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Journal of Zankoy Sulaimani
Part-A- (Pure and Applied Sciences)

Impact behavior of sandwich ferrocement panels

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Article info

Original:
18 January 2016
Revised: 10 April 2016
Accepted:
21 April 2016
Published online:
20 September 2016

Key Words:
Impact load, Strain energy, Sandwich, Crack patterns, Styrofoam

Abstract

Ferrocement is one of the construction materials used to reduce both cross-section and eliminate coarse aggregates. In this experimental study the impact strength and strain energy of thin laminated mortar specimens were investigated. Five series of ferrocement sandwich panels with 400mmX400mmX50mm in dimensions were cast and subjected to drop impact loadings. The results of simply supported tested panels showed that using plastic instead of galvanized wire mesh increased the impact resistance of panels. Including a thin row of Styrophoam between the two mortar layers increased strain impact energy for failure load. Different crack patterns were recorded according to the type, number of wire mesh and percentage of Styrophoam content.

Introduction

Ferrocement is an important laminated unit of building constructions in developed countries. Ferrocement may be used as an independent element of structures like water tanks, walls, infill frames, chemises, silos and marine structures. Ferrocement constituent, cement, sand, wire mesh and water have some attractive properties such as fire-resistance, antirust, seismic resistance, and rot or blow down in hurricanes. It is used also in repairing of damaged buildings or retrofitting. Ferrocement possess large tensile strength and supreme cracking behavior if compared to ordinary reinforced concrete. Many buildings may be subjected to impact loads resulting from a mass drop. Different types of test instrumentations have been used, by researchers, to predict the impact loads due to the lack of standard method for impact testing [1,2,3,4].Murial et al.[5]conducted an experimental study on the ferrocement plates with different type of mesh under impact load. The results laid stress on higher energy absorption in expanded metal mesh as they were effective in controlling the cracks. Al-hadithi et al.[6] investigated an experimental program on the properties of ferrocement specimens consists of plastic fibers under impact loads. They explained that the number of blows was increased with the addition of both waste plastic fibers and mesh layers. Kandasamy et al.[7]conducted a comparable study between theoretical and experimental tests for fly ash concrete specimens subjected to impact loads. The results showed a good correlation between the experimental and predicted results. The number of blows was increased to produce the first crack and failure cracks by increasing polymer content (SBR) and number of mesh layers. Thirumal, [8] studied the effect of galvanized steel mesh and synthetic polyofin fiber on the plates 250mmX 250mmX25mm in dimensions, ferrocement results showed that the increase of polyofin and number of mesh layers increases the absorption of energy

Aim of experimental study

The main goal of this experimental study is to investigate the behavior of sandwich ferrocement panels under impact loading in which galvanized and plastic mesh has been used. Styrophoam grains was used between the two reinforced mortar layers of the panels. The significant out comes of the following variables were considered in this work:

1- Influence of material of the mesh used on the impact loading.
2- Influence of Styrophoam on the impact strain-energy of the sandwich panels.
3- Influence of number of mesh layers on the number of blows of the sandwich panels.

Using the results from this experimental investigation may be used to improve the impact resistance of structures or in rehabilitation of damaged buildings.

Experimental program

This work includes preparing and testing of five series of sandwich ferrocement panels subjected to impact loading. The main variables were galvanized, plastic mesh materials and Styrophoam content. Table 1 shows the details of tested specimens.

Materials:

Cement:

Ordinary cement type I was used according to Iraqi specification No.5 [9] which was produced in Kurdistan region-Iraq.

Sand:

River sand with maximum size of 2.36mm and well graded was used according to Iraqi specifications No.45.[10]

Water:

Ordinary drinking water used for mixing and curing.

Mesh:

Galvanized wire mesh of 0.70mm diameter and plastic mesh were used.

Styrophoam:

Styrophoam grains available in local markets were used for intermediate layer of panels.

