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EXPERIMENTAL ANALYSIS OF FIRE RESISTANCE OF CLAY HOLLOW-BRICK MASONRY NON-LOAD BEARING WALL

Abstract

Testing the clay hollow-brick masonry non-load-bearing wall helps us to understand the behaviour of this type of wall during a fire. It is important to know the fire resistance of hollow brick walls so that we can prevent the fire from spreading to other rooms. In this paper, the experimental analysis of fire resistance of non-load-bearing wall with dimensions 3000 mm x 3000 mm thickness 200 mm were presented. The wall was made from clay hollow-brick masonry blocks with dimensions 500 mm x 200 mm x 249 mm (L x D x H) with mortar on both side of wall of thickness 15 mm. The wall was exposed to a standard fire test according to SRPS EN 1363-1:2014. The temperatures on the unexposed side of the wall were measured in thirteen positions with thermocouples (K – type) according to the national standard SRPS EN 1364-1: 2014, and at the junction between mortar and clay hollow-brick. Deflection of the wall in five places was measured also. Obtained results depending on the time of reaching the critical temperature during the fire test were presented.

Keywords

Clay hollow-brick masonry wall, standard fire test, temperature measurement, thermal behavior

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1. INTRODUCTION

In modern civil engineering, clay hollow-brick masonry blocks are widely used elements for construction of load-bearing and non load-bearing walls. Precise dimensions of the blocks, as well as high resistance to fire and earthquakes of structural elements made of this material, contribute to the construction of a massive and stable structures with a larger surface area. The advantage of using these types of blocks is a fast and simple construction, which achieves great savings in labor and construction time. Also, excellent thermal and acoustic insulation performance of the wall is one of the reasons the designers to choice this type of material during construction due to savings in energy consumption for heating and cooling.

Understanding the behavior of masonry structures when exposed to fire and predicting their fire resistance is crucial and that is expressed by brick manufacturers [4]. Clay hollow-brick masonry blocks are made of non-combustible raw mineral of class A1. Even small wall thicknesses made of these blocks enables optimal fire protection to be achieved. By increasing the thickness of the wall, resistance to fire also increases. Fire resistance is determined by experimental tests in a vertical furnace with a defined standard fire development inside the furnace.

2. DESCRIPTION OF MEASUREMENT EQUIPMENT AND EXPERIMENT

In this paper, the thermal behavior of non-load-bearing walls with dimensions 3000 mm x 3000 mm with thickness of 200 mm exposed to standard fire test is shown. The wall was made from clay hollow-brick masonry blocks with dimensions 500 mm x 200 mm x 249 mm (L x D x H) with mortar on both side of wall with thickness of 15 mm. The wall was tested in a vertical furnace with an acquisition system, according to a standard fire test. The wall had dimensions 3m x 3 m and it was tested in Institute IMS in Laboratory for thermal technique and fire protection. Standard furnace for testing construction consists of four two-step burners in liquid fuel type „Major P25 AB HS TL V.C.“, of heating power 296 kW manufactured by ECO FLAM. Two transmitters of differential pressure type 6321 manufactured by TESTO (Germany) range ±100 Pa inside the furnace were used for pressure measurement. Inside the furnace the temperature on six places with thermocouple of type K were measured. The measure ranges of thermocouple of the type K were -270^{0}C to 1372^{0}C. Acquisition systems for monitoring standard fire tests in the vertical furnace was made completely in the laboratory for thermal technique and fire protection according to standard SRPS EN 1363-1 [1]. Standard fire development was described with a logarithm curve:

$$\Theta_g = 345\log_{10}(8t+1)+20 \tag{1}$$

where: t [min] is time and T[^{0}C] is the temperature inside the furnace depending of time t.
In Figure 1 the standard fire curve is presented.

