Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (39) No. (1) January, 2017

FEASIBILITY OF USING SELF COMPACTING CONCRETE IN CIVIL ENGINEERING APPLICATIONS

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خطة البحث:-

يهدف هذا البحث إلى دراسة استخدام الخرسانه ذاتيه الدمك في تطبيقات الهندسه المدنيه ومن اهم تلك التطبيقات اعمال الانفاق الارضيه ويتناول بحثنا كيفيه انتاج انفاق ارضيه سابقه الصب لتجهيز الانفاق وتركيبها باعتبارها كمرات مفرغه يتم صبها اولا في المعمل مع وجود طرف رباط للحديد لتركب معا في الموقع، وقد تم استخدام الشبك المعدني الممدد والملحوم كحديد تسليح رئيسي كبديل عن صلب التسليح التقليدي.ويشتمل البحث علي برنامج عملي قائم علي صب عدد (١٤) كمرة خرسانية مفرغة ، وكانت المتغيرات محل الدراسه تشمل شكل الكمرات وتخانتها ونوع التسليح وعدد طبقات التسليح وسمك طبقه غطاء الخرسانه بالاضافه الي نسبه احلال لسيلكا فيوم كنسبه من وزن الاسمنت لزياده قوه تحمل الخرسانه و أجريت التجارب المعملية على الكمرات تحت تاثير حمل الانحناء وتشغبل اقصي حمل من خلال تطبيق حمل هيدروليكي حتي حدوث الانهيار ، وقد تم قياس الترخيم عند منتصف الكمرة ، وحساب واستنتاج أحمال التشرخ ، وأقصى حمل وقياس المساحه تحت منحني الحمل والترخيم لقياس الطاقة المختزنة

ABSTRACT:

This research aimed to investigate the feasibility of using self-compacting concrete in civil engineering applications. New construction technique by using precast tunnel as alternative construction to bridge was carried out by reinforced thin hollow beams as permanent precast units to decrease the problems which happened in highway roads due to the difficulty of using crossing bridges especially for children and old people. For this objective, an experimental program was carried out and a finite element model with ANSYS15 was adopted. This paper aimed to evaluate the behavior of thin hollow beams casting with self-compacting concrete. A total of fourteen samples hollow beams were tested in flexure. The main variables taken into consideration in this paper were the type of reinforcement (reinforced bar and steel wire meshes), the types of steel wire meshes (Expanded and welded) and number of layers of steel meshes, concrete cover thickness and the shape of cross section (square or circular).The behavior of the tested thin hollow beams was investigated with special attention to initial cracking ,ultimate load, the deflection under different stages of loading, cracking pattern, energy absorption and ductility index. Good agreement was found compared with the experimental results. Out of this research; this paper presents applications of self-compacted concrete for casting thin structural hollow members. These members can be used as precast units in construction of tunnel which are very useful for developing countries with great economic advantages.

Keywords: self-compacting concrete, wire mesh, thin hollow beams, precast tunnel ANSYS 15, ductility index, energy absorption, economic assessment.

1. INTRODUCTION

The use of self–compacting concrete (SCC) is recommended for all applications. Especially in highly reinforced concrete members like bridge decks or abutments tunnel linings tubing segments, where it is difficult to vibrate the concrete, Dames, underground structures, composite structures, or even for normal engineering structures [2]. The required workability for casting concrete depends on several factors, such as the type of construction the selected placement and consolidation methods, the shape of the form-work and the nature of the reinforcement [3]. The absence of the vibration is decreasing the pressure; the changed consistency dose increases the loads [6].To make SCC interesting for the application in particular as a ready mix concrete, the higher material expenses in comparison to normal concrete must be reduced. Further, it is necessary to cast SCC on the building site reliable and with the accepted level of quality [4]. The characteristic of SCC to flow free segregation into formwork without the requirement for vibration, affects positive the distribution of the concrete strength even in large concrete members [5-7]. The first application of SCC was in a building in June 1990, and then it was used in many applications such as the towers of a pre-stressed cable- stayed bridge in 1991. In 1992, a special type of light weight SCC was used in the main girder of a cable-stayed bridge. Since then the use of SCC in actual structures has gradually increased with the aim that SCC will be the traditional type of concrete.SCC is applied in precast plants, where special conditions are available [6].Atypical application of SCC is the two anchorages of Akashi – kaikyo Bridge opened in April 1998 a suspension bridge with the longest span in the world (1,991meters) [9]. A new construction system, which makes full use of the performance of SCC, the concrete was mixed at the batcher plant beside the site, and was the pumped out of the plant. The use of SCC shortened the anchorage construction period by 20% from 2.5 to 2 years [10].S.Manikandanet. al.[11] presented the flexural behavior of hollow core sandwich beams with different core shape, by using expanded polystyrene foam in tension zone of beams. The results showed an improvement in the behavior of hollow core sandwich beams compared with conventional solid beams.Y.Rudy at. el.[12]conducted an experimental study on fully removed concrete in tensile zone. They studied the affect removed concrete on the flexural mechanical action between tension stress and compression stress of the concrete beam section.As the results, the flexural capacity of the beam decreases.K. Watson and Birman[1] presented a theoretical study on sandwich structures with polymer frame reinforced with hollow core using simple analytical models that describes the contribution to the stability of the structure in hollow at the core.ShiraiA.andOhama[14]used polymer-modified mortar instead of ordinary cement mortar to improve the flexural behavior and impact resistance of ferrocement.Yogendran, V.[15] studied the effect of silica fume in the properties of high-strength concrete. He concluded that the optimum percentage of silica fume is %15 as a replacement of cement content at water-cement ratio of 0.34.

1.2Research significant

This paper introduces a new effective and economic technique for constructing tunnel using permanent precast units casting with SCC. Steel meshes as reinforcement are used as an alternative to ordinary steel bars. The objectives of the experimental program described within this research were (i) studying the behavior of reinforced thin hollow beams cast with SCC under flexure loading. (ii) Studying the effect of the type of reinforcement, types and number of layers of steel wire meshes, shape of cross section and thickness of concrete cover on the structural behavior of tested thin hollow beams. An economic assessment of thin hollow beams as precast tunnel units was discussed. Theoretical analysis will be conducted by ANSIS 15.4 as a finite element package to verify the results of the experimental program.

