Eng. & Tech. Journal, Vol.29, No.13, 2011

Sphrical Slab with Ferrocement

Shayma'a A. Mohammed*

Received on: 18/1/2011
Accepted on: 8/9/2011

Abstract

This research is devoted to investigate the behavior of spherical ferrocement slabs under flexural loading. The main parameters considered in the analysis are the thickness of the slab, vertical and horizontal diameters, and the effect of number of wire mesh layers on the behavior of spherical.

Analysis was done using the finite element software ANSYS V. 11, which is used for solving several problems of structural engineering. The 8-node iso-parametric brick elements in ANSYS are used to represent the mortar, the wire mesh layers are considered as smeared layers elastic-perfectly plastic materials embedded within the brick elements by assuming perfect bond between the mortar and steel.

An improvement was indicated in the behavior of the elements when changing the shape of the slab from straight to spherical slabs found in deflection about 64% (as indicated in ref. [1]). As well as increasing number of wire mesh layers from two to four and from two to six tend to increase the load capacity by 18% and 28% respectively.

The increase in the thickness and the vertical diameter cause decrease in deflection to 20% and 10% alternately.

Keywords: Ferrocement slabs, ANSYS, finite element, flexural behavior, wire mesh layers.

البلاطات الفيروسمنتيه ذات الشكل الكروي

الخلاصة

إن الهدف الرئيسي من هذا البحث هوالتحري عن سلوك البلاطات الكرويه تحت تأثير أحمال الإنحناء. المتغيرات الرئيسيه في التحليل هي سمك البلاطه، تغير القطر العمودي و القطر الأفقي، و تأثير عدد طبقات المشبكات السلكيه على سلوك البلاطه الكرويه.

تم التحليل باستخدام طريقة العناصر المحددة بالاعتماد على برنامج جاهز(ANSYS) نسخه 11 المستخدم لتحليل المنشات الهندسية المختلفة. لقد اقترح موديل ثلاثي الابعاد حيث استخدم العنصر الطابوقي ذي الثماني عقد لتمثيل مونة السمنت أما حديد التسليح فقد مثل بعناصر محورية مطمورة داخل العنصر الطابوقي وافتراض وجود ترابط تام بين مونة السمنت وحديد التسليح .

وجد تحسن ملحوظ في تصرف العنصر بتغير شكل البلاطات من مستويه إلى كرويه و ذلك بنسبة 64% للهبوط (كما موضح في المصدر [1]). بالإضافة إلى زيادة عدد طبقات المشبك الحديدي من طبقتان إلى أربعة و من طبقتان إلى ستة تؤدي إلى تحسين قابلية التحمل إلى 18% ، 28% على التعاقب . كما أن الزيادة في سمك البلاطة و الإرتفاع العمودي (التقوس) يسبب نقصان بالهبوط إلى 20% ، 10% على التوالي.

---

* Electrical Engineering Department, University of Technology/Baghdad

Introduction

Ferrocement is a strong, versatile, low-cost, long-lasting building material made from a wire reinforced mixture of sand, water, and cement. Aferro-cement structure is usually 2-5

cm thick much thinner and lighter than poured concrete structures. Because it has wire reinforcing distributed throughout the structure, ferrocement structures have much greater tensile strength and flexibility than ordinary concrete.

ferrocement is a composite material constructed by cement mortar reinforced with closely spaced layers of wire mesh. The ultimate tensile resistance of ferrocement is provided solely by the reinforcement in the direction of loading. Ferrocement is light in weight and adoptable to any shape of cross section; hence it is ideally suited for pre-cast construction. Even though the thickness of the ferrocement sections is small, choosing proper shapes of cross sections the flexural rigidity of the section can be increased. Unlike studies on the behavior of ferrocement elements under flexure, very limited research reports are available on the behavior of ferrocement compound structural sections like I, C, T and L etc., in general and voided ferrocement compound sections in particular. An experimental program has been planned to investigate the flexural response of these units under flexural loading.

Literature Review

Several investigators reported on the flexural behavior of ferrocement elements. Mansur and Paramasivam [2] Conducted studies on the cracking behavior of ferrocement elements and Predicted the ultimate strength of ferrocement in flexure using plastic analysis. Trian Onet, ET. al., [3], have studied the behavioral aspects of ferrocement in flexure and reported that ferrocement elements have better performance under working loads owing to their very small crack widths and improved ductility at post cracking range. E.Z. Tatsa [4] presented the limit state design philosophy for the design of ferrocement elements in bending. D.N. Trikha, et. al. [5], conducted analytical and experimental studies on the behavioral aspects of cored ferrocement slabs, proposed empirical expressions for the estimation of modulus of rupture and effective moment of inertia to estimate the deflections. S.K. Kaushik et. al. [6].

