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Research paper

Implementation of One Dimensional Finite Difference Heat Conduction Method to Quantity Heat Transfer through Lightweight Cellular Mortar

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Abstract

This paper accounts the origin of Finite Difference technique (one dimensional) to determine thermal performance of lightweight cellular mortar. This paper will also assimilate the execution of the technique and the reasoning of thermal properties model of lightweight cellular mortar. For this work, a one dimensional finite difference heat conduction simple excel program had been developed to foresee the temperature enlargement via the width of the lightweight cellular mortar system, based on initial approximation of the thermal conductivity properties in relation to the temperature growth in the model as a function of the cellular mortar porosity and the effect of radiation and heat emission surrounded by the voids inside the cement matrix. The accuracy of the developed simple model was then evaluated by equalling prophesied and measured temperature growth assimilated from prototype heat transfer assessment on lightweight cellular mortar system to facilitate the temperature growth of the sample premeditated by the program meticulously bouts those verified through the experimental procedure.

Keywords: *Cellular mortar; Heat transfer; High temperatures; Specific heat; Thermal conductivity*

1. Introduction

At the moment, the delinquent of a permeable material like lightweight cellular mortar uncovered to high temperature exposure is of prodigious consideration in construction industry [1,2]. The air pores are created by rousing air with a certain type of surfactant which is mixed together with water; and then the foam cautiously included together with the cement matrix to form lightweight cellular mortar [3,4]. Assimilating the air pores inside the mix will offers a low self-weight and great workability [5,6]. Throughout revelation to high temperatures, many non-linear phenomenon's' regarding the dissimilar phases establishing the porous media in lightweight cellular mortar should be considered methodically [7]. In turn to reflect fire resistance capability of building and structural components, it is critical to differentiate temperature growth and development of these building and structural elements during fire circumstances [8,9].

2. Mathematical Model

2.1. Ordinary Portland cement (OPC)

The common transient heat conduction (taking into account the 3 dimensional situation), the equation can be written as [10,11]:

$$\rho c \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) \qquad (1)$$

where $T(x,y,z,t)$ is measured temperature (˚C); $k(T)$ is mesasured temperature reliant thermal conductivity (W/mK); ρ is the density of the material itself (kg/m^3); c is considered as specific heat capacity of material (J/kg°C); t is time taken (sec); x, y, z are the directions.

If the width of the lightweight cellular mortar is very less in gap to the other sizes, the delinquent will decrease to a 1 dimensional heat transfer exploration. Henceforward, the governing Equation (1) without any heat compeers decreases to [12,13,14]:

$$\rho c \frac{\partial T(x,t)}{\partial t} = \frac{\partial}{\partial x}\left(k(T)\frac{\partial T(x,t)}{\partial x}\right) \qquad (2)$$

where $0 \leq x \leq L$, for $t > 0$ in which L is considered as width of material measured.

Supposing a consistent material and selecting the unambiguous technique, the temperature development of a volume cell in the material at certain time lap is calculated straight away based on the temperatures growth of the neighboring cells in the last time step taken in which leads to a very forthright arrangement of computation [15,16,17]. For a distinguishing part m in the component:

$$T'_m = F_0\left[\frac{2(k_{m-1,m}T_{m-1} + k_{m+1,m}T_{m+1})}{k_{m-1,m} + k_{m+1,m}} + T_m\left(\frac{1}{F_0} - 2\right)\right] \qquad (3)$$

where F_0 is defined as:

$$F_0 = \frac{(k_{m-1,m} + k_{m+1,m})\Delta t}{2\rho c(\Delta x)^2} \qquad (4)$$

T'_m is considered the recorded temperature at certain location of m in the succeeding time step and $k_{i,j}$ represents the effective thermal conductivity of the material at the middling temperature nods of *i* and *j* [15]:

$$k_{i,j} = k\left(\frac{T_i + T_j}{2}\right) \tag{5}$$

3.0 Basic Properties

In turn to employ the suggested model of heat transfer investigation, it is vital to distinguish the density of the material, the specific heat capacity as well as the effective thermal conductivity of the material. All these parameters must be known at first place in order to run the developed system successfully.

3.1. Density of Lightweight Cellular Mortar

The moisture flow in lightweight cellular mortar could be conveyed in terms of the evaporable water inside the material or free water exist in the cement matrix [18, 19, 20]. Evaporation of the internally bounded water (chemically bounded) will lead to dehydration in lightweight cellular mortar, which will stimulus all the above mentioned 3 properties. In general, the process of early dehydration will commences approximately at 105°C. Figure 1 displays the logged density of lightweight cellular mortar at diverse recorded temperatures for cellular mortar density of 650 kg/m^3.

