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An Experimental Investigation of Thermal Properties for Different Building Materials Used in Egypt

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A B S T R A C T

The thermal properties of buildings' envelope play a significant role in determining energy consumption and thermal comfort within a building. This is the direct effect of the heat gain through the building's envelope on temperature distribution over its interiors. The thermal properties of a building material are not constant due to the variation of the material's components and its manufacturing from a place to the other. This work aims to extract the thermal properties of the commonly used building materials across Egypt using a lab-scale designed device. The experiment's device and settings have been validated. The results of this work will facilitate and enhance the performance of thermal simulation of building interiors within the Egyptian context through accurate specification of the local building materials' thermal properties. Commonly utilized building materials across Egypt are examined such as light brick, cement brick, hollow clay brick, ceramic, mosaic tiles, and beech wood. It is noticed that there is difference in the thermal properties' values of some tested materials when compared to the Egyptian code, while they are found to be agreed with some other studies. This difference or agreement can be referred to the component of the material and its manufacturing process.

1. Introduction

Providing comfort conditions for occupants along with minimizing energy consumption in buildings is a main concern for Architects. Thermal loads through building envelope have a significant effect on the temperature distribution over the internal spaces of buildings. Appropriate design of the building envelope can reduce excess thermal gains through the envelope along with reducing the use of mechanical means to achieve thermal comfort. The use of appropriate materials in constructing building envelope can reduce energy use in buildings by 20-30% [1]. However, the variation in climatic regions and their conditions across Egypt, it is, in general, classified as hot arid climate. This in turn creates challenges in introducing climatical responsive treatments for building envelope that can achieve energy consumption reduction and thermally comfortable environment in such harsh conditions.

Recently, lots of mathematical models embedded in thermal simulation software are used to investigate the effect of those treatments' parameters on the thermal performance of the buildings. Within this software, the more accurate modelling process, the more accurate results will be obtained. The modelling process consists of graphically presenting the building in details within its context along with the physical specification of its fabric properties.

In Egypt, there is a shortage regarding the widely used construction materials' thermal specifications in the Egyptian context. Hence, the inputs of different simulation programs rely on the properties of standard materials that are currently accessible. However, differences arise between the actual properties of the used materials and the properties stated by the source, standards, and manufacturers. This may cause inconvenient outcomes when specified in simulation modelling. There is a need for additional studies and research to develop libraries for different local materials with their actual properties. This will help in verifying the accuracy of simulation inputs, instead of relying on the materials' data that already being adopted from codes and standards in simulation programs.

Dealing with this argument, this study aims to develop a cost-effective device for experimentally extracting the actual thermal properties of different local construction materials either, individually or as a composite section of a wall. Such device can introduce quickly measured actual results either for, the tested sheet of material or multi-layer wall section.

Many studies focused on estimating the thermal properties of building materials. The U-values (overall heat transfer coefficient) of building envelopes composed of conventional and bio-based materials are thoroughly reviewed in the study conducted by Jiaqi et al[2] . The following summarizes three research findings on U-values for building envelopes: (a) A thorough investigation of the connection between environmental factors and U-values is necessary; (b) there are notable discrepancies between theoretical and measured U-values, particularly for concrete and brick envelopes; and (c) it is necessary to confirm the accuracy of both theoretical and measured U-values., Toure et al,[3] conducted experimental work for evaluate the time lag and the decrement factor for compressed earth bricks building envelope. They monitored the temperature and both, direct and global solar radiation for the duration of four days. The resulted time delay and decrement factor of the tested material was around 6 hours and approximately 0.40 respectively.

Balaji et al.,[4] theoretically, investigated the impact of various wall configurations of building envelope with different thermal properties on thermal performance of the building. The impact of various wall configurations on time lag, decrement factor and the heat loads of the inner surface were investigated. Many impacts of many factors were calculated such as; thermal capacity, thermal conductivity, and the optimal thickness for maximizing energy storage.

Balhadje et al.,[5] examined the impact of wall orientation on its thermophysical properties such as, time lag and coefficient of decay within hot dry region. Two different configurations of the wall were examined; in the first, wall was constructed from sand concrete mixed with sawdust and in the second was constructed from sand concrete only. The findings indicated that substituting sand with sawdust resulted in enhanced thermal properties of the wall, specifically in terms of thermal conductivity, specific heat, and thermal diffusion. In terms of orientation, the wall that contains sawdust was found to has good performance in all directions. However, the northern and western orientations were found unsuitable for sand concrete alone. Additionally, it was observed that the eastern orientation achieved long time lag.