Performed investigations on behavior of ferrocement cored plates concluded that these slabs improve the heat and sound insulation properties.

The authors focused on the composite action of the ferrocement slabs and steel sheets. The experimental models of ferrocement slabs with and without steel sheeting and their numerical models using the finite element method will be presented. Finite element models are enveloped to simulate the behavior of the slab through nonlinear response and up to failure, using the ANSYS (V. 11) package [7].

Moreover these slabs are lighter in weight there by providing economy for the supporting systems like footings. Aboul-Anen makes the composite action between the ferrocement slabs and steel sheeting [8].

Finite Element Model

A finite element package (ANSYS V.11) was used to simulate the behavior of ferrocement slabs [7].

Solid 65 is considered as one of the solid isoperimetric elements which are formulated by direct extension of procedure used for plane elements [9]. It is defined by eight nodes as shown in Fig. (1)**.** each node has three degrees of freedom, translations in x, y, and z; respectively. This element has one solid material and up to three rebar materials in the three directions. It is isoparametric properties and has a capability to handle plasticity, creep, swelling, stress stiffening, large deflection and large strain capabilities.

The spherical of simply supported slabs with 500x500x20mm (with vertical diameter 60mm high) and 0.7mm wire mesh were selected for the analysis using the finite element software ANSYS. The slabs were reinforced with three percent of reinforcement using two, four and six layers of wire mesh. The supports were applied at 400x400mm and the corner edges were restrained from any movement. The slab mesh model with the load distribution and boundary conditions were shown in Fig. (2). The thickness of the slab change from 20 to 40 mm, the vertical diameter change from 60 to 70 mm with constant thickness and the horizontal diameter change from 500 to 600mm with constant thickness.

Reinforcing wire mesh layer, both longitudinal and transverse are Modeled as smeared in layers throughout slab. The stress strain Diagram of wire mesh of 0.7 mm was shown in Fig. (3) and Table 1 Indicates the properties of wire mesh taken from refs. [1, 10 and 12].

The mechanical properties of reinforcement (wire meshes) are well-known in comparison to mortar. The wire meshes are homogeneous and have usually the same yield stress in tension and in compression. A bilinear uniaxial stress-strain relationship was used for steel in the model, as shown in Fig. (4) [7].

Mortar properties obtained from Refs. [1, 10 and 11] having mix 1:2 ratio by weight (cement: sand) with a water/ cement ratio of 0.5 was used. Table 2 indicates the cement mortar strengths with three specimens for each result at 28 days which was used in the model. The behavior of mortar in compression is simulated by an elasto-plastic work hardening [12] model followed by a perfectly plastic model, Fig. (5), which is terminated at the onset of crushing.

Analysis and Results

The numerical applications on ferrocement members using the finite element analysis are carried out to investigate the behavior of ferrocement flexural slabs. Verification is done in order to check the validity and accuracy of these models. The ability of the constitutive models to simulate the behavior of this type of members is demonstrated through the analysis of the experimentally tested members by others [1]. The increased in the No. of element cased increasing in the accuracy result as well as increase time of analysis, from Fig. (6) we could notice that increase in the No. of elements from 200 to 800 and from 800 to 3200 case different in deflection as 0.024 and 0.0153 respectively. The value is very small so we decide to take no. of elements 200.

The results obtained using finite element models are compared with the experimental results through the load-deflection curves.

The spherical slabs with three different wire mesh layers were analyzed and the results were tabulated in Table 3. The results show an increase in the ultimate load values with the increase of wire mesh layers. The increase in number of wire mesh from 2 to 4 with distributed loads shows an increase in the ultimate capacity by about 18.3% and from 2 to 6 indicates an increase of 28.2% as shown in Table 3 and Figs. (7, 8 and 13). Increasing in the curve curvature for the slab (H, high at middle slab) deflection will decrease to 10%. Also the increase in the slab thickness (t) causes decrease in deflection to 20%, and the increase in the area slab (D) lead to change as 32%, where indicate in Table 4 and Figs. (8, 11, 12 and 14).