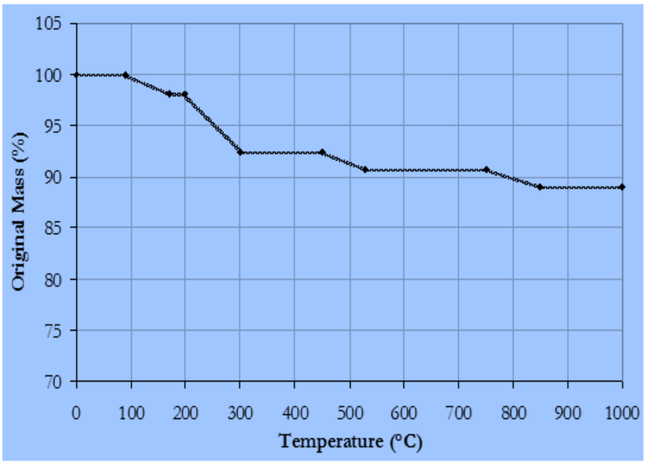

Fig. 1: Lightweight cellular mortar density at difference temperature exposure

3.2 Specific heat of Lightweight Cellular Mortar

Specific heat of lightweight cellular mortar can be distributed into 2 portions; which is the basic rate conforming to the mix dry elements and the consequence of water disappearance [19, 20, 21]. The specific heat capacity of lightweight cellular mortar experience one topmost agreeing to the dehydration reaction of lightweight cellular mortar between 105°C to 165°C as revealed in Figure 2. This topmost signifies the energy expended to detach and disperse water and includes the outcome of water movement and also re-condensation process of water inside the lightweight cellular mortar matrix [22, 23, 24].

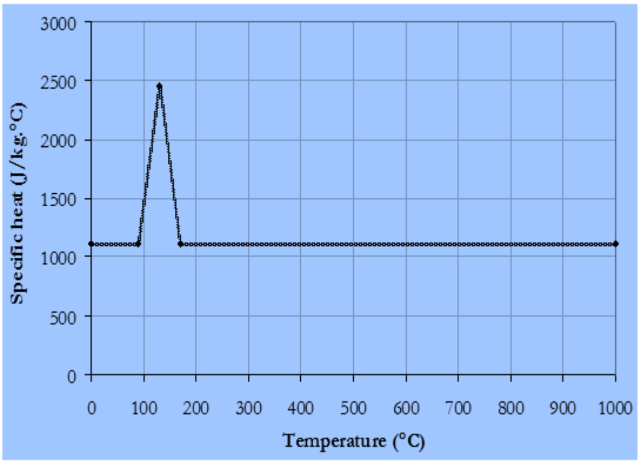

Fig. 2: Specific heat of lightweight cellular mortar at difference temperature exposure

3.3. Thermal Conductivity of Lightweight Cellular Mortar

The measured thermal conductivity of cellular mortar of 650 kg/m^3 density can be summarized into 3 sections as been shown in Figure 3; (a) Persistent measured thermal conductivity up to 95°C prior to water disappearance process; (ii) Undeviating decrease of thermal conductivity to 0.13 W/m°C at 165°C; (iii) Non-linear upsurge in thermal conductivity of the cellular mortar.

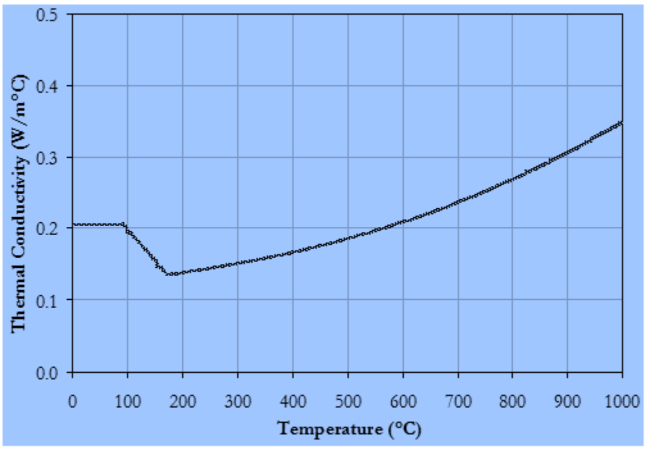

Fig. 3: Thermal conductivity of lightweight cellular mortar at difference temperature exposure

4.0 Justification of Heat Transfer Model

All the dignified measured temperatures growth through the experimental verification at entire recorded positions of the cellular mortar samples were then matched with mathematical exploration outcomes. Thermal properties results are reflected and their forecast results compared. Exposed exterior temperatures growth is utilized as input data in the heat transfer analysis to eradicate indecision in the thermal boundary condition on the exposed side. Figures 4-7 make a comparison of the dignified and mathematical analysis results. As can be seen from Figures 4-7, evidently designate very close agreement amongst estimated and dignified results of temperature growth via the width of the lightweight cellular mortar samples.

