An Experimental Study on using Lightweight Web Sandwich Panel as a Floor and a Wall

Nahro Radi Husein, V. C. Agarwal, Anupam Rawat

Abstract- This experimental investigation was focused on the strength capability of lightweight web sandwich panel (LWSP). This study deals with the LWSP's strength under flexural loading (one point load & third point load) by treating these LWSPs as a floor and also, studying LWSP strength under axial load by treating these LWSPs as a wall. Thirteen specimens of LWSP was casted in this study with size of (500 mm*400 mm*100 mm), with core size of (450 mm*105mm*60 mm), three prism core are used in each panel. Ten specimens are LWSP with aerated concrete as a core and three LWSP with thermocol as a core which are encased by ferrocement with difference water cement ratio (w/c) and difference waterproofing admixture. The performance of the LWSP is investigated in terms of first crack load, load-deflection curve for flexural load with (one point loading and third point loading), modules of rupture, ultimate flexural load, axial load-deformation curve and the failure mode. The unit weight of the LWSPs which have aerated concrete as a core is (1850-1950) Kg/m3 and the unit weight of the LWSPs which have thermocol as a core (1250-1300) Kg/m3.

Keywords- Aerated Concrete, Ferrocement, Lightweight Web Sandwich Panel (LWSP), sandwich, Thermocol.

I. INTRODUCTION

Lightweight pre-fabricated sandwich structural elements in building construction is a growing trend in construction all over the world due to its high strength-to-weight ratio, reduced weight, and good thermal insulation characteristics. Sandwich construction element consists of encasement of high performance material and a thick lightweight and low strength material as core. Ferrocement is regarded as highly versatile thin material possessing superior properties. Aerated concrete is a cellular lightweight material which exhibits relatively higher strength than the conventional core materials.

Sandwich composite structure possesses excellent flexural and shear properties. Their inherent lightweight characteristics make them ideal structural components where weight reduction is desirable (Serrano et al., 2007). Thus structural sandwich panels are becoming important elements in modern lightweight construction.

In concrete construction, self-weight of structure itself represents a very large proportion of the total load on the structures (Mouli and Khelafi, 2006) thus, reduction in the self-weight of the structures by adopting an appropriate approach results in the reduction of element cross-section, size of foundation and supporting elements therebyreduced overall cost of theproject.

Manuscript Received November, 2013.

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The lightweight structural elements can be applied for construction of the buildings on soils with lower load-bearing capacity (Carmichael, 1986).Reduced self-weight of the structures using lightweight concrete reduces the risk of earthquake damages to the structures because the earth quake forces that will influence the civil engineering structures and buildings are proportional to the mass of the structures and building. Thus reducing the mass of the structure or building is of utmost importance to reduce their risk due to earthquake acceleration (Ergul et al., 2004). Among the other advantages, its good thermal insulation due to the cellular thick core makes it an ideal external construction component (Bottcher and Lange, 2006). Some recent investigations suggest their excellent energy-absorbing characteristics under high-velocity impact loading conditions (Villanueva and Cantwell, 2004).

Ferrocement has been regarded as highly versatile construction material possessing unique properties of strength and serviceability. Its advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance, and environmental stability cannot be matched by any other thin construction material (Naaman, 2000). As an alternative construction material, ferrocement has not gained widespread acceptance in both; developed countries in general and developing countries in particular. Its acceptance is hindered mainly due to its small thickness and labor intensive method of production (Abang, 1995). In order to cope with the problem of thickness, one of the options currently suggested isto develop ferrocement sandwich elements. This technique provides not 2 only the thickness but makes the sandwich element lightweight and good heat insulating. Sandwich panel is a three-layer element comprising of two thin, flat facing plates of relatively higher strength material and between which a thick core of relatively lower strength and density is encased or it could consists of thin skin box of relatively higher strength material in-filled with relatively weaker and lower density material known as core. These have been used in the aerospace industry for many years and more recently they are being used as load bearing members in naval structures (Mahfuz et al., 2004). Presently, it has gained attention to be used as an effective structural form in the building and construction industries.

Aerated concrete refers to concrete having excessive amounts of air voids. These air bubbles are created to reduce the density of the concrete and to make it lightweight, which provides good thermo-acoustic insulation too. However, aerated concrete, which is a porous material and classified as cellular construction material exhibits low compressive strength and high rate of water absorption (Arreshvhina and Zakaria, 2002). It can be used as a potential material for core in sandwich composite because of its relatively more compressive strength compared to the traditional lightweight core materials like foam.