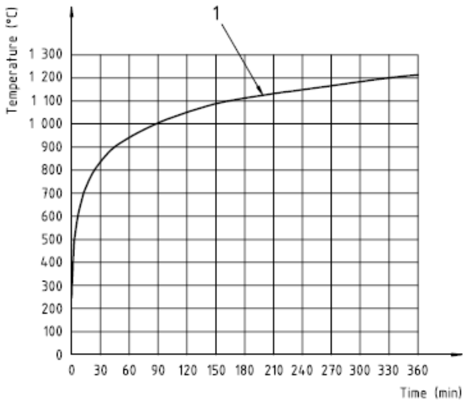

Figure 1. Standard fire curve in accordance with Standard SRPS EN 1363-1:2014

On fire unexposed side, the temperatures on wall were measured with thermocouples of the type T on nine positions according to standard SRPS EN 1364-1 [2]. The criteria for fire resistance of construction are the preservation of integrity, stability, and insulation. The insulation properties of construction are kept when average temperature increases above the initial average temperature by more than 140 K of all thermocouples on unexposed side and temperature at any location (including the rowing thermocouples) increases above the initial temperature by more than 180 K. The initial temperature is the average unexposed side temperature at the commencement test. The furnace pressures are measured and recorded continuously in two control points. In every 12 s (sample rate), the temperature of the furnace, the temperature of a wall on the unexposed side and the pressure has been measured. The measurements of deflections, in the center of the wall, and at mid-height 50 mm from the right and left, right, upper and down edge of the wall have been measured also.

3. EXPERIMENTAL RESULTS AND DISCUSION

In Figures 2 and 3, the measured temperatures T1-T6 and pressure dp in the furnace are presented. In Figure 4 the average temperature of six thermocouples inside the furnace is shown. The uniform temperature conditions, during the test, inside the furnace, have been in accordance with the limits in standard SRPS EN 1363-1:2014 [1]. On fire unexposed side, the ambient temperature T_{amb} and temperatures in thirteen places on the surface of mortar, have been measured. In Figure 5 the temperature distribution of these temperatures is shown. The temperatures T1-T5 are the average temperature and they were measured by thermocouples. The maximum temperature T6max-T13max were measured by thermocouples also. All temperatures of each individual measuring point were less than 180^0C in relation to the initial temperature and the mean temperature of all measuring points was less than 140^0C in relation to the initial temperature. All measured temperatures were within the allowed limits defined by the standard [1] and they are shown in Figure 5. At the start of the fire test, on each wall surface, after the furnace was warred up and the convection and radiation heat transfer mechanisms were started, the temperature of a wall has been obviously constant. After approximately 20 min, due to heat conduction and evaporation of the moisture, the temperature through the wall began to increase [3]. After 80 minutes from start of the furnace, all of the measured temperatures have been rosining and their temperature curves approaching each other. The ambient temperature T_{amb} has been in accordance with the standard [1] and ranged from 9.3^{0}C to 12.5^{0}C and are shown in Figure 5 (strait lines). At five places of the wall deflection of the wall has been measured. There were no significant deflections of the wall during the test detected. In the Figure 6 temperatures T1m and T2m on fire exposed side of the wall, on mortar surface, and at the junction of mortar and clay hollow-brick masonry blocks, at a height of 50 cm from the lower elevation of the wall, were presented. The temperatures T3m and T4m were measured temperatures at the same places and the same side of the wall but at height of 150 cm from lover elevation of the wall, and are shown in Figure 7. In Figure 8 the temperatures T5m and T6m were presented, measured on fire exposed side of the wall, on mortar, and at the junction of mortar and clay hollow-brick masonry blocks respectively at height of 250 cm from the lower elevation of the wall. All these six temperatures were measured with thermocouples of the type K. At start of the fire test, temperature of the surface of mortar exposed to the fire was 5% greater than temperatures at the junction of mortar and clay block at all heights. In Figure 9 temperature differences of mortar surface and junction of a mortar and hollow-brick masonry blocks on side exposed to fire were shown. The temperatures differences on mortar surface and junction of a mortar and hollow-brick masonry block undergone two oscillations with two picks. Initially the difference has increased steeply and reached 87 %. After 5 min of test start, the temperature difference fallen sharply and reached 20 %. The second pick in temperature difference reached 77% followed the exponential decay until the end of experiment. In Figures 10 and 11, the wall on the unexposed and exposed fireside after the fire test was presented. In Figure 11 is shown degradation of mortar on the exposed fireside.