Conclusions

Based on the results obtained from the experimental work, analytical finite element analysis the following conclusions are presented:

1. Spherical slabs show better results in deflection than straight slabs [1] by about 69% for two wire mesh layers, 64% for four wire mesh layers and 60% for six wire mesh layers.
2. The deflection improve 10% when change the curve curvature from 60 to 70 mm.
3. The increase in the thickness of slab from 20 to 40 mm causes increase stiffness of slab which leads to decrease in deflection to 20%.
4. When increase the horizontal distance for slab from 500 to 600 causes 32% increase in deflection.
5. The deflection result shows a reduction with the increase of number of wire mesh layers which cause an improvement in section behavior and capacity in the spherical slabs.
6. It is found that the predicted response obtained using the proposed finite element models are close to the experimental one.
7. The load carrying capacity of the tested ferrocement members are close to with predicted in the proposed finite element analysis.
8. Finite element method can be adapted to the analysis and design of ferrocement slabs.

References

[1] Ibrahim O. A., “Mechanical Characteristics of Ferrocement Slabs Under Flexural Loading”, M.SC, University of Technology, Building and Construction Department, Baghdad, Iraq, Dec. 1999.

[2] Mansur M.A. and Paramasivam P. (1985) “Cracking Behaviour and Ultimate Strength of Ferrocement in Flexure” Proceedings of the Second International Symposium on ferrocement, Bangkok, Thailand, PP 47-59.

[3] Train Onet., Magureanu C., and Vescan V. “Aspects concerning the behaviour of ferrocement in flexure” Journal of ferrocement , Vol.22, No.1, January1992

[4] Tatsa E.Z., “Limit States Design of Feerro Cement components in bending”, Cement and Concrete Composites, Vol.13, 1991 pp49-59.

[5] Trikha D.N..,.Kaushik S.K, Gupta V.K., and S.Mini “Behaviour of ferrocement cored slabs”, Proceedings of the Second International Symposium on Ferrocement, Bangkok, Thailand, PP 135-143.

[6] S.K.Kaushik, V.K.Gupta, D.N.Trikha and S.Mini “Investigations on Ferrocement Cored Slabs”, Journal of Ferrocement , Vol.16, No.3, July1986.

[7] ANSYS, *Program Help and Manual*, 1999.

[8] Boshra Aboul-Anen, Ahmed El-Shafey, and Mostafa El-Shami "Experimental and Analytical Model of Ferrocement Slabs" International Journal of Recent Trends in Engineering, Vol. 1, No. 6, May 2009, pp 25-29.

[9] R. Cook, D. S. Malkus, M. E. Plesha, *Concepts and Applications of Finite Elements Analysis*, 4th ed., John Wiley & Sons, Inc., 2001.

[10] Mohammed N. S., “Analysis and Ultimate Capacity of Ferrocement Flexural Members”, Ph. D., University

[11] Al-Rifaie, W.N., and Nimnim, H.T., “An Experimental and Theoretical Investigation of the Behavior of Ferrocement Box-Beams”, Journal of Ferrocement, Vol.31 No. 1, January, 2001, pp.1-36.

[12] American Society of Testing and Materials (ASTM) (2002)."Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression." ASTM C-469, West Conshohocken, PA.

[13] Karsan, P. and Jirsa, J.O., "Behavior of Concrete under Compressive Loading", Journal of Structural Division, ASCE, Vol.95, No. ST12, December 1969, pp.2543-2563.

Table 1: Properties of wire mesh. [1]

Diameter of wire mesh (mm)	Yielding Stress (MPa)	Ultimate Stress (MPa)	Poisson's ratio υ	Modulus of elasticity (MPa)
0.7	300	520	0.3	67000

Table 2: Subsidiary tests results of mortar. [1]

Mix (cement-sand)	Compressive Strength (N/mm^2)		Tensile strength f_{ct} (MPa)	Modulus of Rupture f_{rm} (MPa)	Poisson's ratio u	Modulus of elasticity Em (MPa)	Elastic stress limit $cp.f_c'$
	cylinders	cubes					
1:2	21	24.78	2.34	2.7	0.184	17380	0.25 f_c'

Table 3: Theoretical and experimental results of load and deflection

Specimen type	Wire mesh number	Experimental results[1] load per point		Theoretical results load per point	
		Pu (kN)	Defl. (mm)	Pu(kN)	Defl. (mm)
Straight slab	2	559	4.12	560	2.70485
	4	634	2.66	600	2.49913
	6	781	3.17	660	2.41052
Spherical slab	2			507	0.83856
	4			600	0.87777
	6			650	0.94896

Table 4: Theoretical results of load and deflection for spherical slab with four wires mesh layers.