Attention has not been paid in order to investigate its suitability as core material in sandwich construction. Most recently, its application as core material in FRP-AAC sandwich panels has been reported so far (Nasim*et al*., 2006). However, the literature is silent about its application as core in cement-based sandwich composite structural panels.

II. REVIEW OF LITERATURE

T. Chandra Sekhar Rao et al., [2012] have an experimental study on the strength and behavioral aspects of cored ferrocement box-beams for precast purposes. As these beams are lighter in weight, they find their place in seismic resistant design of structures.SalihuddinRadinSumadi et al., [2008] havedeveloped two mathematical models to predict compressive strength of high workability slag-cement based mortars and the ultimate load of ferrocement encased aerated concrete sandwich wall elements. The values predicted from the mathematical models were 95%-100% accurate to the experimental results.Ade S. Wahyuni et al., [2012] have an investigation of new lightweight sandwich reinforced concrete (LSRC) section using prefabricated autoclaved aerated concrete (AAC) blocks as infill in the section where concrete is considered ineffective under bending. T. Chandra Sekhar Rao et al., [2012] have an experimental study on the strength and behavioral aspects of cored ferrocement box-beams for precast purposes. Have proposedan empirical formula based on the layers of wire mesh for the ultimate moment capacity of box-beam.Jalal A. Saeed et al., [1997]have experimentally studying on the behaviour and flexural strength of ferrocement one way slabs with square openings under two point loads taking into consideration number of wire mesh layers and size of the openings as variables.

III. OBJECTIVE OF THE STUDYING

The main objectiveof this investigation is

1. To produce aerated concrete with normal lightweight density which is between (1200-1600) Kg/m^3
2. To study the lightweight web sandwich panel's (LWSP) behaviour which isConsist of two core material aerated concrete and thermocol, encased by ferrocement.
3. To investigate the LWSP strength capacity under flexural load (one point loading & third point loading) by using the LWSP as a floor and also investigate the LWSP strength under axial loading using the LWSP as a wall. Then study the modules of rupture, flexural load-deflection curve, lateral deformation in both side left and right under axial load, first crack load and ultimate load.
4. To study the effect of water cement ratio and water proofing admixture for ferrocement on the strength capacity of LWSP.

IV. MATERIAL AND METHODOLOGY

A. Materials

Cement: Cement which is used in this study is Portland Pozzolana Cement "Jaypee cement Brand" (PPC).Surpasses the requirements laid down by IS: 1489 Part (I):1991.

Fine Aggregate: For aerated concrete the sand was sieved from 600 micron sieve (0.6 mm). For encasement (ferrocement) the fine sand which is used is passed through sieve 1.18 mm.The gradation was in accordance with the specifications of ASTM C33-03 (2003).

Waterproofing Admixture: The waterproofing admixture which is used is (ENICON – L$^{®)}$ from Star Coatings & Membranes Pvt. Ltd. (As per IS: 2645-1975)

Aluminum Powder:The aluminum (metal) fine powder was used as the gas-forming agent in producing the slag cement based aerated lightweight concrete with minimum assay (99.0 %)Wire Meshes: Square welded wire mesh and square woven mesh were used as the skeletal in ferrocement encasement. Square welded with opening size (17mm*17mm), diameter (1.4mm and 1.2mm)) and weight (1.42 Kg/m^2 and 1.23Kg/m^2) respectively. Square woven mesh opening size is (5mm*5mm) with diameter 0.5mm and weight is (0.77 Kg/m^2).

B. Lightweight Web Sandwich Panel shape, Size and its specification

Aerated concrete and thermocol as a sandwich core dimension:(450 mm x 105mm x 60mm)(Figure 1).

Web sandwich panel dimension:(500mm x 400mm x 100mm)(Figure 2).

Number of mesh layers: (6) layers of chicken wire mesh are used in all panels 3 layers at top and 3 layers at bottom and (1) layer from square woven mesh around the core for aerated concrete only

Curing regime: Water.