2. Experimental Program

To evaluate the aim of this study, an experimental program, including the test of fourteen reinforced hollow beams was conducted. Fixed supported hollow beams have 1500mm in length. A square cross section has a dimension 400mm× 400 mm. A circular cross section has a diameter 400 mm. 60mm and 40mm was the cross-section thickness for reinforced by steel bars and steel meshes, respectively. The geometrical and reinforcement details of the tested beams are shown in Table (1) and Figure (1). The following code was used for the sample designation: the first letter defines the shape cross (Q for square cross section and C for circular cross section) the second letter S defines the steel reinforcement, the letter W is for welded steel wire mesh. The letter (ex) is for expanded wire mesh. Letter V defines the cover concrete which is equal 15 mm. the letter r defines the stirrups used with the wire mesh. The number 1 for one layer wire mesh and the number 2 for two layers wire mesh.

Table [1] Details of the tested specimens

Designation of Beam	Reinforcing wire Mesh			Steel Reinforcement		Thickness (mm)	Length (mm)	Concrete cover (mm)	Total weight of steel (Kg)
	Type	No. of layers	Vf%	Main	Stirrups				
QS	-	-	-	Φ 8/ 15 cm	ϕ6/20 cm	60	1500	20	6
CS	-	-	-	Φ 8/ 15 cm	ϕ6/20 cm				5.8
Q1w	welded mesh	1	5.2	-	-	40			1.2
C1w		1	5.4	-	-				1.15
Q1ex	expanded mesh	1	6.3	-	-				1.25
C1ex		1	6.5	-	-				1.2
Q2w	welded mesh	2	10.4	-	-				2.4
C2w		2	10.8	-	-				2.3
Q2ex	expanded mesh	2	12.6	-	-				2.5
C2ex		2	13	-	-				2.4
Q1wv	welded mesh	1	5.2	-	-			15	1.2
C1wv		1	5.4	-	-				1.15
Q1wr		1	10.2	-	ϕ6/20 cm			20	2.97
C1wr		1	10.4	-	ϕ6/20 cm				2.92

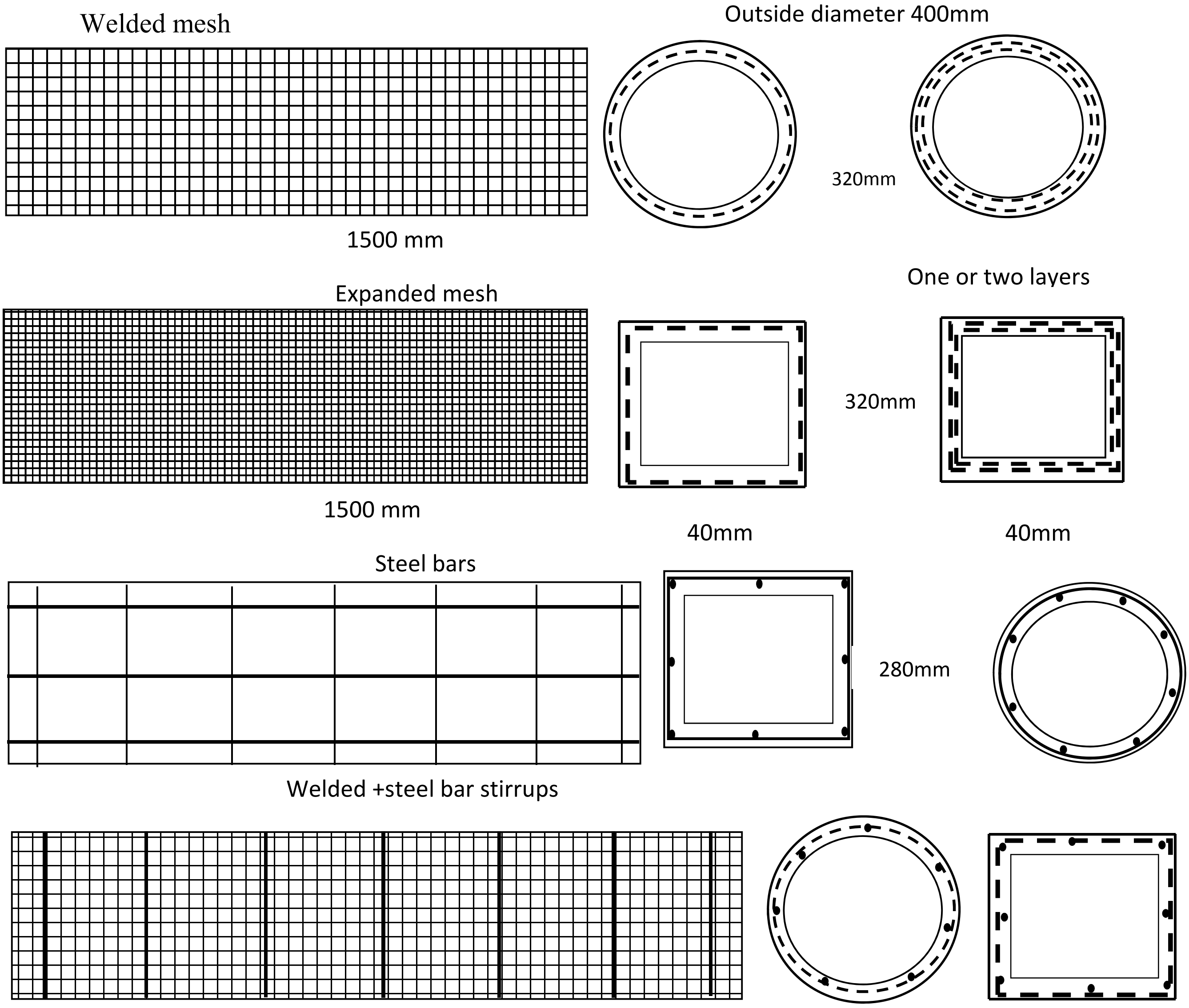


Figure (1) Geometrical and reinforcement details of the tested hollow beams.

