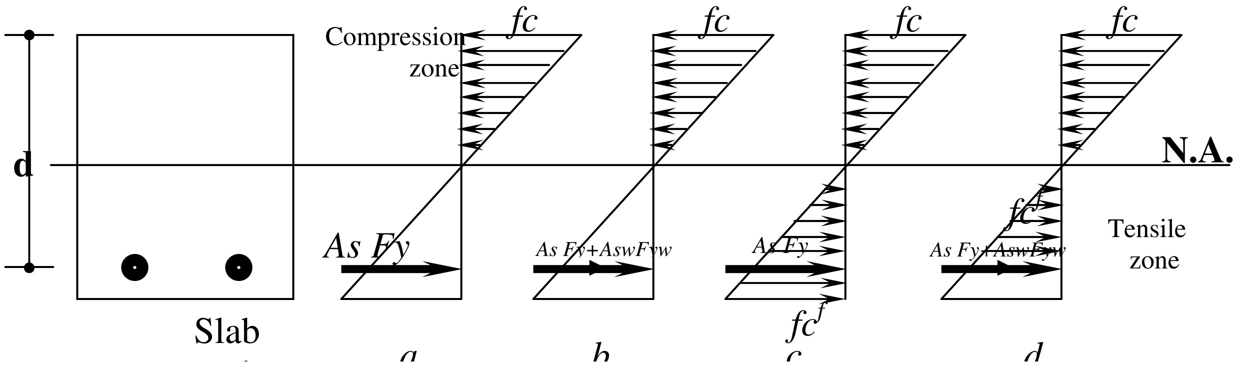

Fig. 4.(*a*) stress distribution diagram for group A under elastic stressing, (*b*) stress distribution diagram for group B (wire mesh + steel bars) in tension zone only ,(*c*) stress distribution diagram for group C (SLSN + steel bars) in tension zone only and (*d*) stress distribution diagram for group C (SLSN + wire mesh + steel bars) in tension zone under elastic stressing .

From the other hand ,if we note that the maximum load capacity obtained from group B and D ,was 18.75 kN ,one conclusion may be reached : is that the available of 15mm from SLSN in mortar below the steel bars being more efficient than one layer of wire mesh at the same place .Although the average of maximum load capacity obtained from group B and D was the same, fibers act to reduce the maximum deflection occurred in group D in comparison with group B, which mean that fibers enhanced the resistant behavior of the panels against deflection .

The use of one layer of wire mesh in associated with the main bar reinforcement (group B) produced good increasing in flexural resistant capacity in comparison with the results of group (A) (which was 17.25 kN) to be equal to 18.75kN, furthermore ,it is action was acceptable in resisting central flexural deflection .A reduction in maximum deflection was obtained in using wire mesh as an additional reinforcement equal to 18.85mm in group B rather than 24.75mm in group A (about 23.8% reduction (Table 2)), also it should be note that the existence of SLSN in the tensile zone of the panel section in group D (Fig. 4*d*) give a larger reduction value in resisting maximum deflection (total deflection equal to 8.55mm with about 65.4% reduction) ,therefore ,the higher the depth of fibrous tensile resistance zone ,the higher the reduction amount in maximum deflection (group C provide 4.9mm total deflection with 80.2% reduction).

Table 2. Obtaining results (maximum loads and deflections) for all specimens and the average value for each group

Group	Specimen	Maximum load (kN)	Average load (kN)	Increasing load amount with respect to group A (%)	Maximum deflection (mm)	Average deflection (mm)	Reduction amount with respect to group A (%)
A Control specimens	1	17.0	17.25	-------	25.0	24.75	-------
	2	17.5			24.5		
B	3	17.5	18.75	8.7	18.7	18.85	23.8
	4	20.0			19.0		
C	5	20.0	20	15.9	5.3	4.9	80.2
	6	20.0			4.5		
D	7	20.0	18.75	8.7	9.1	8.55	65.4
	8	17.5			8.0		

(*a*)

(*b*)

Photo 2. (*a*) sample installation before testing , (*b*) dial gauge reading during testing

(*c*)

(*d*)

Photo 2. (*c*) cracks propagation for all specimens after complete failure, and (*d*) loading measurements during the test

The control panels (group A) give a total deflection of 24.75 mm and ultimate flexural capacity equal to 17.25 KN, which were the lowest values among all results ,and all the obtained results can be seen in Table 2.

Finally, after complete failure occurred ,cracks take placed under each point of load for all specimens noticeably (Photo 2*c*) ,and then ,two line of cracks propagate at each specimens meant that flexural failure had been occurred. Flexural crack propagation started from a hairy state to about 8mm at the state of complete failure. Fibers were obviously appear through the cracks ,while the wire mesh wasn't able to be seen through it .

Fig 5 . Load – Deflection (P-Δ) relationship for panels in group (B) in comparison with the control specimens (group A)

Hago et .al (2005) [1] show that it is not sufficient to use single layer of wire mesh to make a ferrocement cover for the concrete panels in order to improve there behavior ,so that it is important to find another supports represented by fibers or increasing the mesh layers to reach near the typical case.

Fig 6 . Load – Deflection (P-Δ) relationship for panels in group (C) in comparison with the control specimens (group A)

Fig 7. Load – Deflection (P-Δ) relationship for panels in group (D) in comparison with the control specimens (group A)

Fig 8. Load – Deflection (P-Δ) relationship for all groups

7.Conclusions :

Several conclusions may obtained according to present study as following :

1- It is able and more economic to use short length of steel nail (SLSN) as fiber reinforcement in mortar mix instead of the traditional types of short length of steel fibers (SLSF),with the same aspect ratio (L/D) for each , and same efficiency will produce.
2- The use even of one layer of wire mesh to make a ferrocement cover for the mortar panel ,will reduce central deflection to an acceptable range of about 24% for these panels .Furthermore, an increasing in ultimate flexural capacity for mortar panels will obtained .
3- SLSN have successfully increased flexural tensile strength of mortar from 0.945kN to about (4.54 – 13.78)kN for the plain mixes in beams prototypes ,whereas the increasing amount was from (17.25 – 20)kN for the reinforced slab panels, and the use of 1% fiber volume fraction could be sufficient to produce these enhancements .
4- SLSN decreases maximum central deflection for the reinforced slab panels with about 80% decreasing amount with respect to the ordinary reinforcement panels .
5- The use of about 15mm of fibrous mortar thickness will increase flexural tensile resistant capacity for slabs more than the efficiency of ferrocement cover have one layer of wire mesh with about 6.7 % increasing.
6- Both fibers and ferrocement convert the brittle action of concrete to a ductile one .

8-References :

1- Hago A.W., Al-Jabri,K.S., Alnuaimi A.S. , Al-Moqbali H., al-Kubaisy M.A. ”Ultimate and service behavior of ferrocement roof slab panels” .Journal of construction and building material 19 (2005) Elsevier Science Ltd. , pages (31 – 37) .
2- American Concrete Institute (ACI), “Building code requirements for reinforced concrete” .(2008).
3- Ibrahim J.K. ,”Punching shear strength of steel fiber reinforced concrete slabs’ MSc. Thesis submitted to the civil engineering ,University of Baghdad ,Iraq ,1984.
4- SnydeM. J. r , . Lankard D.R, ”Factor affecting cracking strength of steel fibrous concrete “ ACI journal proceeding ,vol.69, No.2 ,Feb.1972, p.p. 69-100 .
5- Al-Ani H. A., “Fiber reinforced high strength concrete incorporating pozzolanic cement” M.Sc. thesis submitted to the university of technology , Baghdad, Iraq, 2005.