H= the distance from horizontal to the top point in the curve in the middle slab
t= the thickness of slab

Slab type	Case	Theoretical results load per point	
		Pu(kN)	Defl. (mm)
1	H=60, t=20, D=500	600	-0.87777
2	H=70, t=20, D=500	610	-0.788865
3	H=60, t=40, D=500	1350	-0.699992
4	H=60, t=20, D=600	620	-1.1623

D= the horizontal distance for slab

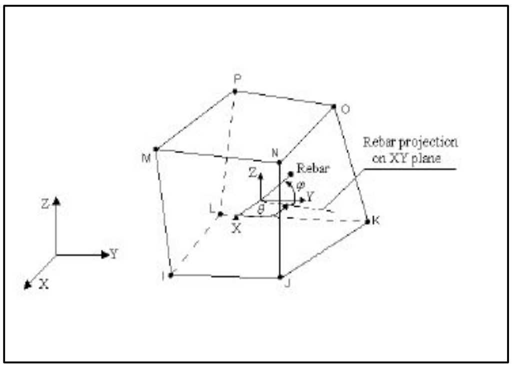


Figure.1: Eight-node solid isoparametric element (solid

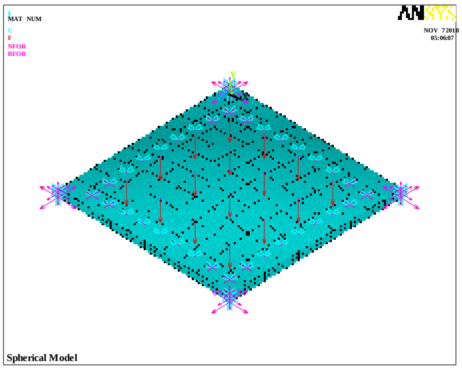


Figure.2: Typical finite element mesh for ferrocement spherical slabs with loading

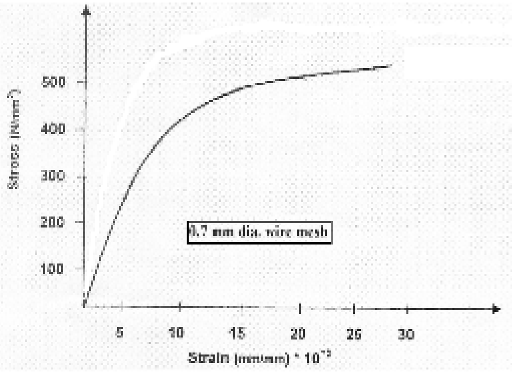


Figure.3: Stress-strain relationships for wire mesh [1].

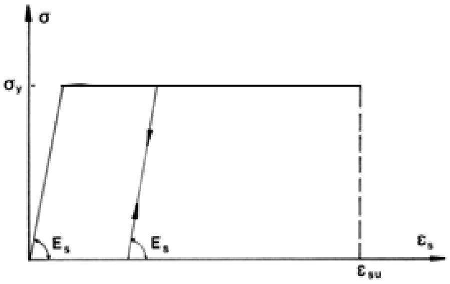


Figure.4: Stress–strain relationships of wire meshes

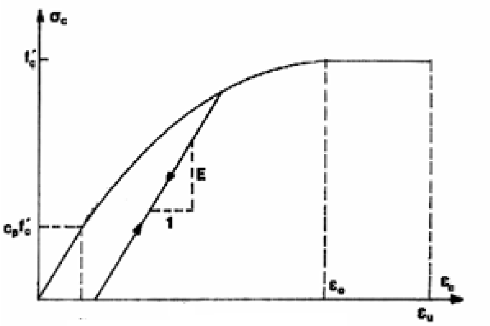


Figure.5: Uniaxail stress-strain curve for mortar in

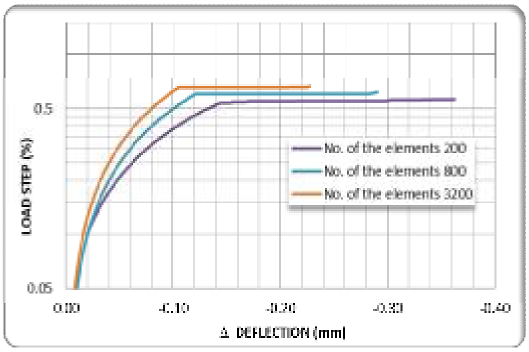


Figure.6: Effect the Increase in No. of element and node in the sample analysis. * Δ = different deflection bet ween maximum node deflection and