2.1 Material Properties

Ordinary Portland cement type (CEMI 42.5N) according to the requirements of E.S.S.4756-11, 2007[16] with a specific gravity of 3.15 and a specific surface area (Blaine fineness) 3700cm²/gm. was used. Locally produced identified Silica Fume(S.F.) was delivered in 25-Kg sacks according to the manufacturer; the powder had an average particle size of 0.1 micrometer, specific surface area 170000 cm2/gm. and specific gravity of 2.2.Natural siliceous sand was used as fine aggregate throughout the current research. The fine aggregates used was obtained from Suez zone with 2.62 specific gravity and 2.67 fineness modulus of and the percentage of particles finer than sieve No. 200 resulted absorption percentage of 0.79%.Coarse aggregate (dolomite) with a nominal size of 10 mm was used, with a specific gravity 2.64 and absorption value of 1.8%.High range water reducer (HRWR) of a synthetic type dispersion base was used to improve the mixes workability. HRWR complies with ASTM C494 Type A&F, [17]. Expanded metalwiremesh of 0.7 mm in diameter and 12.7 x 12.7 mm in spacing was used. Welded steel wire mesh of 2.7 mm in diameter and 25 x 25mm in spacing was used. Tensile tests on welded steel wire mesh and expanded metal wire mesh were carried out. The proof stress for welded steel wire meshes and expanded metal wire meshes was 315 and 210 MPa, respectively. The ultimate tensile strength for welded steel wire meshes and expanded metal wire mesheswere600 and 315MPa, respectively. These values comply with of ACI 549.1R-97, [18].Mild steel rebra (nominal diameters 8 mm) was used as reinforcement. The rebar had yield and ultimate tensile strength of 292 and 455 MPa, respectively. Mild steel rebar was used for stirrups (nominal diameters 6 mm) with yield strength and ultimate tensile strength of254 and 390MPa, respectively.

2.3Casting and testing procedures

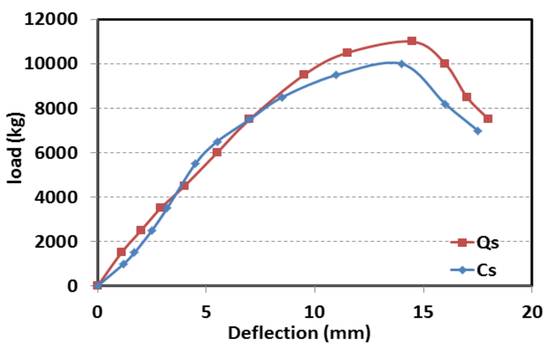
Table [2] Mix proportions (Kg/m3)

Mix code	cement	Sand	Dolomite	VEA	S.F.	Water	W/c*	Compressive strength (kg/cm2)		
								3 days	7 days	28 days
M1	400	838	686	4.25	21.25	148.5	0.35	255	290	440

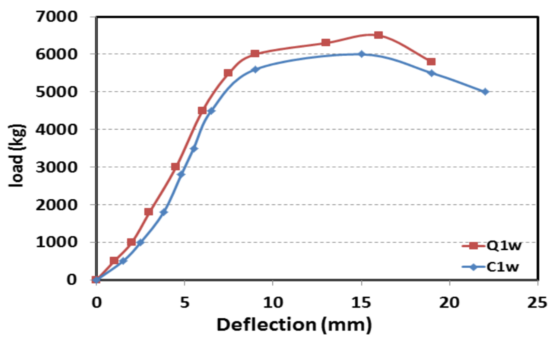
3. Results and Discussion

3.1Effect of shape of cross section

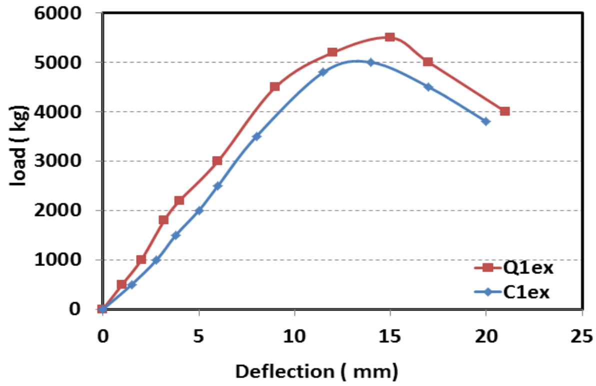
The effect of cross section thin hollow beams was studied. Figure (4-a) shows the effect of shape for hollow beams reinforced with steel bars. The shape showed a difference , 9% in the ultimate load, and 8 % in the energy absorption. Figure (4-b&c) shows the effect of shapes for hollow beams reinforced with steel meshes. The stirrups showed a difference of 7 % in the first cracking load, 6% in the serviceability load, 8% in the ultimate load, and 8 % in the energy absorption. Square section is better than circular section in case of using one layer meshing steel.



(a) Control specimens



(b) Specimens reinforced with welded wire mesh



(c) Specimens reinforced with expended wire mesh

Figure (4) effect of shape of cross section

3.2Effect of number of mesh layers

The effect of number of mesh layers of thin hollow beams was studied. Figure (5) shows the effect of number of mesh layers for hollow beams reinforced with mesh steel. The study showed a difference 19% in the ultimate load, and 35 % in the energy absorption for square sections reinforced with one &two layer welded mesh. Figure(6) shows the effect of number of mesh layers for circular section reinforced with one &two layers of welded mesh showed a difference 28% in the ultimate load, and 30 % in the energy absorption. Figure (7) for square sections reinforced with one & two layers of expanded mesh a difference 22% in the ultimate load, and 27 % in the energy absorption. Figure (8) For circular section reinforced with one &two layers of Expanded mesh showed a difference , 22% in the ultimate load, and 25.3 % in the energy absorption.