A numerical model has been developed by Mavromatidis et al.,[6] to assess the time lag and decrement factor for building walls, incorporating various configurations of Multi-layer Thermal Insulation (MTI). The combined heat transfer coefficient for that composite walls were numerically calculated. The collected climatic data of the two different locations were applied to the tested wall exterior to examine its thermal behaviour against actual outdoor climatic conditions. It was found that the selection of a specific wall configuration is influenced not only by external climatic conditions but also by the overall characteristics of the building such as its orientation and other relevant factors. The developed numerical model in the study were found to be valid in designing the optimal configuration of the MTI. In addition, it can be manipulated according to different climates and orientations, which in turn may effectively help in producing more efficient solar buildings and other associated energy-saving domains.

Using a numerical model, Jin et al.,[7] examined how the time delay action and decrement factor affect the thermal performance of the external wall. The research findings indicated that by increasing the heat capacity of the wall, it is possible to mitigate the volatility of heat flow through the wall. However, it is not possible to decrease the overall heat flow during daylight hours. Furthermore, the time delay grows as the heat capacity and wall thickness rise. On the other hand, it decreases when the conductivity increases. It is also found that the coefficient of decrease of the wall's thermal conductivity was inversely proportional to both, the wall thickness and its heat capacity. Also, it was directly proportional to the wall's thermal conductivity.

Using a commercial energy rating tool developed by the Australian Commonwealth Scientific and Industrial Research System (GIRO), Gregory et al,[8] conducted a numerical investigation on the impact of thermal mass on the thermal performance of several types of Australian residential buildings. The research aimed to measure a material's ability to absorb, store, and release heat [9,10]. Three envelope's materials were attached to the tested model including clay hollow brick, reverse brick veneer, and lightweight construction. The thermal performance assessment was conducted in four distinct domains. The results indicated that the thermal performance of hollow core bricks and reverse brick veneer is highly comparable. In conclusion, it can be inferred that reverse brick veneer consistently exhibits the lowest energy use across all scenarios.

Albatayneh et al.,[11] explore a technique for assessing the thermal efficiency of whole structures by employing the strategy of adaptive thermal comfort. They measured the duration of time in which the internal air temperature of the building stayed within the designated adaptive thermal comfort range over the year. The study employed a multi-unites residential building with various envelope's materials. Their results revealed that the unit with insulated brick achieved the best building thermal performance over the year. In terms of thermal performance, units with inverse brick veneer, insulated brick veneer, and hollow brick came in order in the 2nd , 3rd , and 4th place respectively.

Md Din [12] analysed the thermal characteristics of four commonly used building's outer shell materials across Malaysia namely (brick, concrete, granite, and white concrete tiles). Surface temperature sensors, data recording system, and infrared thermography were installed and used through the experiment. The findings indicated that bricks have a higher capacity to absorb and retain heat compared to other tested materials during the experiment. The results highlighted the substantial release of heat into air via both; radiation and convection. The absorbance and heat-storing values of the tested materials from high to low were found to be brick, concrete, granite, and white concrete tiles. According to the results, it was recommended to use granite and white concrete tiles in covering building facades to achieve thermally comfortable building's outer microclimate.

Asan[13] examined the time lag and decrement factor associated with various construction materials. The Crank-Nicolson scheme was employed to solve the one-dimensional transient heat conduction equation, using convective boundary conditions. Specified boundary conditions were periodically imposed on the external surface of the wall. Twenty-six distinct construction materials were employed in this study with eight thickness values for each material. The effects of thickness and material type on the time delay and decrement factor were analysed. The findings of this study highlighted the significance of selecting the composition of building walls to enhance their thermal efficiency. The study concluded that with a multi-layer wall consisting of materials with distinct thermophysical characteristics, the heat flux of the interior surface of a building wall, as well as its thermal transmittance and heat storage capacity, are significantly influenced by various wall configurations. Hence, it may be inferred that materials with high thermal inertia exposed to high surface heat transfer coefficients decrease the decrement factor. Moreover, the results showed that both the thickness and the composition of the material significantly influence its thermal behaviour.

Khaled[14] developed a methodology that integrates thermal performance data derived from empirical trials with simulation data to enhance the efficiency of solar buildings design. This study employed a comparative methodology to analyse the performance of three wall sections' configurations tested in different climatic circumstances. The three configurations of the wall cross-section were system 01(2.5 cm plaster +20 cm brick+5 cm extruded polystyrene insulation +2.5 cm plaster +1.3 cm panted gypsum board layer), system 02 (2.5 cm plaster + 20 cm brick + 2.5 cm plaster), and system 03 (2.5 cm plaster + 10 cm brick + 2.5 cm plaster). The thermal conductivity, specific heat, and heat transfer coefficient for the three wall systems were tested in different conditions and then compared with simulation results for the same experiment scenarios. The thermal properties of materials in simulation scenarios relied on standards values. In general, different wall systems' performance was observed in experimental work that came compatible with simulation technique results in terms of total heat transfer coefficient. The experimental results indicated that wall system 03 had the highest yearly thermal gain, accompanied by the lowest U value and hence the least heat absorption. This study introduced a novel approach to determine the thermal characteristics of various sections by substituting the generic values from material libraries with tailored values for the specific wall systems utilized on-site.

