PREFABRICATED FERROCEMENT SANDWICH ELEMENTS IN FIRE CONDITIONS

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Summary: *In this paper the experimental results of two-dimensional non-stationary temperature fields of prefabricated ferrocement sandwich panels in fire condition, were presented. In order to determine resistance to fire, the temperature fields of two walls dimensions of 3000 mm × 3000 mm and a thickness of 190 mm made from precast ferrocement sandwich panels, were analyzed. The first panel has been insulated with styro-concrete, and the second with styro-concrete and expanded polystyrene. The panels were exposed to conditions of real fire corresponding to the standard fire curve defined by the standard SRPS EN ISO 834-1. The tests have shown that, due to the detonations that occur when the panels are exposed to fire, these panels have unpredictable behavior.*

Keywords*: prefabricated ferrocement sandwich element, heat transport, fire test*

1. INTRODUCTION

Ferrocement is fine grained reinforced concrete, made from cement mortar, reinforced with multiple layers of thin, dense steel mesh which enables homogeneous armature layout [3]. Because of its easiness to form different complex constructions, the ferrocement is widely used for fabricating round shaped elements of buildings, arched halls, domes, cathedrals, etc... Prefabrication of ferrocement elements, in high quality molds, indoors (without any effects of weather conditions), achieves high quality of the

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product and significant savings in time of building construction. High energy efficiency and building construction without thermal bridges are the advantages of the buildings constructed using prefabricated ferrocement elements.
Fire occurrences in buildings are inevitable due to malfunction of electrical installations and different accidents. During fire, very high temperatures are reached in a short period of time which leads to the damage of the protective layer, loss in load capacity and decrease in construction stability. By protecting constructions with different materials (cement, expanding materials, fiber materials and composite materials) a higher fire endurance is achieved (the longer time period). Ferrocement is, by its structure, made as a fiber, composite material with hydraulic cement mortar and with dense armature mesh, which enables it higher heat absorption than concrete construction, and thus higher fire endurance [4].
In this study, experimental data retrieved via fire tests of the two prefabricated ferrocement sandwiches, are shown. The difference between the two panels is in the type of insulation. The tests were conducted without load. For the fire tests, the standard fire curve, which is usually used for fire endurance validation of building constructions, defined by the standard SRPS EN ISO 834-1, is used.

2. STANDARD FIRE TEST

The standard fire test, defined by the standard SRPS EN ISO 834-1, is also suggested by the International Organization for Standardization. The fire test for testing fire endurance of different types of building constructions is defined in the standard. Mean temperature inside the furnace is defined by the standard fire curve, shown in the Figure 1. The temperature is measured using thermocouples and the acquisition system, and is controlled using the controlling algorithm applied on a standard PC. The temperature is controlled in a way to satisfy the equation [1]:

$$\mathrm{T} = 20 + 345\log(8t + 1) \qquad (1)$$

where T is the average furnace temperature [°C], and t is the time [min].

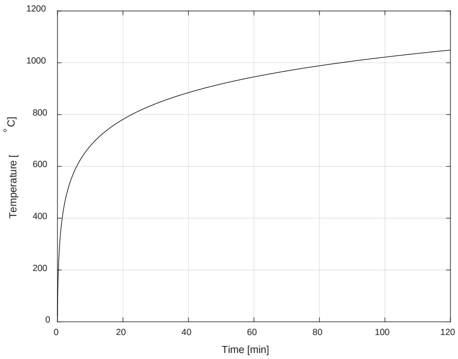

Figure1. The Standard fire curve defined SRPS EN ISO 834-1

Standard test furnace achieves the temperature using four two stage liquid fuel burners, manufactured by “Eco Flam” (Italy), with the heating power of 296 kW. Overpressure is measured using two differential preasure transducers manufactured by „Testo“ (Germany), range ±100 Pa. Preassure and temperature values of exposed and unexposed side of sandwich panels are acquired each 12 seconds.Temperature on fire unexposed side of specimens were measured according the Standard SRPS U.J1.090 [2] .

