Experimental investigation of thermal performance of mortars

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ABSTRACT

Increasing rate of energy consumption in building sector has led the constructors towards the low-energy consuming methods. The enhancement of thermal performance of structural elements in conjunction with mechanical properties yields to the decrease in environmental impacts. In this paper, thermal performance of ASTM mortars has been investigated. Considering the limitations of typical methods in the measurement of thermal parameters, in this investigation, the parameters of lag time, decrement factor and thermal conductivity of mortars have been measured using the method of hygrothermal chamber. Results show that type O mortar with the minimum thermal conductivity of 0.264 (watt per kelvin-meter) and the maximum lag time of 66 minutes, had the significant thermo-buffering capacity among the ASTM mortars. However, due to the low cementitious materials in the mixture of the mortar, type O lacks of the acceptable strength features. Consequently, the optimum type of mortar must be produced in which the thermal performance has the same value of the mechanical properties.

Keywords

Mortars, Masonry structures, energy consumption, thermal performance, ASTM standard

1. Introduction

The high rate of energy consumption in the building sector has led the designers towards the construction methods that consume less energy during construction up to serviceability. The energy demand in developing countries is two to three times higher than in other European countries. For instance, in 2013, it was reported that the building sector in developing countries consumed 45% of the total energy.

More than 30% of the population in developing countries lives in rural areas. In these areas, the buildings are mostly built of masonry materials. Masonry walls are mainly constituted of brick and mortar and are constructed by untrained labor which leads to energy-consuming buildings [1]. In this subject of study, many researchers investigated the effect of thermal characteristics of masonry structures on the amount of energy consumption in the buildings. Tavil et al. [2] evaluated the thermal performance of masonry walls with different insulating systems. Aste et al. [3] conducted an experimental and analytical analysis to study the impacts of inertial mass on the thermal energy saving factors of monitored schools made of masonry blocks.

All the researchers mentioned above stated that the response of building materials subjected to the thermal loads is fluctuating with time. Moreover, this response is not only affected by thermal conductivity, but also by time-dependent parameters like time lag and decrement factor. Therefore, it is necessary to measure these parameters to conduct a comprehensive comparative study. Besides, there are a few studies on the thermal effects of mortars between the bricks. Current study focuses on the thermal characteristics of all types of mortars in ASTM.

2. Methodology

2.1. materials

The sand used for the preparation of specimens was collected from Tehran, Iran. The dry density and the existing moisture content of this sand are 2.6 gr/cm^3 and 2.4%, respectively. The Portland cement (type II) and the clay have the density of 3.16 gr/cm^3 and 2.3 gr/cm^3, respectively.

2.2. Specimen preparation

The specimens are made of sand, Portland cement (type II) and clay. The mixture ratio was based on ASTM C270 and the mix designs are shown in Table 1. The amount of existing water was calculated and applied in the mixing water content. The required quantities of soil and water were combined until an integrated mixture was obtained. The wooden formwork was located such that the specimen was 4 cm thick. Then, the mixture was placed in the mold to the one-third of the height of formwork and compacted. Soil compaction continued until the height of the specimen reached 30 cm. Therefore, the ultimate size of each specimen was 4×30×50 cm. All the specimens were cured at 20˚c±5˚c and the moisture of 90% for 28 days. The specimen preparation and the procedure of the experiments are shown in Figure 1.

Table 1. Mix design details of specimens

specimens	water	clay	sand	cement	ratio
N	1.92	1.18	8.00	1.62	1:1:6
O	2.18	1.57	8.00	1.08	1:2:9
S	1.77	0.78	8.00	2.08	1:0.5:4.5
M	1.42	0.47	8.00	2.59	1:0.25:3.75

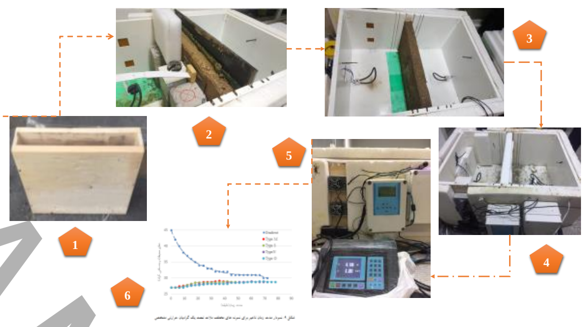

Figure 1. Experimental proceure and specimens preparation

2.3. Experimental procedure

A simplified "box method" implemented to determine the thermal conductivity of construction materials using Fourier's law. after equalizing the initial conditions, when the heater at subspace 2 was shut off, the temperature at subspace 1 reached 45°c. The duration of stabilizing the temperature at subspace 1 was three hours. In this case, the steady-state condition was reached. Using Fourier's law and establishing the similar condition, thermal conductivity was determined for all the wall specimens. Besides, the time taken for the temperature of both sides to be equalized was noted as time lag. In order to evaluate the mechanical characteristics of the mortars besides the thermal features, the compression test was conducted. To increase the accuracy, 3 specimens with the dimensions of 5×5×5 cm (Figure 2) were constructed for each type of mortar and the results are the average of the 3 specimens.