According to the outlined above, it can be clearly observed that there is a significant disparity in the data obtained from different sources for the same building materials. The thermal properties of a building material are not constant due to the variation of the material's components and its manufacturing from a place to the other. Hence, this work aims to experimentally extract the thermal properties of the commonly used building materials across Egypt. The building materials that have thermal properties stated by the Egyptian code for enhancing energy efficiency were employed in this work as benchmark to compare with. The thermal conductivity (k), thermal resistance (R), and specific heat (C) for tested samples have been investigated to determine their impact on the temperature distribution along the wall surfaces.

2. The research methodology overview

This work is mainly an experimental work. It is trying to set up an experimental approach and methodology to extract thermal properties of some commonly used building materials across Egypt through methodological steps as shown in Figure 1. Firstly, the experiment' set up has been conducted through designing the experiment's device (namely the simulation unit) with its attached peripherals that help in controlling inputs, reading measurements as well as recording outputs. The peripherals were calibrated and the device' outputs were validated. In the validation process, the experiment readings were used to mathematically calculate the thermal properties for well-known properties tested sample. The error in calculations was estimated through uncertainty analysis. According to these steps in validation process, refinements in the experiment's set up were performed until an acceptable error was determined and in turn, the device outputs have been validated. Finally, the samples were tested, and the results were analysed in the light of the Egyptian code values.

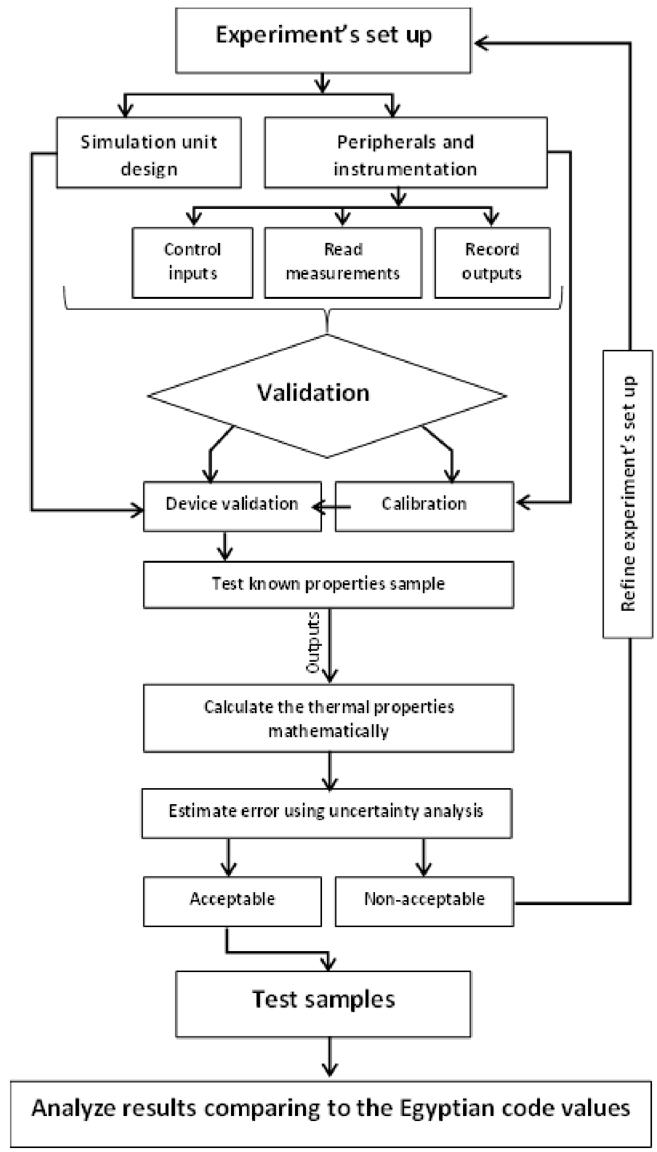

Figure 1: Methodology overview

3. Experimental setup

3.1. Test- rig

The aim of the test – rig shown in Figure 2 is to simulate the actual case of the building along with the actual position of the wall sample between outdoor and indoor environments. The experimental device (Simulation unit) shown in Figure 2 consists of three basic parts; the heat source part that represents outdoor environment, the sample location part that represent the building envelope wall, and the internal environment part that represents the indoor environment. which include the simulation unit represented by the basic part, the measurement box. Many peripherals were attached to the experiment device for either control inputs or record outputs. For controlling the temperatures inputs electrical regulator, contactor, and wattmeter were installed. Datalogger to record the outputs measurements readings. as shown in Figure 2.