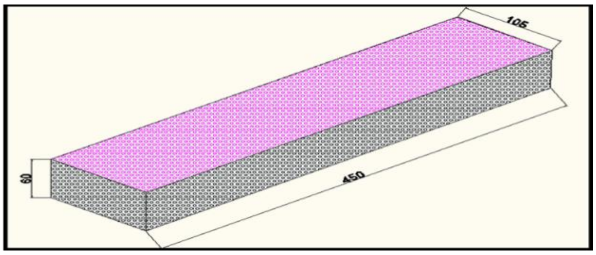

Figure (1)showing Aerated concrete&thermocolas a core for web sandwich panel

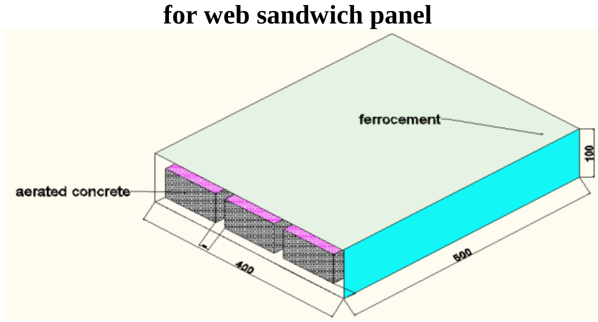

Figure (2)showing web sandwich panel aerated concrete encased by ferrocement

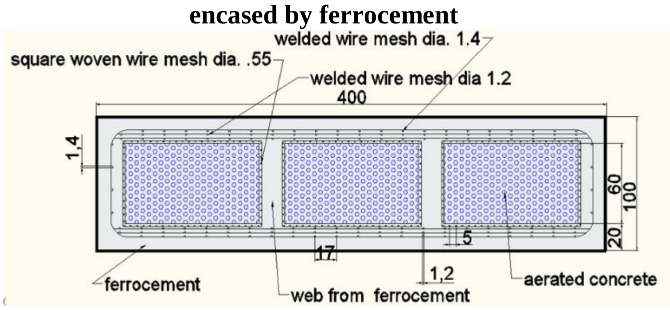

Figure (3) showing the distance and wire mesh detail of the web sandwich panel in front view

V. EXPERIMENTAL PROGRAM

A. Mix proportion for aerated Concrete

Cement:sand ratio is 1:1 and 100% (PPC) cement was used as a binder with water dry mix 0.23 by weight and powder aluminum 0.5 by total dry mix and waterproofing admixture 0.55 of total binder by weight.

B. Aerated concrete preparing procedure

After mixing the material properly so it will be ready for casting.Some significant point during the casting procedure will be mention with following figures as:
The mix was poured in the molds approximately up to 80% of their height. This can be viewed from Figure (4).

Figure (4)

Immediately after pouring the mix in mold, expansion convened and continued for next (30-45) minutes as showed in figure (5).

Figure (5)

1. The specimens became hard enough after 3-4 hours of casting and were ready to be trimmed the expanded portion above the top of the specimens.

After 24 hours the specimens were remolded and covered by square woven as shown in figure (6).

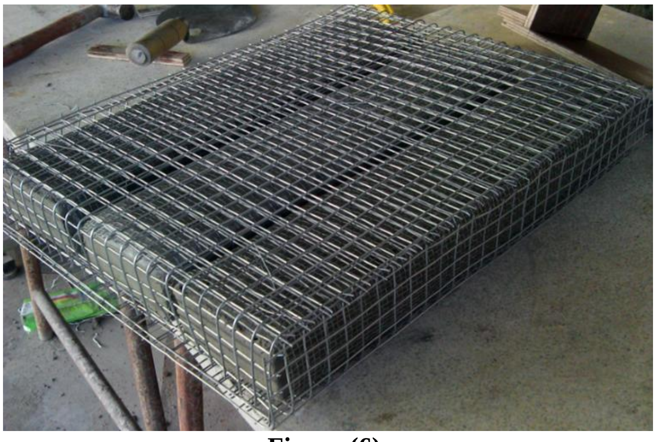

Figure (6)

C. Aerated concrete size, weight and density

The size for each aerated concrete prism was 0.02835 m3 and the weight range for all 30 prisms of aerated concrete which were casted about (3.710 – 4.400) Kg so the density range for all aerated concrete prisms were about (1300 – 1550) Kg/m^3.