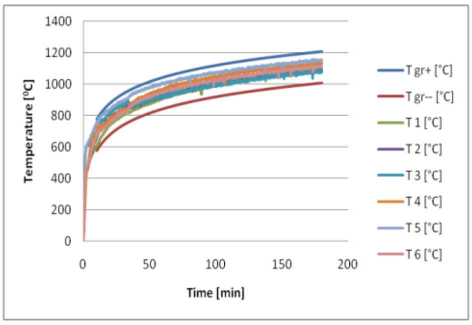

Figure 2. Temperatures T1-T6 and T_{gr+} and T_{gr-} in furnace during the fire test

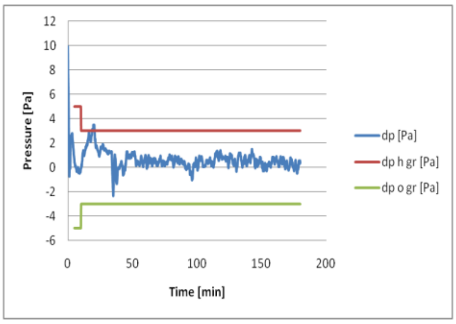

Figure 3. Air pressure in furnace during the fire test

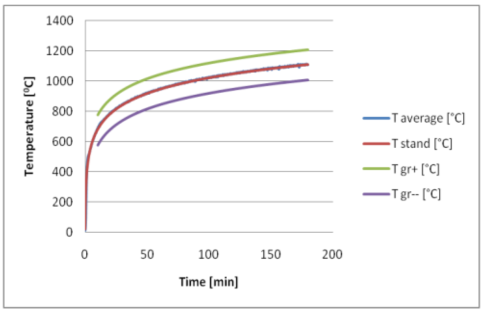

Figure 4. The average temperature in a furnace during the fire test

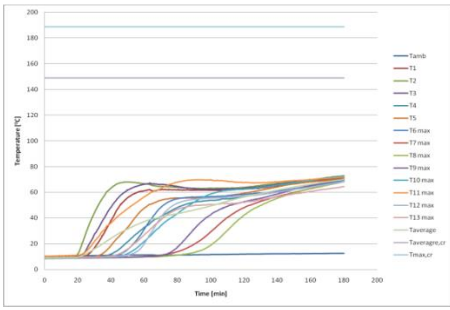

Figure 5. The temperatures on unexposed fire side

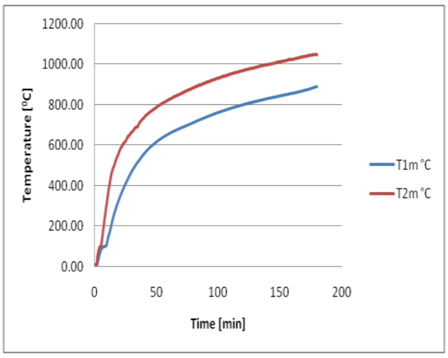

Figure 6. The temperatures on mortar T2m and junction between mortar and clay hollow-brick masonry blocks T1m, inside the furnace, during the fire test at a height of 50 cm from the lower edge of the wall

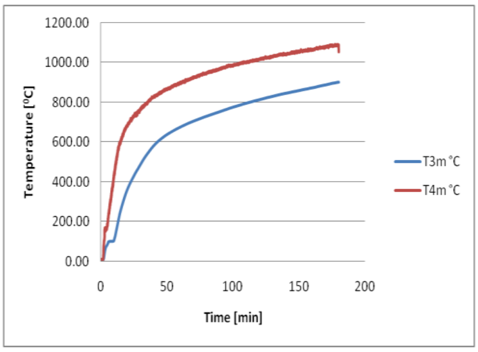

Figure 7. The temperatures on mortar T4m and junction between mortar and clay hollow-brick masonry blocks T3m, inside the furnace, during the fire test at a height of 150 cm from the lower edge of the wall