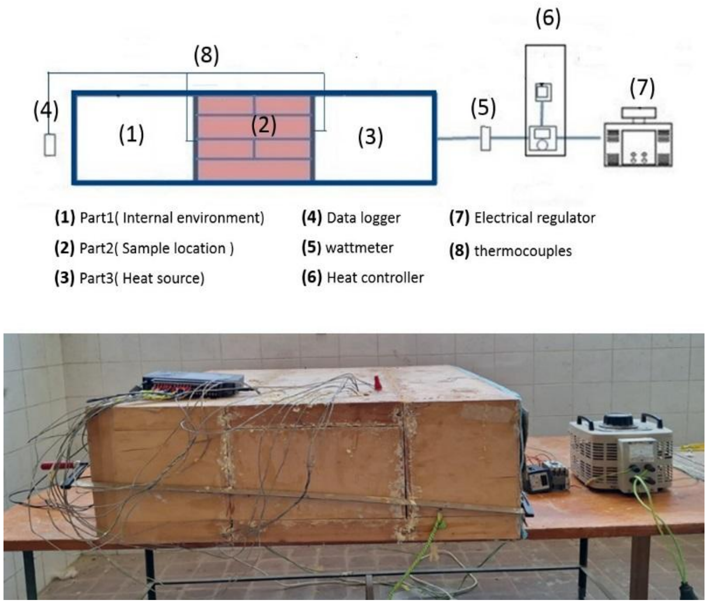

Figure 2: Description of various parts of the test- rig

3.1.1 The Simulation unit

The simulation unit represents a lab-made environmental chamber in which the ambient temperature is created, and the samples are then exposed to different temperatures to represent changing climatic conditions. The unit's walls are designed and manufactured using a wooden sandwich panel consists of two layers of 2.5 cm thickness pine wood with 5 cm gab between them filled with high density polyurethane thermal insulation, as shown in Figure 3, The insulation ensure to achieve one-directional thermal flow. The simulation unit consists of three parts as mentioned before. In the first part that represents the outdoor, an electric heater was placed to simulate the sun with heat flux similar to the actual solar radiation. An electric regulator has been connected to the electric circuit of the heater to change the voltage, consequently, the heat supplied to the sample will be changed. The middle part of the simulation unit is dedicated for installing the sample under test. The last part represents the indoor space of the building. In order to reduce test time and examine many samples at the same time, the middle and last part of the unit is divided into three equal parts. Each part can hold a sample with height of 25 cm , width of 25 cm, and thickness up to 40 cm. The samples under test are exposed to temperatures for a full day which is the test period. The side of the sample exposed to the temperature from the heat source is known as the outer surface of the wall and the other side is known as the inner surface of the wall.

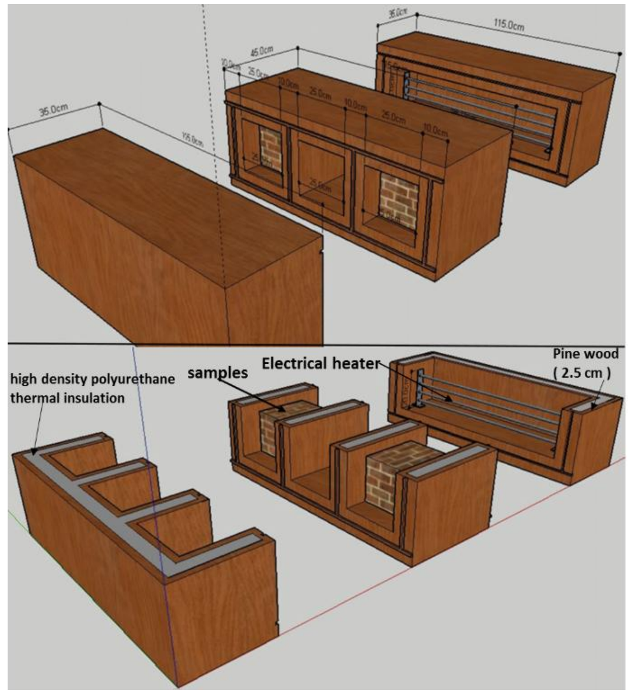

Figure 3: Simulation unit of the experimental device.