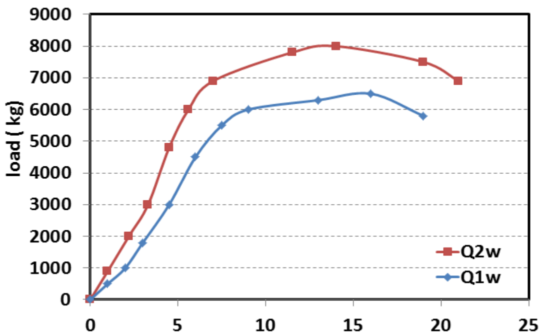


Figure (5) Effect number of layer for square section reinforced with welded wire mesh

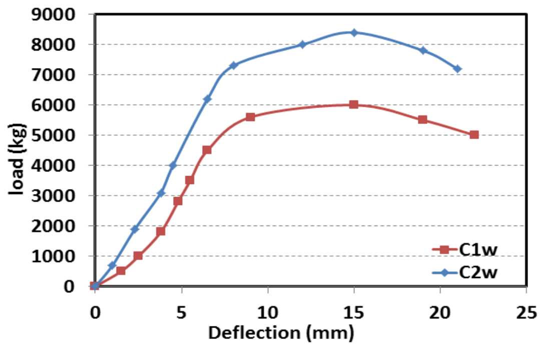


Figure (6) Effect number of layer for circular section reinforced with welded wire mesh

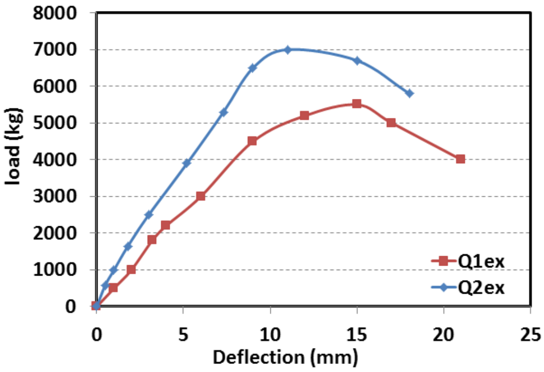


Figure (7) Effect number of layer for square section reinforced with expanded wire mesh

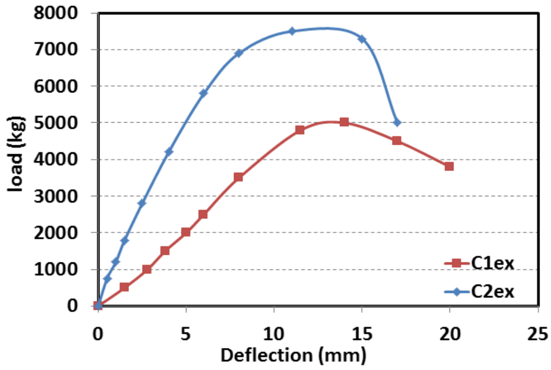
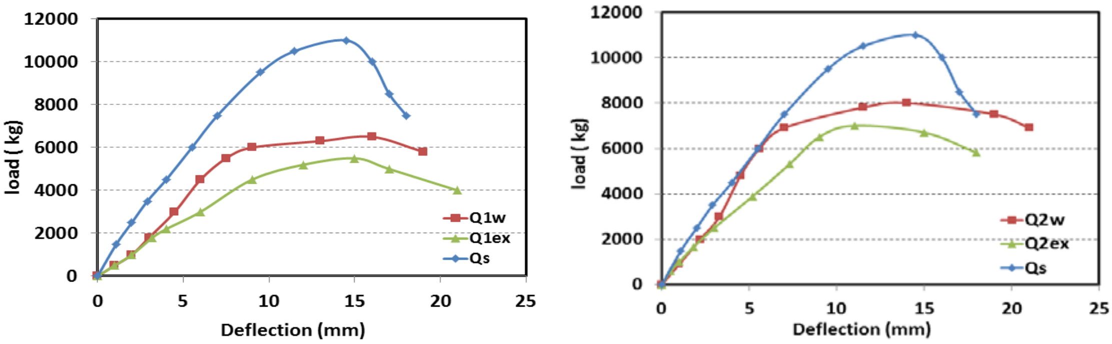


Figure (8) Effect number of layer for circular section reinforced with expanded wire mesh

3.3 Effect of type of reinforcement.

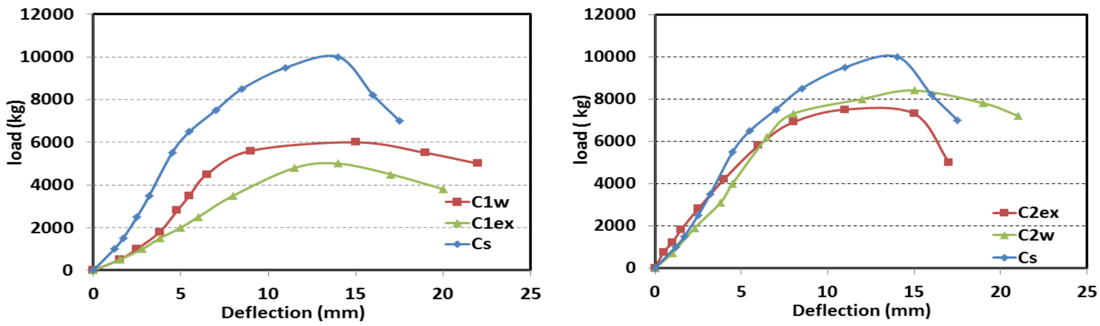
The effect of type of reinforcement of thin hollow beams was studied. Figures (9a&9b) show the effect of type of type reinforcement For square sections reinforced with one layer of Expanded mesh a difference -50%& -41% respectively in the ultimate load to sections reinforced with steel bars. For square sections reinforced with one layer of welded mesh a difference -50%& -39% respectively in the ultimate load to sections reinforced with steel bars. For square sections reinforced with two layers of expanded mesh a difference , 22% in the ultimate load, and 27 % in the energy absorption.