Table 1: Details of panels

Series	***Sandwich panels detail***			***Wire mesh details***
	Galvanized mesh layers	***Plastic mesh layers***	***Styrophoam content***	
C- 0.00 Control panel	----	----	*0.00%*	----
P1- 0.00	----	*One*	*0.00%*	*Plastic type with large hexagonal openings*
P1- 0.50	----	*One*	*0.50%*	
P2- 0.50	----	*Two*	*0.50%*	
S1- 0.00	*One*	----	*0.00%*	*Galvanized type with large hexagonal openings*
S2- 0.50	*Two*	----	*0.50%*	

Mix proportion and casting

The matrix consists of cement-sand ratio 1:2, water cement ratio 0.45. The cement and sand were mixed well. The water was added to the dry mix and a workable mortar was obtained. Steel angles fixed with bolts and nuts were used to build a frame of the mold. Wooden rods and 4mm thick glass were used to control the base of the mold. The lamination process started with placing first layer of prepared mortar into the mold. The measured mesh layer was placed in the mold and Styrophoam grains dispersed to form a thin row followed by the final mortar layer. According to ASTM [11] a standardtemplate was used for hand compaction of each layer of mortar. The upper surface of the panels were straightened and smoothened by special tools as shown in figures 1 to 4.

Curing

The panels were demolded after 24hours of casting and placed into a water tank for curing up to 28 days.

Figure 4: Impact test arrangement

Figure 1: Compaction the mortar of panels

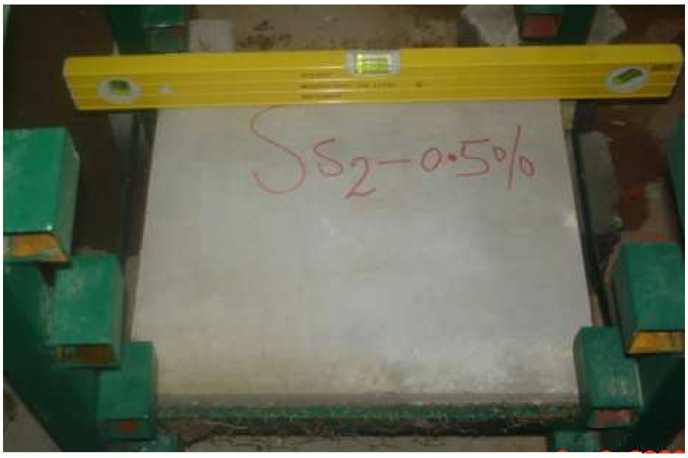


Figure 2: Surfacing of the panels

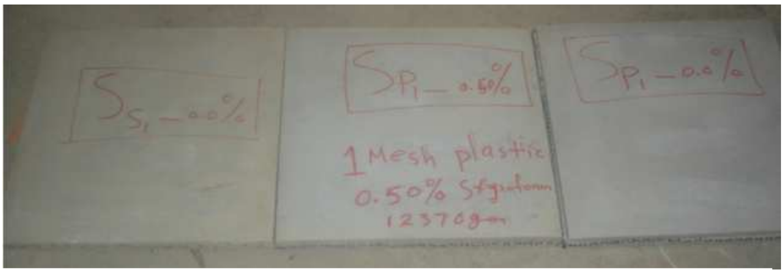


Figure 3: Smoothen surface panels before impact test

Impact test

Each sandwich panel was placed simply supported on the steel frame designed for impact drop loadings as shown in figure 4.Five series of sandwich ferrocement panels were tested at age of 28days and compared to a control panel (mortar without meshes and Styrofoam). Dropping of 3.0kg mass steel ball from a height of 1.3m was used as an impact load testing. The ball in each drop was in contact with the upper smooth face of the panel. The first crack occurred by repetition of the loading then number of blows were recorded. This procedure was continued with reporting all changes in the panels (new cracks, increasing width of cracks, separating of layers), until failure blow (collapse of the panels).