D. Mix proportion of mortar for encasement (ferrocement)

Binder: Sand	1:2
PPC	100% of total binder by weight
Sand	Passing through sieve size # 16 (1.18 mm)
Water cement ratio	0.55 , 0.56 , 0.58 and 0.6
Waterproofing admixture (ENICON–L®)	0.4 , 0.5 , 0.6

E. Amount of encasement material (ferrocement) used in each panel

C (Portland Pozzolana Cement) = 6.84 Kg
S (fine Sand) = 16.14 Kg
Weight of wire meshes for encasement in each panel = 1.54 Kg
Total weight for encasement in each panel (dry condition) = 6.84 (cement) + 16.14 (sand) + 1.54 (wire mesh) = 24.52 Kg
Average weight of aerated concrete three prisms in each panel = (12 – 12.27) Kg in each panel.
Total weight of each web sandwich panel = (36.5 – 37)Kg indry condition.
Weight of each web sandwich panel in wet condition = (39.5 – 40) Kg with water.

F. Ferrocement preparing procedure

Afterpreparing aerated concrete prisms which is covered by square woven wire mesh, then put three of aerated concrete prism in the wire mesh box which is prepared earlier. Figure (7) showed the aerated concrete in a wire mesh box ready for casting.

Figure (7)

After casting the ferrocement then after 24 hours the LWSPs were remolded and putted for curing until 28 days.After 28 days LWSPs were tacked outside for testing.

G. web sandwich panel with thermocol as a core

Instead of the aerated concrete as a core thermocol was used. The difference behavior was studied between LWSPs with aerated concrete core and LWSPs with thermocol core with same dimension (105 mm * 60 mm * 450 mm) and encased by same ferrocement specification (3 layer of welded wire mesh at top and 3 at bottom with same cover thickness). The comparison studying which are considered in this experimental studying was in weight, flexural strength (modules of rupture) under flexural loading (one point loading third point loading) and lateraldeformation under axial load using the panel as a wall.

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Blue Eyes Intelligence Engineering
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VI. EXPERIMENTAL TESTING

Thirteen panels of LWSP were casted which ten panels with aerated concrete with difference ferrocement water cement ratio and difference waterproofing admixture and three panels with thermocol core.

A. LWSP's name with its specific testing are explain in following table

Table (1) showed specimens names with tests

sample name	Core Material	W/C	admix.	Type of testing
S1A	Aerated	0.55	0.4	Flexure (tow point load)
	Aerated	0.55	0.4	Flexural (one point load)
	Aerated	0.55	0.4	Axial load
S2A	Aerated	0.6	0.4	Flexure (tow point load)
	Aerated	0.6	0.4	Flexural (one point load)
	Aerated	0.6	0.4	Axial load
S3A	Aerated	0.55	0.5	Flexural (one point load)
S4A	Aerated	0.56	0.5	Flexure (tow point load)
S5A	Aerated	0.56	0.6	Flexure (tow point load)
S6A	Aerated	0.58	0.5	Flexural (one point load)
S7TH	thermocol	0.6	0.4	Flexural (one point load)
	thermocol	0.6	0.4	Flexure (tow point load)
	thermocol	0.6	0.4	Axial load

Figure (8) LWSP under flexural loading for testing purpose

VII. RESULT AND DISCUSSION

A. Flexural strength with one point loading

Chart (1) flexure testing results for sample S1A, S3A,S6A and S2A which have an aerated concrete core encased by ferrocement with w/c = 0.55, 0.55, 058 and 0.6 respectively.With waterproofing admixture = 0.4, 0.5, 0.5 and 0.4 respectively.