Figures (10a&10b) show the effect of two layers of mesh For circular section reinforced with two layers of welded mesh showed a difference -25%&-16respectively in the ultimate load,For circular section reinforced with two layers of Expanded mesh showed a 22% in the ultimate load, and 25.3 % in the energy absorption



(a) One layer mesh **(b) Double layers meshes**

Figure (9) effect of types of reinforcement for square sections



(a) One layer mesh **(b) Double layers meshes**

Figure (10) effect of types of reinforcement for circular sections

3.4 Effect of concrete cover

The effect of concrete cover for thin hollow beams was studied. Figures (13 and 14) show the effect of decrease concrete cover. For square sections reinforced with one layer of welded mesh and concrete cover 15mma difference 10% in the ultimate load, and 23 % in the energy absorption. For circular section reinforced with one layer of welded mesh showed a difference 10% in the ultimate load, and 25.3 % in the energy absorption

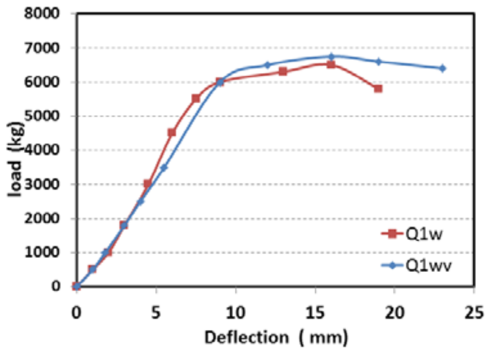


Figure (13) Effect of concrete cover for square section

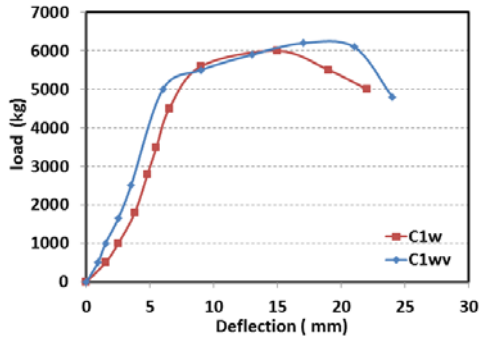


Figure (14) Effect of concrete cover for circular section

3.5Effect of using steel stirrups to one layer welded mesh

Figure (15&16) show the effect of using steel stirrups for reinforced with welded steel mesh was studied. The using of steel stirrups has effect on the shape of cracks it was near center and horizontal

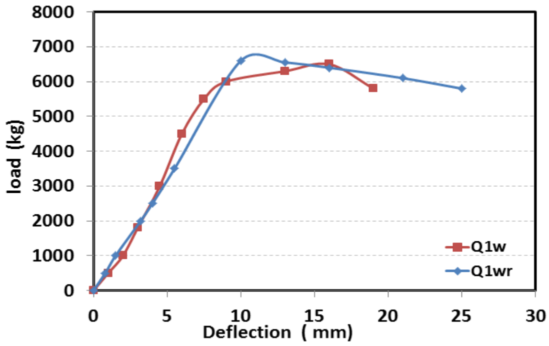


Figure (15) Effect of using steel stirrups for square section

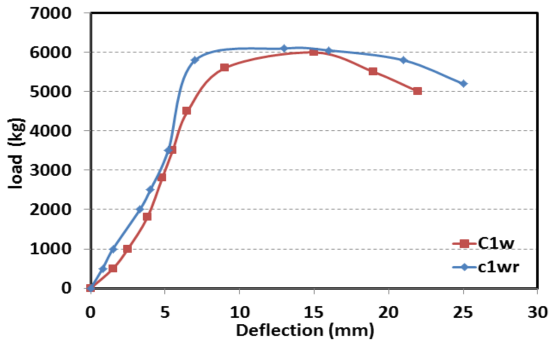


Figure (16) Effect of using steel stirrups for circular section

Table [3]Test results for the Thin hollow beams.

Beam code	First crack load (kg)	Ultimate load (kg)	Deflection (mm)		Δu/Δy	Energy absorption (kg.mm)
			Δy	Δu		
Qs	3500	11000	4.7	15	3.14	81000
Cs	3200	10000	4.9	15.5	3.125	75000
Q1w	1900	6500	4.7	16	3.42	84000
C1w	1800	6000	4.2	14	3.33	93000
Q1ex	1600	5500	4.3	14.5	3.43	69000
C1ex	1500	5000	4	13.5	3.33	71000
Q2w	2280	8000	3.3	11.5	3.5	129500
C2w	2380	8400	3.1	11	3.52	135100
Q2ex	2330	7000	4	12	3	92000
C2ex	2140	7500	3.6	12.5	3.5	95000
Q1wv	1800	6750	4	15	3.75	110000
C1wv	1600	6200	3.6	14	3.875	115000
Q1wr	1750	6600	3.55	13.5	3.77	120000
C1wr	1500	6100	3.7	15	4.06	117000

3.6 Ductility index and Energy absorption

The test results are listed in Table 3. The table shows the obtained experimental results for each specimen as well as the average ultimate failure load, the first crack load, service load, ductility ratio, and energy absorption properties for each group. Ductility ratio is defined here in this investigation as the ratio between the mid-span deflection at ultimate load to that at the first crack load (Δu/Δy), while the energy absorption is defined as the area under the load-deflection curve. Computer program (BASIC language) was used to calculate the area under curve by integrated the equation of the load-deflection curve for each beam specimens as follow: ultimate load Energy absorbed=$\int_0^{\Delta u} L(\Delta)d\Delta$; Where L (Δ) is the equation of load-deflection curve, and Δu is the mid-span deflection at ultimate load. Service load, or flexural serviceability load, is defined as the load corresponding to a deflection equal to span/350

The value of ductility index and energy absorption for all beams is presented in table 3and figures 21 and 22.It was observed the ductility behavior of circular hollow beams is better than of square beams. Also the beams reinforced with wire meshes had ductility ratio more than with steel bar. The ductility ratio for the test specimens ranged from 3.0 to 4.06.
The energy absorption ofbeams reinforced with mesh steelwas higher than that with steel bar. The serviceability load, ductility index and energy absorption showed change with the number of layers of reinforced mesh. This illustrates the effect of the stiffness of the beams.

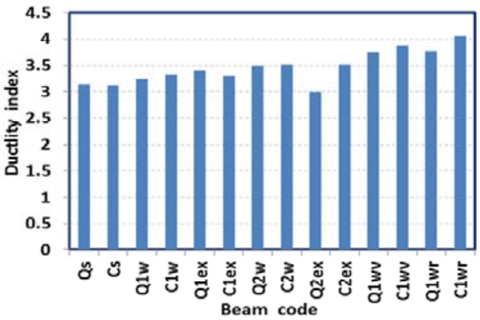


Figure (19) Ductility index of tested thin hollow beams

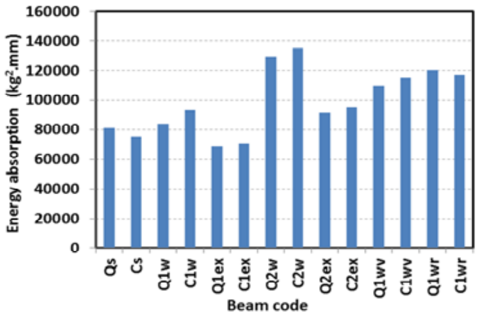


Figure (20) Energy Absorption of tested thin hollow beams

4. Crack pattern

Initial stages of loading, all beams were un-cracked beam. When the applied load reached to the rupture strength of the concrete on specimen, the concrete started to crack the failure pattern in the all tested beams was observed as failure. Crack patterns and failure modes are shown in figure (21)

Figure (21) Cracking Pattern of Tested Beams.