3. TEST SPECIMENS

In this study two samples of wall sandwich panels, with different thermal insulation fill, are analized. The samples are of nominal thickness of 190 mm with the height and width 3000 mm×3000 mm, corresponding to the standard SRPS U.J1.090 [2]. Wall sandwich panels were exposed to the standard fire on one side, while on the other side, the temperature of the wall in nine different places was measured. Wall testing was performed with two tests. Both samples were formed in situ in an opening on the wall of the furnace. Furnace wall is built from ytong blocks with the thickness of 250 mm. Inside the opening of the furnace wall, using a crane, two rectangular ferrocement sandwich elements, with the nominal thickness of 190 mm, were built in.
The elements had hooks for transportation and installation. The elements were standardized with dimensions of 1800 mm × 3800 mm and 2250 mm × 3750 mm, and for the purpose of the testing were modified to dimensions 1380 mm×2900 mm both. Rectangular ferrocement sandwich elements are consisted of layers of ferrocement panels with the thickness of 25 mm on the exposed side, and the thickness of 15 mm on the unexposed side. Between the ferrocement panels, a thermal insulation was built in. For the first sample, layer of the thermal insulation is composed of styro-concrete with the thickness of 150 mm, while, for the second sample, the layer of thermal insulation is composed of expanded polystyrene immersed into concrete with the total thickness of 150 mm. The ferrocement panels are built from thin layer of concrete reinforced with multiple layers of rabic mesh, while the thermal insulation of styro-concrete is made from polystyrene balls immersed into cement milk with additives. On one transversal and longitudinal side of the rectangular ferrocement sandwich panels, reinforced concrete ribs with the height of 230 mm, are cast. Total thickness of elements with reinforced concrete ribs is 420 mm. Reinforcement is placed on the top side of the sample. The area between the furnace wall and the sample is filled with a fast setting mortar. Between the two ferrocement sandwich elements, a concrete beam with dimension of 240 mm × 190 mm, is cast. On the unexposed side of the sample, scaffolding is set up for the stability of the sample. On Figures 2-5 exposed and unexposed sides of both samples are shown.

Figure 2. The 1st test - unexposed side

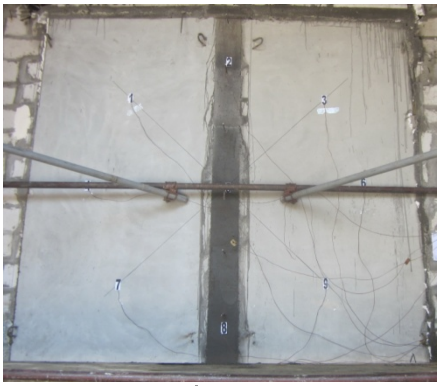

Figure 3. The 2nd test - unexposed side

Figure 4. The 1st test - exposed side

Figure 5. The 2nd test - exposed side

4. EXPERIMENTAL RESULTS AND DISCUSSION

Mean temperatures inside the furnace are shown on Figure 6. Black curve represents the standard fire curve, red and blue curves represent top and bottom limit while the green and purple curve represent the achieved temperatures inside the furnace during the testing of the first and the second sample. On the start of the test difference between the standard fire curve and the achieved temperatures can be observed. The reason for this difference is due to thermal inertness of the samples for the reason of different mases and thermal capacities of the samples. The tested sandwich panels need to be exposed to a high amount of thermal energy for the temperature inside the furnace to follow the standard fire curve. Due to the fact that that amount of energy cannot be produced by the burners, on the beginning of the test the temperature inside the furnace is lower that the temperature of the standard fire curve. During the test, the wall absorbs a certain amount of energy until the end of the preheating process of the wall. After the end of the preheating process, the burners have enough power to enable for the temperature of the furnace to follow the standard fire curve.

Overpressures inside the furnace are shown on Figure 7. On the beginning of the test, for the purpose of reaching the desired temperature, the overpressures are not controlled. The control of overpressures, after the moment that the temperature inside the furnace achieves the temperature specified by the standard fire curve, is started. After that the overpressures are inside the boundaries 10±2 Pa.

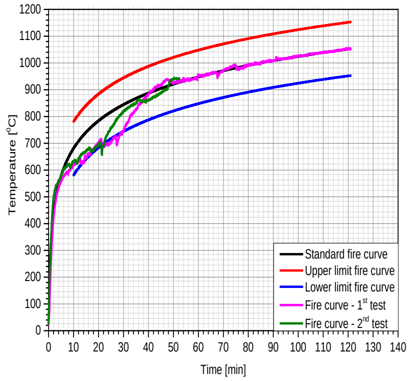

Figure 6. Temperature in the furnace during the fire tests

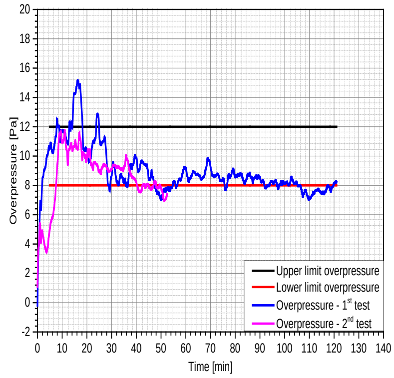

Figure 7. Overpressure in the furnace during the fire tests

The temperature on the unexposed side of the first sample (with thermal insulation of styro-concrete), on the beginning of the test, was 21 °C, while on the second sample (with thermal insulation composed of expanded polystyrene panels immersed into concrete), was 26 °C. During the test, there were multiple detonations of the sample. At elevated temperatures of the wall structure, polystyrene balls melting and evaporation occurs. Beside the rise of temperatures, the rise of pressure within the structure also occurs, which has as a consequence the gas leakage and detonations when the gas gets into contact with oxygen.