Test results and discussion

In this experimental tests, both the mass of the ball and height of falling were fixed, 3.0kg and 1.3m respectively. The results are shown in table 2 is an average of three tested panels. The first crack occurs due to the impact load is nominated as the first crack load and the final load is the failure load of the ferrocement panels. As the ball impacted the surface of the ferrocement panel, the strain energy is absorbed by the hardened mortar. The capacity of strain energy of (P1- 0.00, P1- 0.50, P2- 0.50, S1- 0.00 and S2-0.50) panels were (10, 16, 25, 4 and 7) times that of control panel, respectively. The optimum capacity of energy absorption is in sandwich ferrocement panel P2-0.50 due to both high plastic mesh and percentage of Styrophoam content as shown in table 2 and figure 5.

Crack Pattern

Test results showed that the number of blows to produce cracks (first or failure) increased when the number of meshes increased, meanwhile combined plastic mesh layers and percentage of Styrophoam, had a significant effect on increasing number of blows to reach the failure load. Most of cracks started at the center of the impact face at point of dropped ball and propagated towards the edges of the panels. The panels with plastic meshes and Styrophoam had greater number and wider cracks than the panels with galvanized mesh. An impact dent occurred on the upper surface of the panels, while did not penetrate to the lower surface especially in panels with galvanized meshes. Separation of the two sandwich layers were noticed at the failure load with split of some pieces from upper surface. All crack patterns are shown in figures 6 and 7.

Table 2: Average of drop test results

Series	*Number of blows*		*Strain energy first crack N.m*	*Strain energy failure crack N.m*
	First crack	*Failure*		
C- Control panel	------------	*1*	--------	*38.26*
P1- 0.00	*3*	*10*	*114.78*	*382.60*
P1- 0.50	*3*	*16*	*114.78*	*612.16*
P2- 0.50	*5*	*25*	*191.30*	*956.50*
S1- 0.00	*2*	*4*	*76.52*	*153.04*
S2- 0.50	*2*	*7*	*76.52*	*267.82*

Energy = number of blows X weight of the ball X height of drop
Where: weight and height are constant (3.0kg mass and 1.30m)respectively

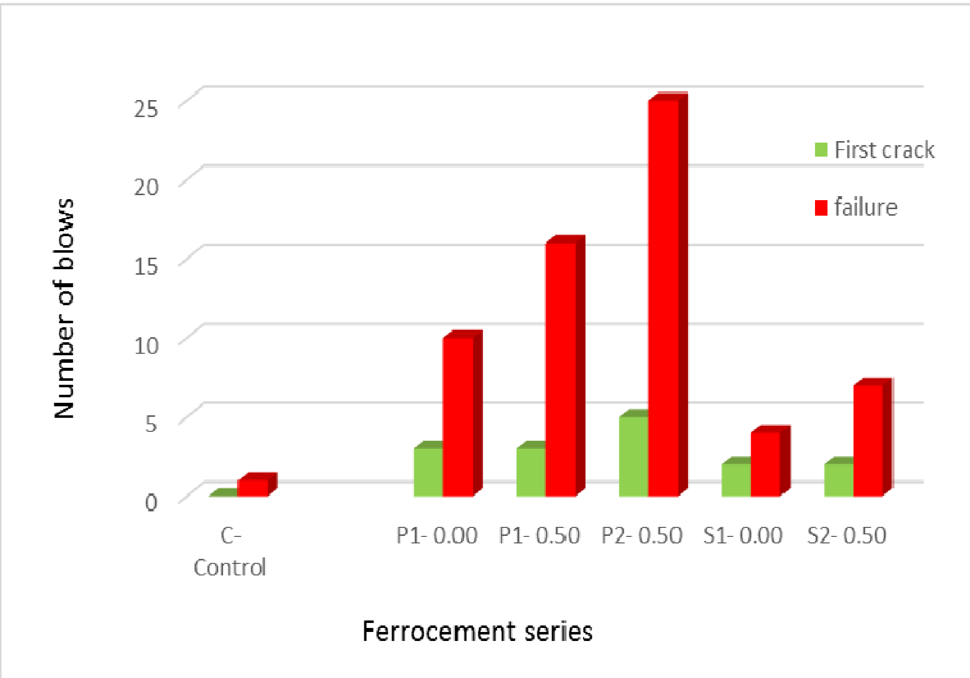
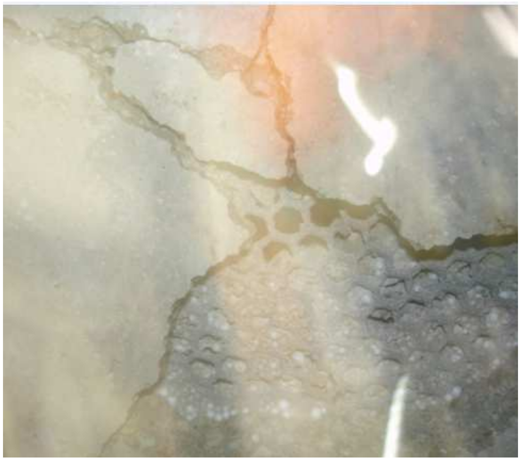