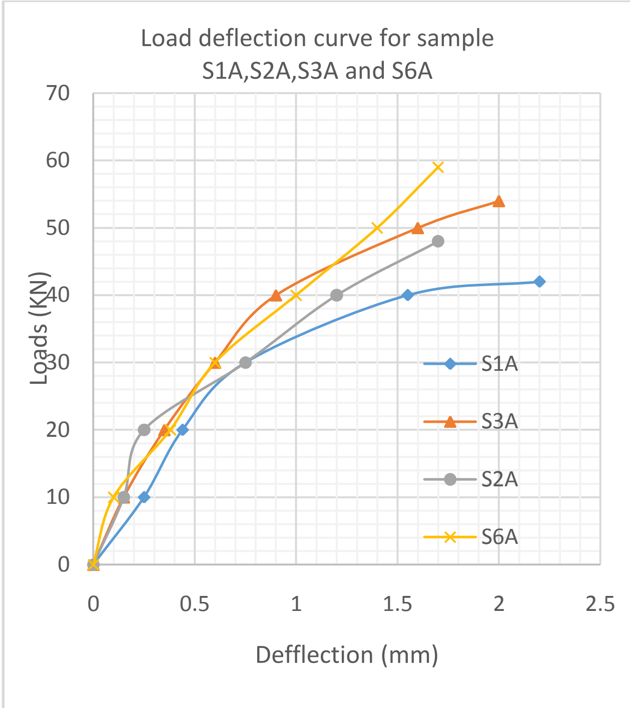

Chart (1)

The chart (1) showed that the panel with w/c = 0.58 and waterproofing admixture = 0.5 has a good resistant against flexural one point loading.

Next chart showed the difference in load and deflection between two web sandwich panels under one point flexural load, one has aerated concrete as a core and another has thermocol as a core with same ferrocement w/c = 0.6 & waterproofing admixture = 0.4

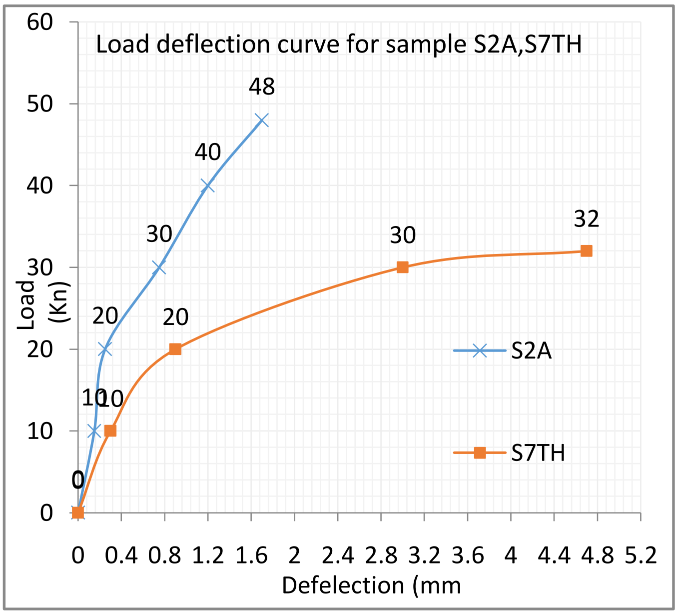

Chart (2)

The chart (2) showed that the LWSP with aerated concrete has a resistant against flexural one point loading about 33% more than LWSP with thermocol.

Table (2) showed the LWSPs under flexural one point loading first crack load and ultimate with deflection and modules of rupture

Table (2)

specimen name	first crack load (KN)	first crack def. (mm)	ultimate load (KN)	Ultimate crack Def. (mm)	modules of rupture (Mpa)
S1A	31	0.95	42	2.2	4.2
S2A	38	0.95	48	1.7	4.8
S3A	45	1.1	54	2	5.4
S6A	48	1.4	59	2.3	5.9
S7TH	20	0.9	32	4.7	2.97

B. Flexural strength with third point loading

Chart (3) flexure testing results for sample S1A, S2A,S4A and S5A which have an aerated concrete core encased by ferrocement with w/c = 0.55, 0.6, 0.5 and 0.5 respectively.With waterproofing admixture = 0.4, 0.4, 0.5 and 0.6 respectively.

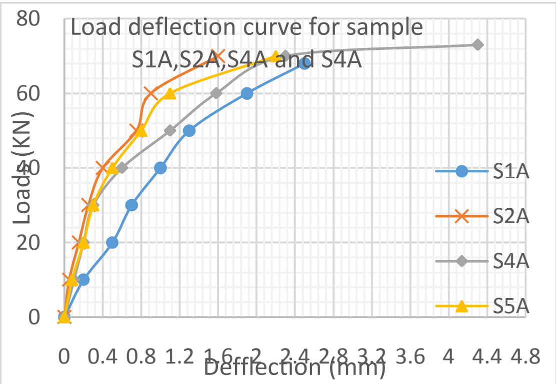

Chart (3)

The chart (3) showed that the LWSP with aerated concrete core with w/c = 0.55 and waterproofing admixture = 0.5 has a good resistant against flexural third point loading.