3.2. Instrumentation

3.2.1 Temperature measurement

In terms of monitoring and recording temperature, thermal data logger was used to receive readings coming from thermal sensors installed over the surfaces of the tested samples during the experiment. Thermal thermocouples (Type K) were placed according to the guidelines of the American Society for Testing and Materials (ASTM) [14], Six thermocouples are placed on sample's both surfaces with three for each surface, and they were distributed at equal distance over the samples' surfaces. as shown in Figure 4. Their data are recorded by a data logger (midi LOGGER Gl820) at five-minute intervals for 24 hours (the duration of the experiment), Figure 5. The temperature, the sample is exposed to, is controlled while the other side (internal space) is left uncontrolled without cooling or heating. The data logger acts as a unit for storing the measured data.

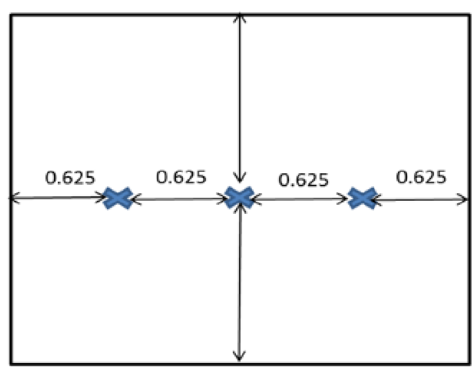

Figure 4: Distribution of temperature thermocouples over each surface of the sample

Figure 5: Data store and transfer unit to the computer

(midi LOGGER GL820)

3.2.3 Heat flux measurement

Heat controller (Contactor) is used in the test to determine the capacity of the heater during the period of the experiment.

In general, the design of the experiment was based on obtaining data measured by thermal sensors and then mathematically calculate the thermal characteristics of the tested samples. The factors that could be controlled during the experiment were the heater capacity of the heater and the temperature of heater compartment that represents the external environment.

4. Governing mathematical equations

Four equations are used to calculate the thermal properties of the tested materials. These are

$$Q = \frac{\Delta T}{R} \tag{1}$$

$$R = \frac{L}{k \times A} \tag{2}$$

$$Q = \frac{\Delta T}{R} = U \times A \times \Delta T \tag{3}$$

$$U = \frac{1}{R \times A} \tag{4}$$

where: A :sample surface area, m2; L:thickness, m; k: thermal conductivity, W/m.K; R:thermal resistance, K/W; ΔT : temperature difference between the inner and the outer surfaces of the sample, K; Q: thermal power, W; and U= overall heat transfer coefficient W/m2..K.

5. Uncertainty, calibration, and validation

Accurate representation of temperature measurement results is crucial for successful experimental study in the field of thermal sciences. The accuracy of these measurements significantly relies on the accompanying uncertainty of the recorded temperature.

Calibration refers to the procedures of measuring or modifying the deviation of an instrument (which is being calibrated) from a specified standard. This is accomplished by comparison the device or the output of an instrument with a standard that possesses established properties.

5.1. Temperature measurement calibration

Precision calibration of a type K thermocouple was conducted utilizing the fixed-point technique with water. The analysis determined a range of temperature record between 0 o C and 100o. The accuracy of the thermocouple readings was calibrated. Given that the thermocouple measurement was within a range of ±0.5o about the true temperature value.

5.2. An uncertainty analysis

In order to precisely evaluate the range of error in the calculated output parameters based on the measurements during the experiment, an uncertainty analysis was conducted. The instruments used in the experiment were already calibrated by the manufacturers. The measurement error associated with each instrument was obtained using calibration certifications, manufacturer specifications, and datasheets of the instrument.

The uncertainty in the calculated parameter, derived from experimental measurements of individual values, is calculated using the law of uncertainty propagation [15] provided below.

$$\boldsymbol{W_f} = \sqrt{\left[(\frac{\partial f}{\partial f_1})^2 \times \boldsymbol{W_{f1}^2} + (\frac{\partial f}{\partial f_2})^2 \times \boldsymbol{W_{f2}^2} + \cdots (\frac{\partial f}{\partial f_n})^2 \times \boldsymbol{W_{fn}^2}\right]} \tag{5}$$

where: Wf = the total uncertainty in the calculated value of the function f based on individual uncertainties of independent parameters that are included in its calculations.