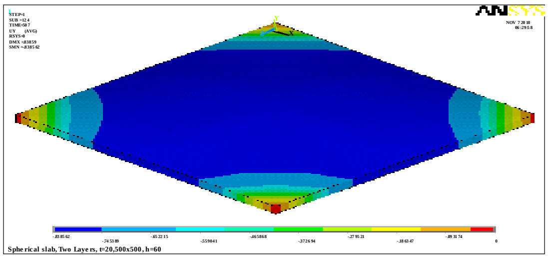


Figure.7 : Deflection distribution for

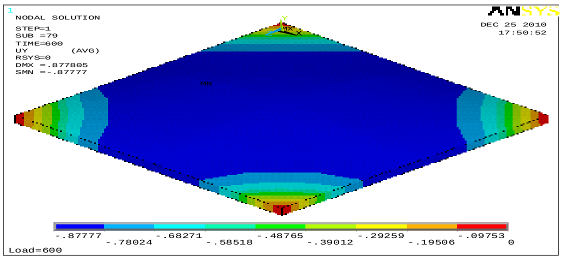
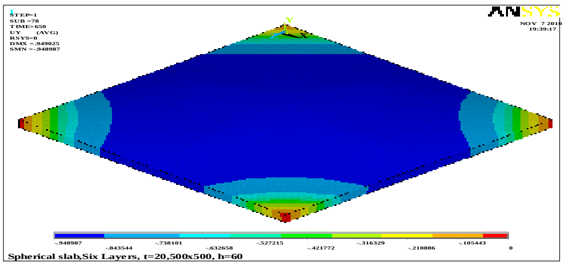


Figure.8 : Deflection distribution for



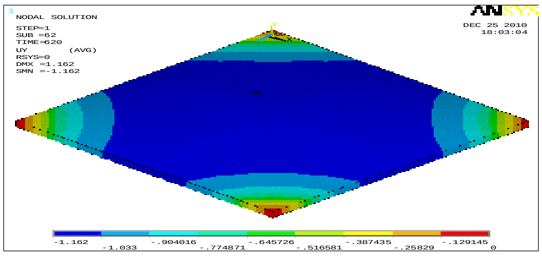
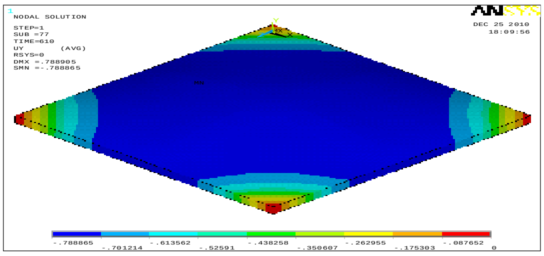


Figure.9 : Deflection distribution for

Figure.10 : Deflection distribution for



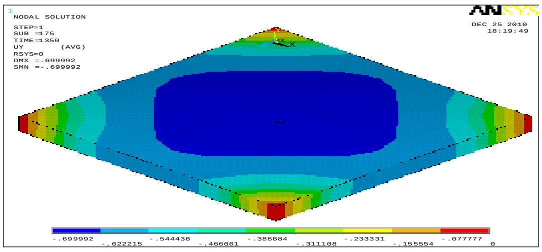
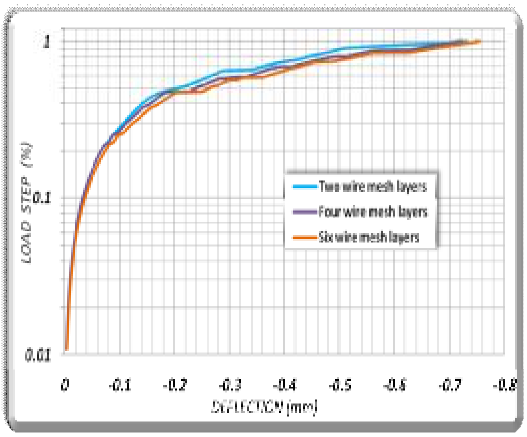


Figure.11 : Deflection distribution for

Figure.12 : Deflection distribution for



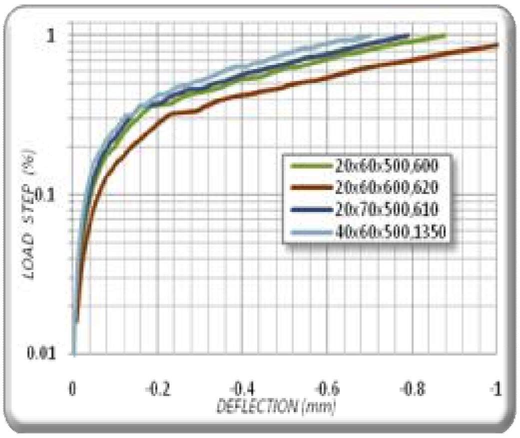


Figure13 : Load deflection relation under distributed loads

Figure14 : Load deflection relation with four wier mesh layers under distributed