Next chart showed the difference in load and deflection between two web sandwich panels under flexuralthird point loading, one has aerated concrete as a core and another has thermocol as a core with same ferrocement w/c = 0.6 & waterproofing admixture = 0.4

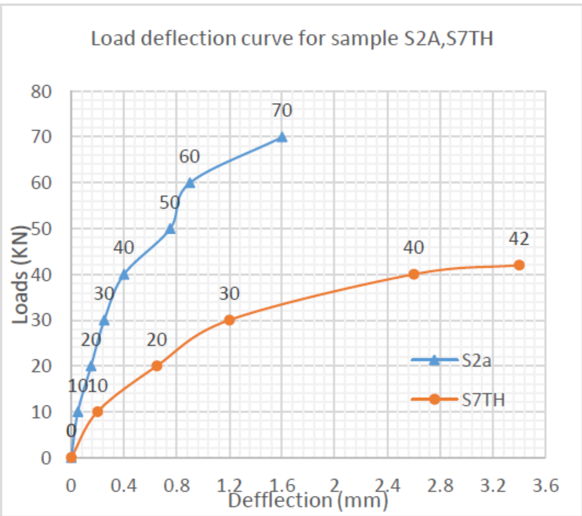

Chart (4)

The chart (2) showed that the LWSP with aerated concrete has a resistant against flexural one point loading about 40% more than LWSP with thermocol.

specimen name	first crack load (KN)	first crack def. (mm)	ultimate load (KN)	Ultimate crack Def. (mm)	modules of rupture (Mpa)
S1A	49	1.08	68	2.5	6.8
S2A	57	1.2	70	1.6	7
S4A	50	1.1	73	4.3	7.3
S5A	44	0.6	70	2	7
S7TH	28	1	42	3.4	4.12

Table (3)

Table (3) showed the LWSPs under flexural third point loading first crack load and ultimate with deflection and modules of rupture.

C. Testing results from applying axial load on the web sandwich panel

S1A under axial load				
Load (Kn)	Left deformation (mm)	Right deformation (mm)	First crack load (Kn)	Ultimate load (Kn)
20	0	0.78	200	235
40	0	1.1		
60	0	1.2		
80	0	1.2		
100	0.05	1.2		
120	0.2	1.17		
140	0.23	1.12		
160	0.3	1.05		
180	0.3	1		
200	0.2	1.2		
210	0	1.5		
220	0	1.8		
230	0	1.87		
235	0	2.3		

Table (4) showing S1A strength under axial load

S7TH under axial load				
Load (Kn)	Left deformation (mm)	Right deformation (mm)	First crack load (Kn)	Ultimate load (Kn)
0	0	0	118	120
20	0	0.9		
40	0	1.5		
60	0.2	2.1		
80	0.4	2.3		
100	0.8	2.7		
120	1	3		

Table (5) showing S7TH strength under axial load

S2A under axial load				
Load (Kn)	Left deformation (mm)	Right deformation (mm)	First crack load (Kn)	Ultimate load (Kn)
20	0.55	0.002	215	218
40	0.8	0.002		
60	0.9	0.002		
80	0.9	0.2		
100	0.86	0.3		
120	0.8	0.4		
140	0.6	0.5		
160	0.3	0.8		
180	0.1	1		
200	0	1.3		
210	0	2		
218	0	2.4		

Table (6) showed S2A strength under axial load

Chart(5) display the web sandwich panel (S1A) under axial load and display the lateral deformation

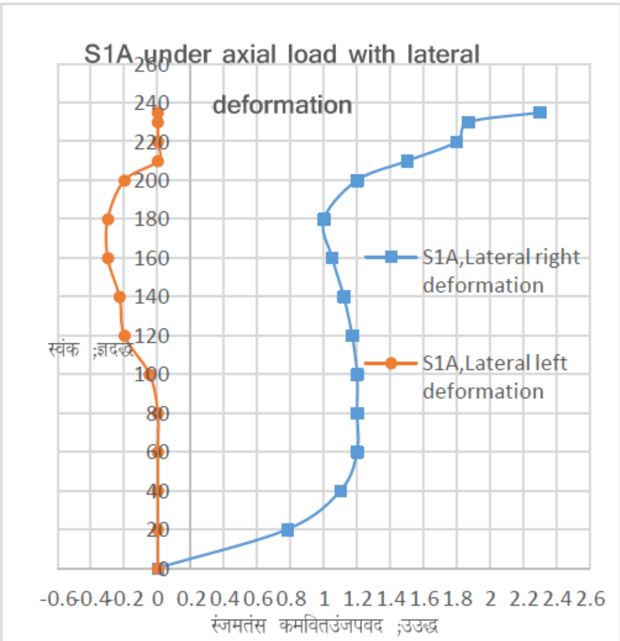

Chart (5)