For instance, the uncertainty of the calculated thermal power flew through the tested material (Q) based on measured independent parameters, is:

$$W_Q = \sqrt{\left[\left(\frac{\partial Q}{\partial k} \times \Delta k\right)^2 + \left(\frac{\partial Q}{\partial A} \times \Delta A\right)^2 + \left(\frac{\partial Q}{\partial (t_2 - t_1)} \times \Delta (t_2 - t_1)\right)^2 + \left(\frac{\partial Q}{\partial L} \times \Delta L\right)^2\right]}$$

W_Q = 0.380 watt

$$W_k = \sqrt{[\left(\frac{\partial k}{\partial Q} \times WQ\right)^2 + \left(\frac{\partial k}{\partial A} \times WA\right)^2 + \left(\frac{\partial k}{\partial T} \times WT\right)^2 + \left(\frac{\partial k}{\partial L} \times WT\right)^2}$$

W_k = 0.113 W/m°C

5.3. Device validation

Prior to performing the experiment and testing the proposed material samples, the designed simulation device results should be validated. The validation was conducted by comparing the thermal pro+perties calculated from its measurements with the well-known properties of a specific sample. Thermal conductivity parameter of a light brick sample, that was measured by the Egyptian Housing and Building National Research Centre (HBRC), was used in the validation process.

In the validation process, two 12 cm thickness samples of light bricks were placed in a row considering being tightly adjacent to each other with no air gaps. The first sample exposed to heat source placed to determine the value of the energy reached to the second sample to facilitate determining the value of the thermal conductivity coefficient and perform validation.

The value of the thermal resistance (R) of the first sample was calculated given its thickness and the area exposed to heat, as well as the value of its conductivity coefficient. The value of ΔT was figured out through the results of the experiment. The value of (Q) passing through the first sample was calculated using Equ.1. The thermal conductivity coefficient of the second sample was calculated using Equ.2 with calculated (Q). It was found that there is agreement with error not exceeding 10% between resulted thermal conductivity coefficient of the second sample and the coefficient value reported by (HBRC) for such material. The results of the validation experiment are shown in Figure 6.

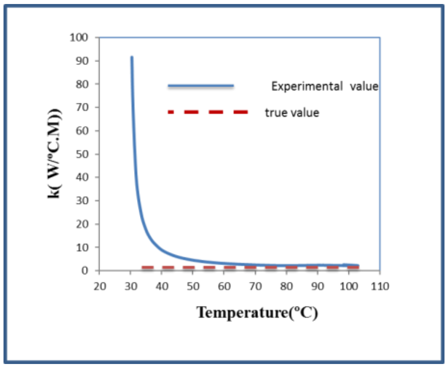

Figure 6: Results of a validation experiment for the sample of light brick

6. Results and discussion

Six commonly used different building material samples within the Egyptian context were employed in this experiment as follows:

- Hollow clay brick with dimensions (25 cm × 25 cm ×12 cm)
- Cement brick with dimensions (25 cm × 25 cm ×12 cm)
- Ceramic with dimensions (25 cm ×25 cm ×1.0 cm)
- Mosaic tiles with dimensions (25 cm ×25 cm ×2 .0 cm)
- Beech wood with dimensions (25 cm × 25 cm × 5.0cm)
- Limestone with dimensions (25 cm ×25 cm ×12 cm)

Generally, the materials adopted in the current study can be divided into two categories: the first one includes the main building materials (clay hollow brick, cement brick, and limestone), while the other category includes the finishing materials (ceramic, mosaic tiles, and beech wood).

The calculated values of the thermal properties for various material samples under study depend on the temperatures on both sides of the sample (the hot sides and the cold sides), and the average temperatures measured for each surface.

The results show noticeable agreement with values reported by the Egyptian code for the studied two samples, namely the hollow clay brick and the cement brick, where the percentage of difference between the values was 26 % and 22%, respectively.

regarding the ceramic and mosaic tile samples, the percentage of difference was larger. Both samples achieved deviation from the code value by 66% for each of them. This can be referred to the possible difference between the tested sample and the sample tested by the Egyptian code. This difference could be related to the manufacturing procedures, the difference in the ingredients incorporated in the manufacturing process, as well as the source of raw materials utilized to make these samples.

Figures (7&8) show the temperature variation for both faces of the hollow clay brick, cement brick, limestone, mosaic tiles, ceramic, and beech wood samples during the experiment duration which was 24 hours in order to give a greater opportunity for more accurate results.

As for the samples face exposed to heat source (outside face), the average temperature starts at (25ºC) and then significantly increases until reaches steady-state conditions.