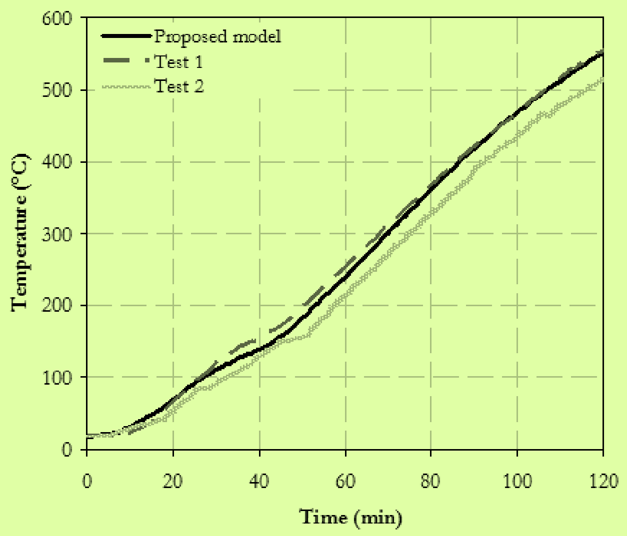

Fig. 4: Located at 37.5mm from unprotected flank

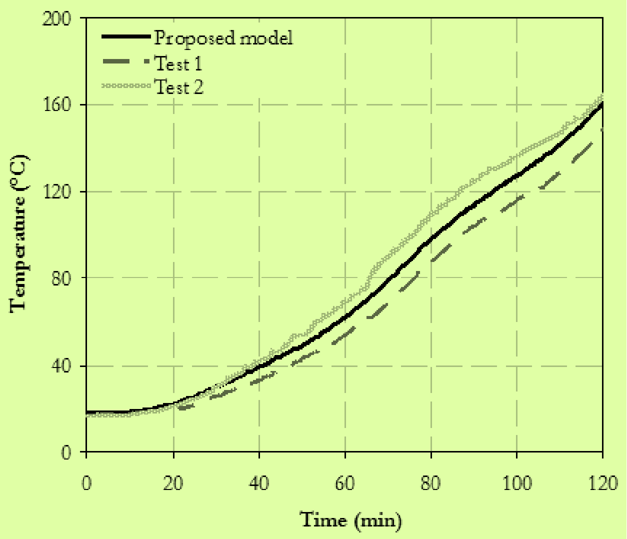

Fig. 5: Located at 75.0mm from unprotected flank

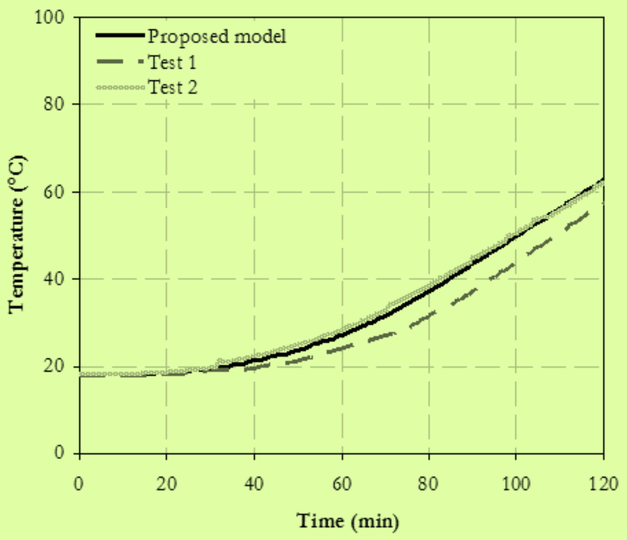

Fig. 6: Located at 112.5mm from unprotected flank

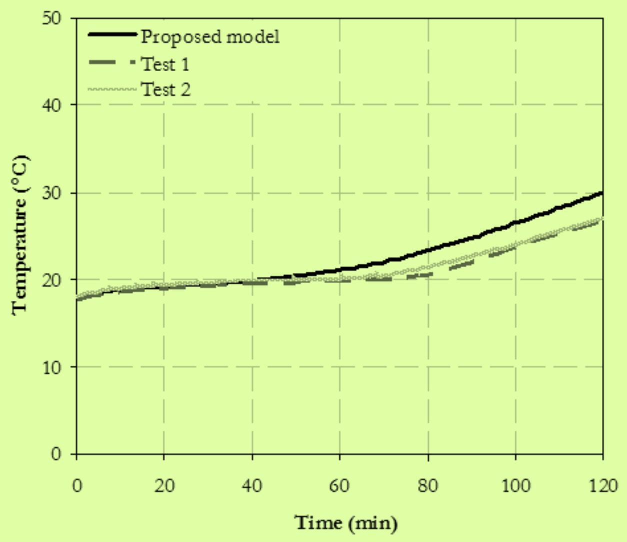

Fig. 7: Located at unexposed side

5. Conclusion

From the study, it can be concluded that the comparison of experimental results with the mathematical heat transfer model results using the recommended thermal properties equations is adjacent, ratifying the cogency of the simple model. In spite of easiness, the aforesaid investigative components for the average specific heat and thermal conductivity of lightweight cellular mortar contribute to precise results. The suggested model is frank yet adept and can be browbeaten to support manufacturers to improve their products deprived of having to perform abundant bigger scale experimental work.

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