Figure 5: Impact strength relationships

6a: P1-0.00

6b: P2-0.50



6c: P1-0.50

6d: S2-0.50

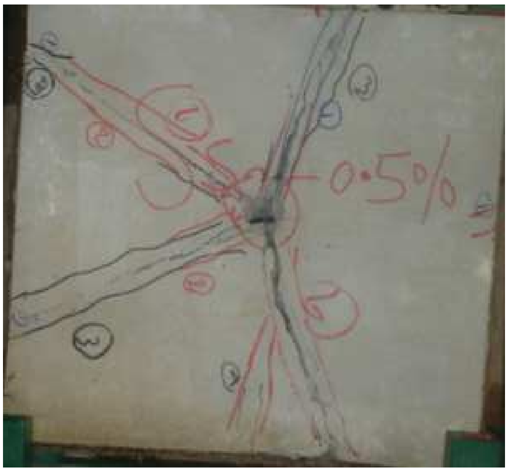
6e: S1-0.00

Figure 6: Crack failure at lower face of ferrocement panels

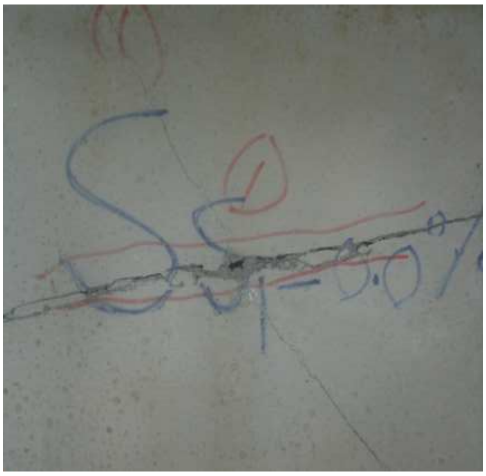
7a: P1-0.00

7b: P2-0.50

7c: P1-0.50



7d: S2-0.50



7e: S1-0.00

Figure 7: Crack failure at upper face of ferrocement panels

Conclusion

The effect of wire mesh and Styrophoam content when added to plain mortar panels was experimentally investigated as subjected to impact loadings. The following conclusions can be drawn:

1. The impact resistance of sandwich ferrocement panels with plastic mesh and Styrophoam is higher than that of the control panel and panels with galvanized mesh.
2. Each panel type has a specialfailure mode different from other panels for the same arrangement of impact loadings, this is due to the variety of materials response to impact load.
3. Panels with higher mesh content have more visible cracks.
4. Styrophoam content increased the number of blows of the impact loading.
5. The strain energy required for first crack of most of the panels were small numbers due to the simply supported of the panels.

Practical Utility

This product may be used in strengthening or retrofitting of the structures applied to dynamic stresses. The impact resistance of buildings may be improved with the tested units in economic method. This work will be a main concept of the project for military resistance utilities.

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