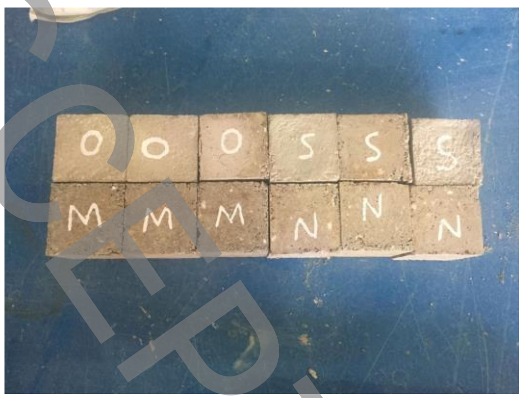

Figure 2. Specimens for compressive strength test

3. Discussion and results

3.1. Time lag

Figure 3 shows the time lag results for ASTM mortars. Based on the results, specimens with high amount of clay had the longer time lag duration. This reveals that the clay enhances the mortar's thermo-buffering capacity.

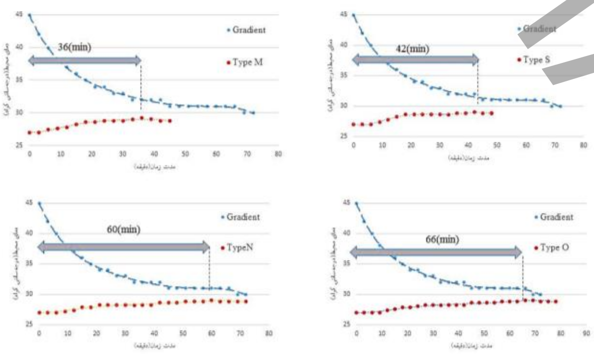

Figure 3. Time-lag results

3.2. Thermal conductivity

Figure 4 demonstrates the thermal conductivities of all the mortar specimens. As expected, the mortar type O had the lowest and type M had the highest value for the thermal conductivity. This fact reveals the effect of clay to cement ratio on the thermal characteristics of mortars.

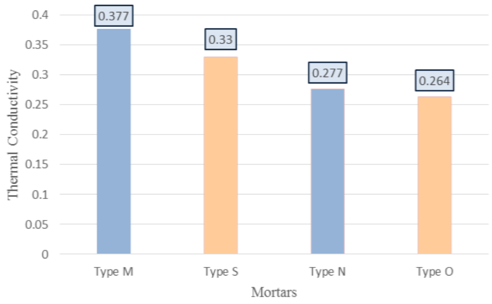

Figure 4. Results for thermal conductivity measurement

3.3. Compressive strength

Figure 5 shows that mortar type O has the lowest and mortar type M has the highest value for compression test. This is because the high amount of cement added to the type M.

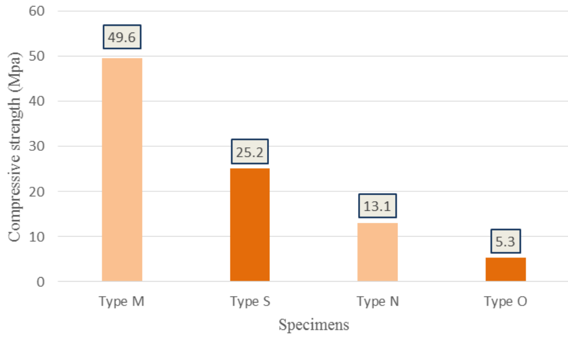

Figure 5. Comparative diagram of compressive strength of mortar specimens

4. Conclusion

In order to decrease the rate of energy consumption and enhance the thermal performance, the optimum mix design was chosen for the mortars. Based on the results, mortar type O with the lowest thermal conductivity of 0.264 wat/K.m and the highest time lag of 66 minutes had the best performance among the ASTM mortars in the case of energy performance. However, this type had not the acceptable compressive strength due to low amount of cement used in its mix design.

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