5. Finite Element Model

A finite element package (ANSYS version 15), was used to simulate the behavior of hollow beams. Two types of elements were used; solid 65 and link 8. Figure (22) shows the SOLID65 3-D Reinforced Concrete Solid. Link 8 (figure 24) was defined by two nodes, the cross-sectional area, an initial strain, and the material properties as shown in Figure 23. The element x-axis is oriented along the length of the element from node I toward node J. Figures 25-28 show some theoretical results for the ANSYS program.

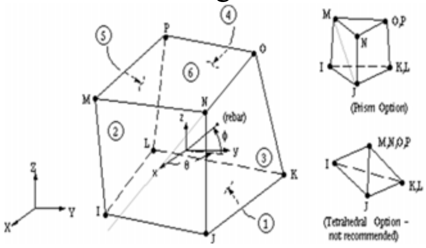


Figure (22) SOLID65 3-D Reinforced Concrete Solid

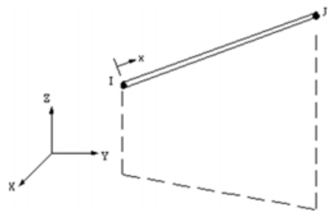


Figure (23) LINK8 3-D Spar

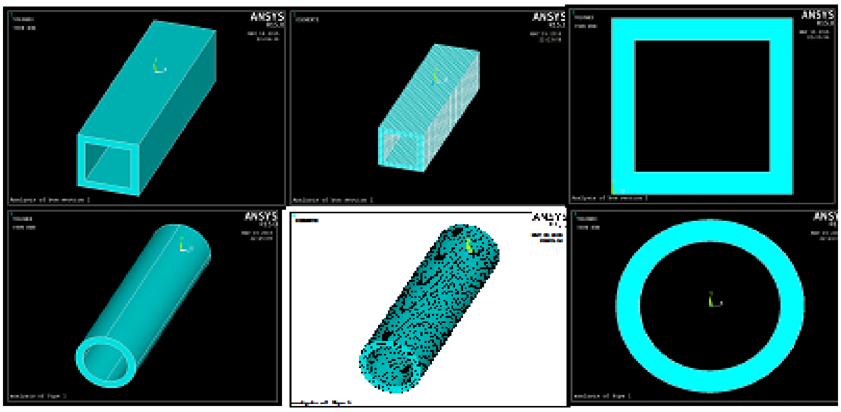


Figure (24)The Configuration of thethin hollow beam.