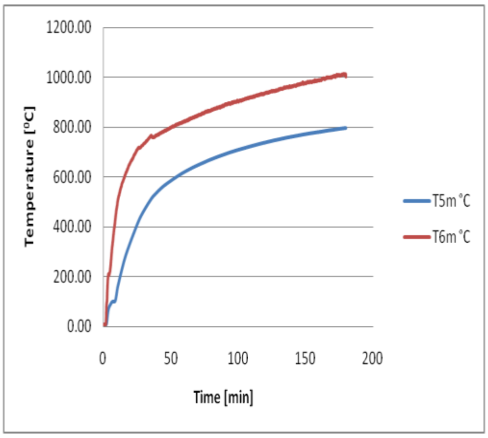

Figure 8. The temperatures on mortar T6m and junction between mortar and clay hollow-brick masonry blocks T5m, inside the furnace, during the fire test at a height of 250 cm from the lower edge of the wall

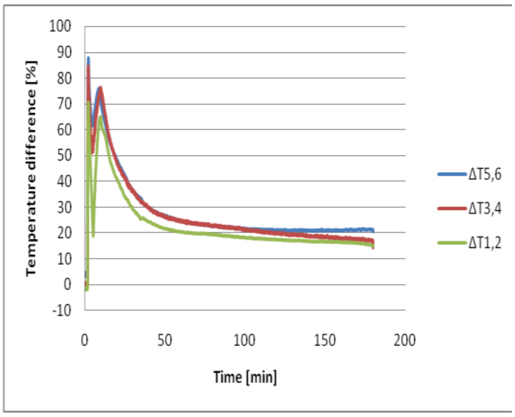

Figure 9. Temperature differences of mortar surface and junction between mortar and clay hollow-brick masonry blocks on side exposed to fire in [%]

Figure 10. Unexposed fire side of a wall at the start of test

Figure 11. Exposed fire side of a wall at the end of test

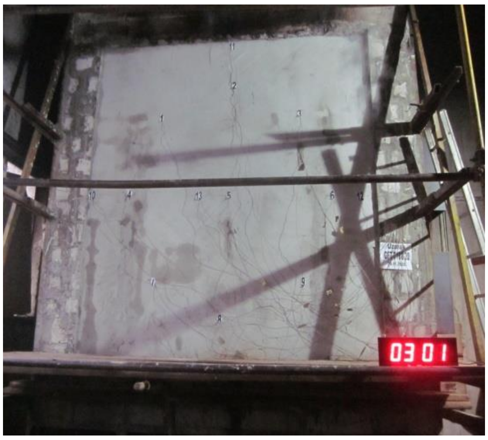

Figure 12. Unexposed fire side of a wall at the end of test

4. CONCLUSION

In this paper, the fire resistance of a wall made from clay hollow-brick masonry blocks with dimensions 500 mm x 200 mm x 249 mm (L x D x H) with mortar on both side of wall with thickness of 15 mm were presented. The dimensions of the tested wall were 3000 mm x 3000 mm and thickness 200 mm. The wall has been exposed to a standard fire test according to the standard SRPS EN 1363-1:2014. At the unexposed side, the temperature has been measured on thirteen positions with thermocouples type T according to the standard SRPS EN 1364-1:2015. Also, the deflection of a wall in five positions has been measured. At the exposed fireside the temperature on a mortar and junction between mortar and hollow-brick masonry blocks at the 50 cm, 150 cm, and 250 cm from the lower edge of a wall has been measured. All obtained temperatures during the fire test were presented. The temperature in the furnace has been according to the standard SRPS EN 1363-1:2014. The temperature and deflection of the unexposed fireside have been in according to standard SRPS EN 1364-1:2015. The wall has reached fire resistance of 180 min. Temperature difference at a mortar and junction between mortar and hollow-brick blocks, at the start of test has been 5%, then at the first 5 min of the test that difference has grown up to 80%. After 5 min of the start of test temperature were falling down and at the end of a test temperature difference has been 20%. The temperature difference on mortar and junction between mortar and hollow-brick blocks has been higher at 250 cm than at 50 cm from the lower edge of a wall. In conclusion the criteria for fire resistance for the wall tested are met.

ACKNOWLEDGEMENTS

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