On the second sample (with thermal insulation composed of expanded polystyrene panels immersed into concrete), due to a detonation in the 46th minute of the test, there was crack of the sample which caused the occurrence of flames and the loss of the integrity of the sample, while in the 52th minute the temperatures of the unexposed side of the sample passed the limit which resulted into the loss of thermal insulation capabilities. The sample with thermal insulation of styro-concrete, preserved the integrity in the period of 120 minutes. Temperatures on the unexposed side of the samples are shown on Figures 8 and 9. The exposed and unexposed sides of the samples are shown on Figures 10-13.

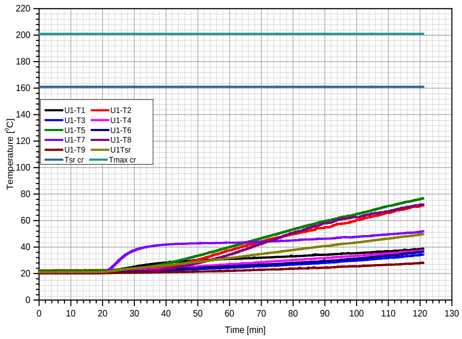

Figure 8. The 1st test - Temperature on unexposed side

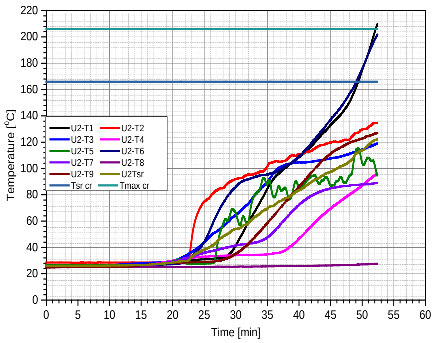

Figure 9. The 2nd test - Temperature on unexposed side

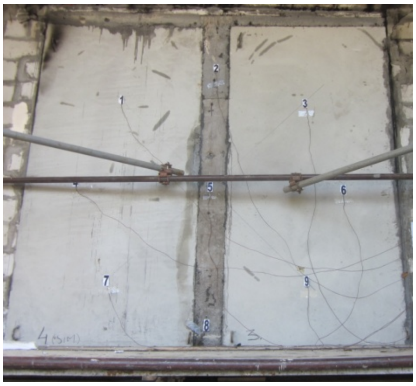

Figure 10. The 1st test - fire unexposed side, after fire test

Figure 11. The 2nd test - fire unexposed side, after fire test

Figure 12. The 1st test - fire exposed side, after fire test

Figure 13. The 2nd test - fire exposed side, after fire test

5. CONCLUSION

In this study experimental results of the fire tests of two prefabricated sandwich panels with total thickness of 190 mm, and thermal insulation of 150 mm, are shown. First panel was insulated using styro-concrete, while the other was insulated using expanded polystyrene panels immersed into concrete. Both panels were, on one side, exposed to standard fire defined by the standard SRPS EN ISO 834-1, while temperatures were measured on the other side of the panel. The temperatures were measured in nine places in accordance with the standard SRPS U.J1.090. During the fire test of the samples, due to styrofoam melting, rise of temperature and breach of oxygen through the cracks in the concrete, detonations occurred. Due to detonations, in the 46th minute, there was a crack in the panel that had thermal insulation composed of expanded polystyrene panels immersed into concrete, which resulted in loss of integrity and loss in thermal insulation capabilities of the sample. The panel which had thermal insulation composed of styro-concrete maintained its integrity and thermal insulation capabilities for the declared time of 120 minutes. The tests have shown that, due to the detonations that occur when the panels are exposed to fire, these panels have unpredictable behavior.

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OTPORNOST PREMA POŽARU PREFABRIKOVANIH FEROCEMNTNIH SENDVIČ PANELA

Rezime: *U radu su prikazani eksperimentalni rezultati dvodimenzionalnih nestacionarnih temperaturskih polja kod prefabrikovanih ferocementnih sendvič panela u uslovima požara. U cilju određivanja otpornosti prema požaru, analizirana su temperaturska polja dva zida dimenzija 3000 mm × 3000 mm debljine 190 mm formirana od prefabrikovanih ferocementnih sendvič panela. Prvi panel je bio izolovan stirobetonom, a drugi stirobetonom i pločama od ekspandiranog polistirena. Paneli su bili izloženi uslovima realnog požara koji odgovaraju standardnoj požarnoj krivi definisanoj standardom SRPS EN ISO 834-1.*

Ključne reči*: prefabrikovani sendvič paneli, temperatursko polje, otpornost prema požaru*