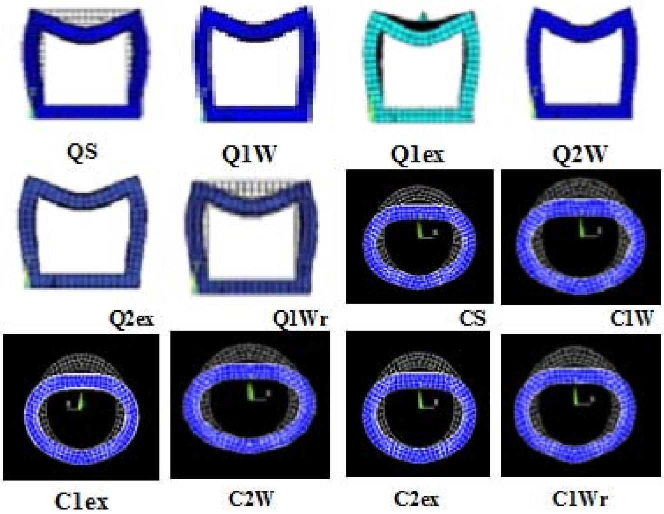


Figure (25) displacement of tested specimens

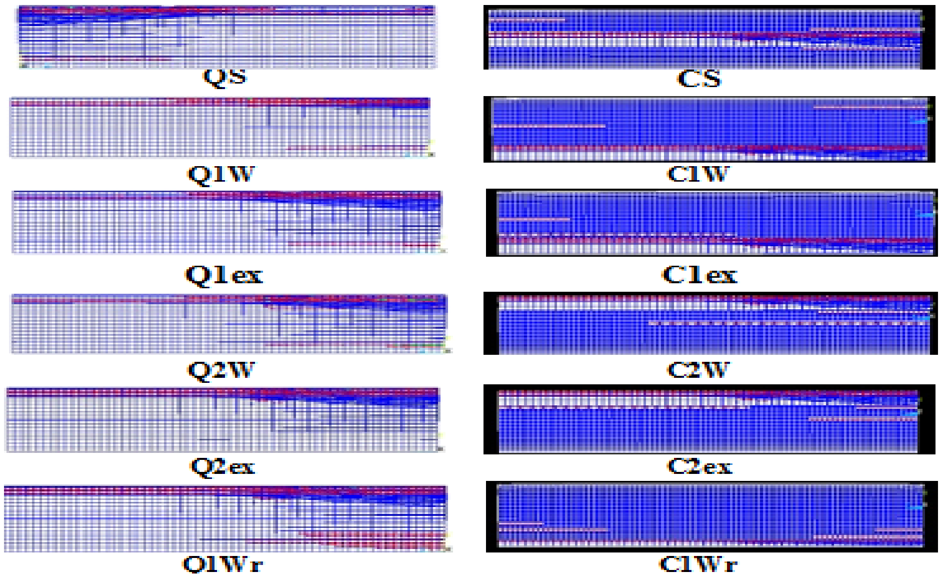


Figure (26) cracks patterns of tested specimens

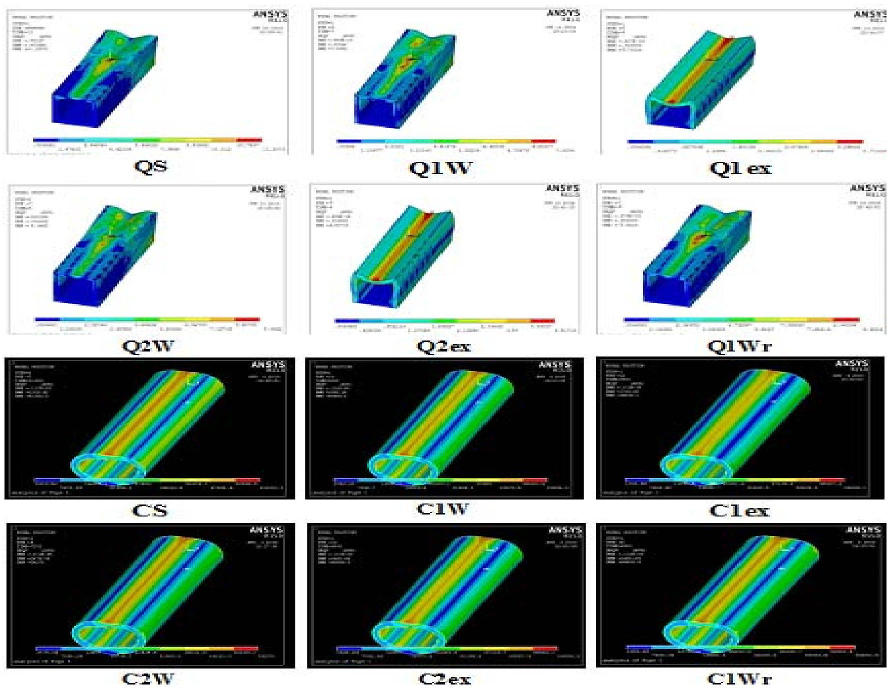


Figure (27) von mass stress for tested hollow beams

6. Economic assessment of thin hollow beams as precast tunnel units

To solve the problem of several accidents which always happen in high way roads due to people passing throw these roads because they have difficulty to use bridges. For example one of these bridges has125 steps in every side.As an application could be achieved use the thin hollow beam as precast units for construction the tunnel is considering an alternative solution instead of theses bridges. This application can be save time in casting in the site and to save much money to establish alternative road.Because we can use the same road without any stop period and avoiding traffic jam. Tables [4] and [5] illustrate the time table for conventional construction of tunnel and the suggested method. Figure (26) shows the details of suggested method.

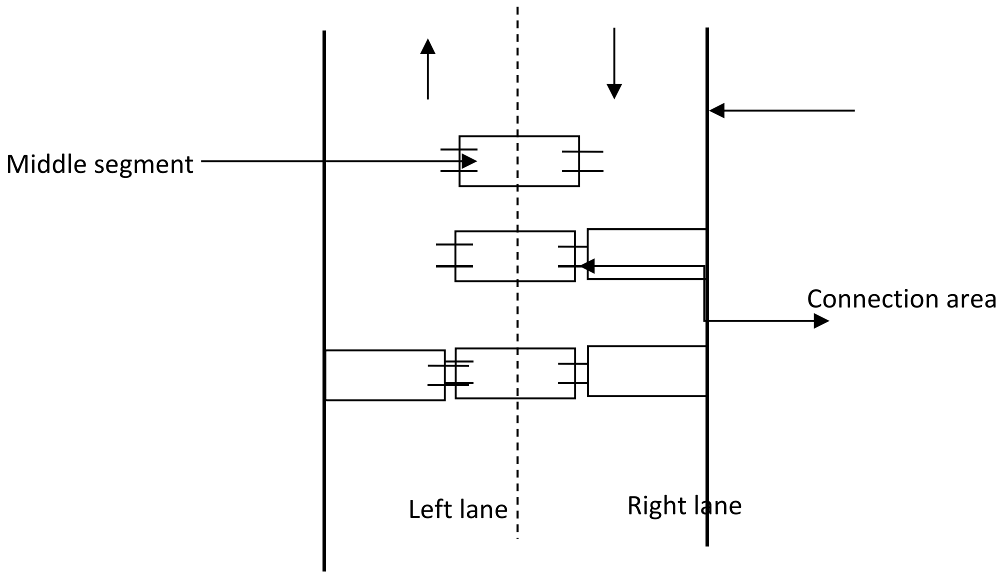


Figure (28) Geometric shape for suggestion method

Table [4] cost comparison of thin hollow beam

code	Volume m^3	concrete						reinforcement						
		Cement kg	Sand kg	Dolomite kg	s.f kg	v.c kg	Co	No.of layers	area	Price/m2	No.of bars	Price/bar	length	Total cost
Qs	0.144	55	122	98	6	1.1	150	-	-	-	8	63	1.5	213
Cs	0.052	20	44.3	35.3	2	0.4	65	-	-	-	8	63	1.5	128
Q1w	0.096	36.8	81.8	65	4	0.74	86	1	2.4	16.8	-	-	1.5	102.8
C1w	0.038	15	32.4	25.8	1.6	0.3	40	1	1.875	13.125	-	-	1.5	53.125
Q1ex	0.096	36.8	81.8	65	4	0.74	86	1	2.4	16.8	-	-	1.5	102.8
C1ex	0.038	15	32.4	25.8	1.6	0.3	40	1	1.875	13.125	-	-	1.5	53.125
Q2w	0.096	36.8	81.8	65	4	0.74	86	2	4.8	33.6	-	-	1.5	119.6
C2w	0.038	15	32.4	25.8	1.6	0.3	40	2	3.75	26.25	-	-	1.5	66.25
Q2ex	0.096	36.8	81.8	65	4	0.74	86	2	4.8	33.6	-	-	1.5	119.6
C2ex	0.038	15	32.4	25.8	1.6	0.3	40	2	3.75	26.25	-	-	1.5	66.25
Q1wR	0.096	36.8	81.8	65	4	0.74	86	1	2.4	16.8	2	20	1.5	122.8
C1wr	0.038	15	32.4	25.8	1.6	0.3	40	1	1.875	13.125	2	20	1.5	73.125