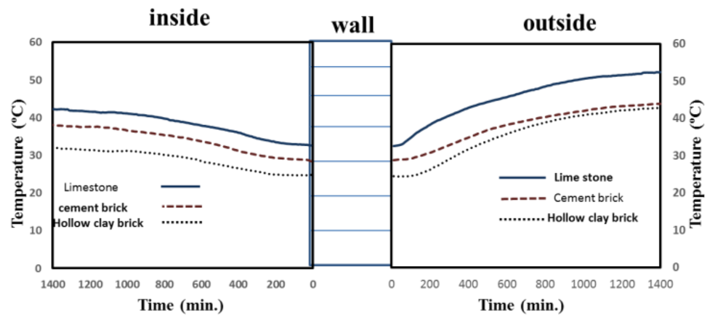

Figure 7: Average temperatures on the outside and inside surfaces of the clay brick, limestone and cement brick samples

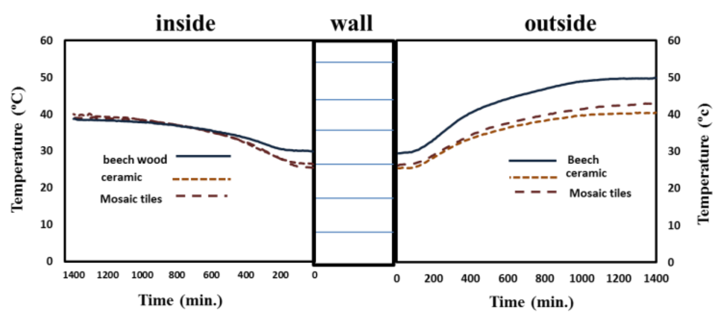

Figure 8: Average temperatures on the outside and inside surfaces of beech wood, ceramic, and mosaic tiles samples

The thermal conductivity has been calculated for the samples after they reached the steady-state condition. Figures (9,10, and 11) illustrate the change of thermal conductivity with temperature and time of the clay hollow brick, cement brick, and limestone samples, respectively considering the Egyptian code value as a reference.

The experimental value for the three samples, in order, starts with a good agreement with the code values. After that the difference reaches its peak at (90, 103, and 216W/ºC.m, respectively). Finally, the steady state is reached, with estimated difference of (32 %, 2.9 %, and 87 % respectively). This is attributed to part of transmitted heat is stored within the material according to its thermal capacity.

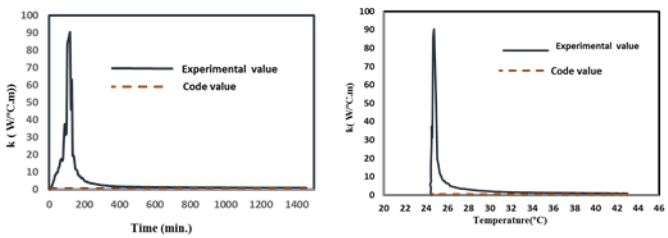

Figure 9: Thermal conductivity with time and temperature of the clay hollow brick sample

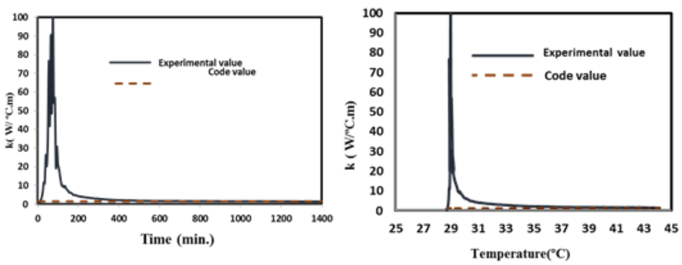

Figure 10: Thermal conductivity with time and temperature of the cement brick sample

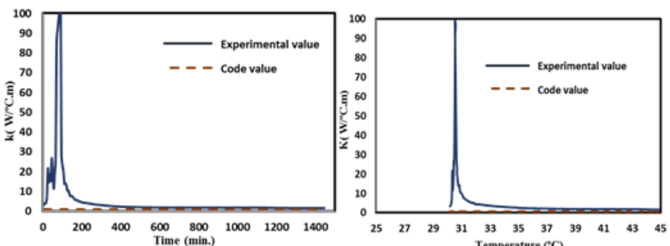

Figure 11: Thermal conductivity with time and temperature of the limestone sample

Figures (12,13, and 14) illustrate the change of thermal conductivity with temperature and time of the ceramic sample, mosaic tiles sample, and beech wood sample, respectively considering the Egyptian code value as a reference. The experimental value starts with a good agreement with the code values, after that the difference reaches its peak at (14, 32, and 54.78 W/ºC.m, respectively). Finally, the steady state is reached, with the estimated difference of (66 %, 63 %, and 67 % respectively) This is attributed to part of transmitted heat is stored within the material.