The above chart (5) explain the LWSP behavior under axial load and the lateral deformation in both sides left & right. The chart showed sample S1A with water cement ratio 0.55 & waterproofing admixture 0.4 have a capability to resist axial load until 235 KN with maximum lateral deformation at right side 2.3 mm and left side 0.3 mm.

Chart (6) display the difference between tow web sandwich panel (S1A & S7TH) under an axial load with difference core material aerated concrete and thermocol.

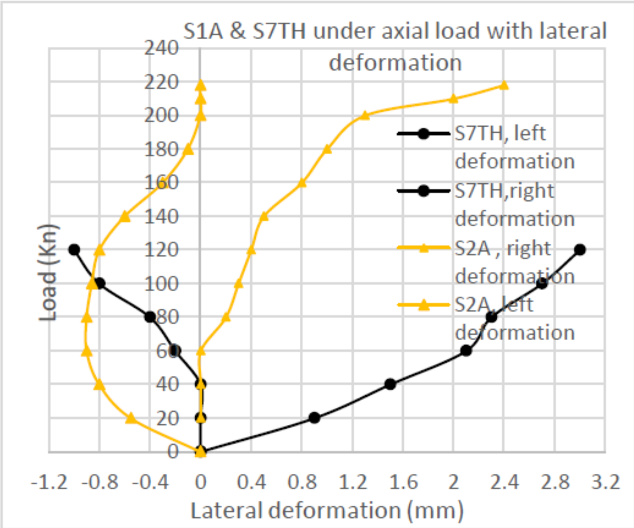

Chart (6)

Chart (6) explain the comparison between S2A and S7TH with a difference core material aerated concrete and thermocol respectively. It showed that S2A have axial resistance capability with 218 KN and maximum right deformation 2.2 mm and maximum left deformation 0.9 mm. on the other side S7TH have axial resistance with 120 KN and maximum right deformation with 3.1 mm and maximum left deformation with 1 mm.

VIII. VIII. CONCLUSION

1. Lightweight web sandwich panel showed a significant resistance proportion to its weight under flexural load which maximum resistance is 58 KN under one point flexural loading with LWSP w/c = 0.55 and waterproofing admixture 0.5, maximum resistance with tow point loading is 73 KN which with LWSP w/c = 0.56 and waterproofing admixture = 0.5
2. The procedure and proportion which was taken to prepare and casting the aerated concrete is pronounced to produce an aerated concrete with density (1300-1550) Kg/m^3 with good strength which is suitable as a core for precast panels used as a wall and floor.
3. The reduction percentage of weight between these LWSPs with aerated concrete core with normal concrete is about 20% in weight.
4. Changing the web sandwich panel core from aerated concrete to thermocol was reduced the weight of the sandwich panel about 30% but the increasing percent in strength capability between LWSP with thermocol core to LWSP with aerated concrete core about (34 – 40) % with same encasement properties.

5. Due the the high stiffness of LWSP with thermocol the strength between first crack load and ultimate load is about (34 – 38) % under flexural load with one point loading and third point loading.
6. The LWSP specimens resistance to axial load were significantly high so its suitable to use it as a wall specially with aerated concrete core which have w/c = 0.55 and waterproofing admixture = 0.4 which its ultimate axial load is 235 KN.
7. The role of wire mesh was in a strength capacity and in failure mode which prevents the suddenly and brittle failure of these panels and increase in ductility of the panels.

RECOMMENDATION

1. Make an experimental study on the thermal insulation for lightweight web sandwich panel with aerated concrete and thermocol as a core then comparing the results between each.
2. Make theoretical investigation on the lightweight web sandwich panel using ANSIS program and comparing the results with this experimental results.

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