Table (5) time table for conventional method

code	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week	17th week	18th week
Mobilization																		
Cutting asphalt																		
Excavation																		
Fixing floor form work																		
Fixing floor steel																		
Casting floor																		
Fixing walls form work																		
Fixing walls steel																		
Casting walls																		
Fixing roof scaffolding																		
Putting roof form work																		
Fixing roof steel																		
Casting roof																		
Removing scaffolding																		
Removing shuttering																		
curing																		
Painting inside tunnel																		
Fixing asphalt																		

Table (6) time table for suggestion method

code	First week	2nd week	3rd week
Excavation +putting middle segment			
Right segment+casting overlap conection			
Left segment+casting overlap conection			
covering			

7-Conculsions

The following conclusions could be drawn from the results of the paper carried out to evaluate the behavior of thin hollow beams casting with self-compacting concrete:

1. The properties of fresh self-compacted concrete decreased with the increase of percentage of silica fume as replacement of cement content.

2. The optimum ratio of silica fume improve the properties of hardened self-compacted concrete was 10% as a replacement of cement content.
3. The ultimate load decreased for the circular cross section by 8 % compared with the square cross section in case of using one layer mesh. On the other hand an improvement was recorded for using two layer mesh for circular cross section that ultimate load increased by 6 % compared with square cross section.
4. Using welded wire mesh improves the behavior of hollow beams compared with expanded welded wire mesh as The energy absorption and ductility index was increased by 25 % and 10 %, respectively for cross sections reinforced with welded mesh compared with cross sections reinforced with Expanded mesh
5. Using welded metal mesh increases ductility index and improve the energy absorption by 38 % than obtained when using skeletal steel bars which lead to increase resistance to earth quick and impact.
6. Using stirrups of mild steel bars with one layer welded metal mesh leads to increase number of cracks and consequently increase ultimate load by 10% than that obtained when using only one layer without rings which lead to increase construction age.
7. For the specimens reinforced with one layer welded wire mesh, the ultimate load decreased by 40% compared with hollow beam reinforced with steel bars
8. The ultimate load decreased by 16% for hollow beams reinforced with two layer welded wire mesh compared with hollow beams reinforced with steel bars.
9. For the specimens with one layer welded steel wire mesh, the ultimate load increased by decreasing the concrete cover in beams reinforced with welded one layer mesh increase ultimate load by 10%.
10. Good agreement was found compared with the experimental results.
11. Suggestion method in fixing precast tunnel cheaper and save time three times and six times respectively than ordinary method.
12. These results clarify that there is increase in the ultimate load is 2.5 % at slight increasing in the total cost.

References

[1] **Housing and Building Research Center**, Strength of Material and Quality Control Department, "State of the Art-Report on Self-Compacting Concrete" October 2002.

[2] **Y.Klug, K.Holschemacher**, "Material properties of Hardened Self-compacting Concrete ", 2003
http:/aspdin.wifa.uni.-leipz[g.de/institute/lacer/lacer07/107_13pdf

[3] **K. H. Khayat, K. Manai, and A. Trudel,** "In Situ Mechanical Properties of Wall Elements Cast Using Self-Consolidating Concrete", ACI Materials Journal, V.94, No.6, November – December 1997, page 491.

[4]**TiloProske, Carl-Alexander Graubner**, "Self-Compacting Concrete-Pressure on Formwork and Ability to Deareat", PHD, Darmstadt, 2002
http://www.darmstadt-concrete- de/2002/deaerate.html.

[5]Khayat, K. H., Manai, K., Trudel,A., "In suit Mechanical Properties of wall Elements Cast Using Self-Consolidating Concrete", ACI Materials Journal 96, No.2, March-April 1997, PP.491-500.2000
[6] SabryBdelReheem Ahmed Abdel Hady, "Review Article on self compacting concrete ", May 2003
[7] Vanhove, J.,"Proceedings of the Second International Symposium ofSelf-Compacting Concrete", Coms Engineering Coporation, Fukui, Japan, 2001.
[8]Skarendahi,A., "Self-Compacting Concrete in Seweden, in Proceedings of International Symposium of Self-Compaction Concrete", Kochi, Japan, 1998.
[9] Ozawa, k.(editor), et al.,"proceeding of the International Workshop on Self-Compaction Concrete", Japan Society of Civil Engineers, March, 1999.
[10]MasahiroOUCHi "self-compaction Concrete Development,Applications and Investigations",http://www.is/ncr/publications/doc-23-3pdf.2000
[11]S.Manikandan, S.Dharmar and S.Robertravi "Experimental Study On Flexure Behavior Of Reinforced Concrete Hollow Sandwich Beams"P.S.R. Engineering College, International journal.vol.No.4 p.45-60-india.march2015
[12]Rudy Djamaluddin, Yasser Bachtiar and RitaIrmawati 2014."Effect of the Truss System to the Flexural Behavior of the External Reinforced Concrete Beams" International Journal of Civil, Architectural, Structural and Construction Engineering Vol:8No:6
[13]C.Kocher, W.Wtson, M.Gomez, and V.Birman 2002, "Integrity of Sandwich panels and beams with truss-reinforced cores"Journal of Aerospace Engineering , ASCE,University of akron ,USA, vol.15,no.3,pp.111-117
[14]Shirai,A.,andOhama,Y.,"Improvement in Flexural Behavior and Impact Resistance Of Ferrocement by use of Polymers"Journal of ferrocement Vol.20,No.03,July,1990,pp.247-264
[15]Yogendran, V.,Langan, B.W.,Haque,M.N.,and Ward, M.A.,"Silica Fume In High Strength Concrete, "ACI Materials Journal ,Title No.87-M51,March-April,1987,pp.124-129.
[16] Egyptian Standards Specification, E.S.S, 4756-11, 2007, (physical and mechanical properties examination of cement, part 1), Cairo, 2007.
[17] ASTM C494/C 494M,Standard Specification for Chemical Admixtures for Concrete, Annual Book of ASTM Standards 2001, 04, 02, p.9.
[18] ACI Committee 549. State-of-the-Art report on ferrocement". ACI549-R97, in manual of concrete practice. ACI, Detroit, 1997, 26pp..(reapproved 2009)