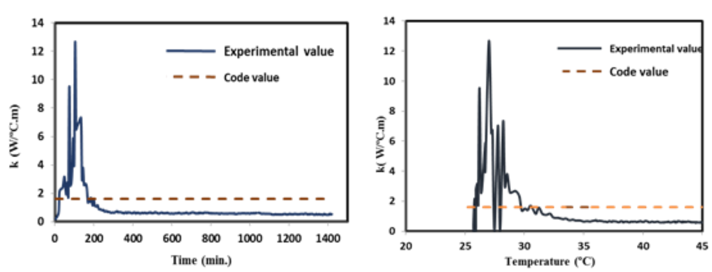

Figure 12: Thermal conductivity with time and temperature of the ceramic sample

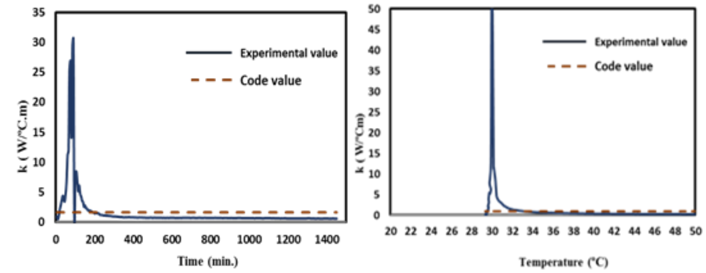

Figure 13: Thermal conductivity with time and temperature of the mosaic tiles sample.

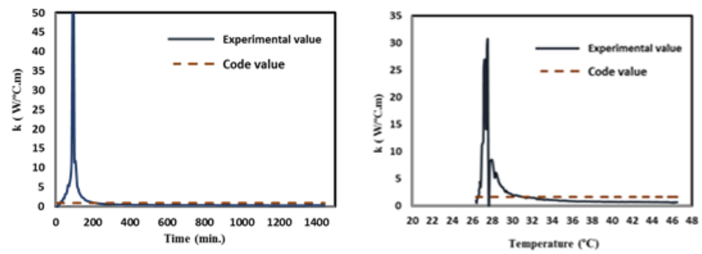

Figure 14: Thermal conductivity with time and temperature of beech wood sample

The value of the thermal conductivity coefficient of the beech wood in the Egyptian code is 0.87 W/m.ºC. However, its value is found to be vary over previous experimental work. It was reported to be 0.35 [16] and other work reported it as 0.17 W/m.ºC [17].

Based on the experimental outcomes, other thermal properties that are essential in the assessment of the thermal performance of building materials' samples, such as thermal resistance and overall heat transfer coefficient are calculated. Summary of the research experimental and calculated results compared to the Egyptian code values are shown in Table 1.

Table 1: Thermal properties for the tested materials

Thermal properties		Thermal conductivity (k) W/m.ºC		Thermal resistance (R) (m².K/W)	U- value W/m².K
		Experimental value	Code value[18]		
Materials	Hollow clay brick)	0.796	0.60	0.218	79.63
	Cement brick	1.440	1.40	0.1204	144.195
	Ceramic	0.531	1.60	0.3264	53.1898
	Mosaic tiles	0.589	1.60	0.2942	59.01
	Limestone	1.19	0.79	0.14589	119
	Beechwood	0.279	0.87	0.622	27.91
	Light brick	0.142	0.132	1.2226	14.2

7. Conclusions

- A test rig has been installed to simulate the actual conditions of building structures, and the following are the significant remarks: The thermal resistance and overall heat transfer coefficient have been calculated as important indicators for the thermal performance of building materials

- The developed test rig shows experimental results meet a good agreement with calibration material around10%.
- The studied materials are beech wood, hollow clay brick, cement brick, light brick, ceramic and mosaic tiles.
- As expected, the highest temperature difference is recorded for light brick (22ºC) which has the lowest thermal conductivity of around 0.142 W/m.ºC While the lowest temperature difference is ceramic and mosaic tiles (2ºC) for the highest material's thermal conductivity of around 1.44 W/m.ºC
- The nature of material affects the percentage of difference with Egyptian code, the maximum difference is for ceramic and mosaic tiles because it is considered as a fabricated material. In addition, the variation of source of natural material affects the properties of the materials (66% for both of them).
- As expected, the highest thermal resistance of light brick (1.22 m^2.K/ W) meets the lowest thermal conductivity (0.142 W/m.ºC), On the other hand, the lowest thermal resistance is for cement brick (0.1204 m^2.K/ W) meets the highest thermal conductivity (1.44 W/m.ºC)
- The overall heat transfer coefficient is recommended to include the other heat transfer coefficient in particular for building sections.
- It is recommended to conduct the experiment at steady state conditions to avoid the energy storage issue for materials.
- The research recommends that there is specific research for each region or country that reflects the actual design of the building level and methods of the construction industry, as well as trying to find a way to determine to what extent we can generalize in the information on which the simulation programs are based, to obtain more accurate results.

Conflict of Interest

The authors declare no conflict of interest.

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