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Temperature Measurement System for Building Material and Built Space Thermal Evaluation

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ABSTRACT

This paper examines the temperature profile of a building material and also a built space. The study directly examines the influence of solar radiation on building material and the heat it generated and diffuses into the built space. Two experiments are presented. The first look at a simple technique for evaluating heat performance of a building material, and the second evaluates the performance of a cross-ventilated built space with respect to solar radiation.

Introduction

Awareness of the need for improvement in the efficient use of energy in buildings without compromising thermal comfort has long being established. It was more than 24 years ago, the Malaysian energy policy was established (1979). The objective is to have an efficient, secure and environmentally sustainable supply of energy in the future as well as to have an efficient and clean utilization of energy utilization [1].

Any effort or strategy to further improve the energy efficiency in buildings without compromising thermal comfort should be encouraged because a large percentage of the energy utilization is from the residential

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and commercial building sectors. In 1998, the residential and commercial building sectors account for 35 % of all US energy related carbon emission [2]. One of the purposes of Malaysian code of practice in buildings is to encourage the development of new buildings, so that they can be constructed, operated and maintained in a manner that reduces the use of energy without constraining the creativity, building function, nor the comfort or productivity of the occupants and with appropriate regard for cost consideration [3].

Figure 1 shows a typical day in Shah Alam, Malaysia which receives an abundance of solar energy from the sun. In its natural form, the solar energy usually transforms and develops into excess heat which may creates discomfort. The total energy received for this typical day is 6.25 kWH/m^2.

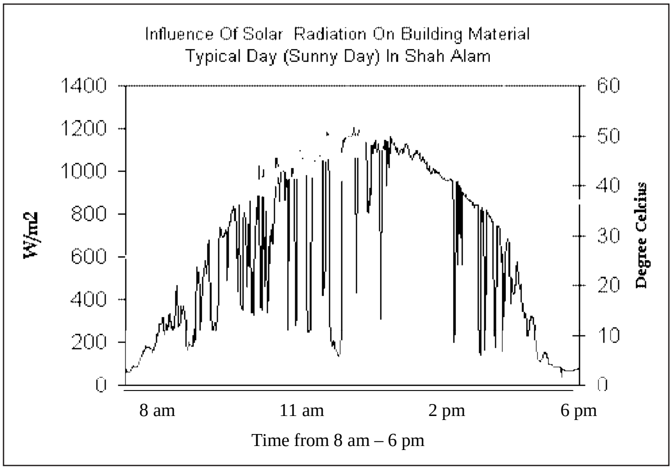

Figure 1: Typical Solar Radiation in Shah Alam

The main objective of this study is to examine the effects of solar radiation on building materials and how insulation will influence the thermal properties of the building material and a built space thermal behaviors when built using insulated building material such as a concrete slab. The thermal behavioral studies and estimation of temperature profile inside a building material will enable an optimum design for building envelope thermal performance. A well understood thermal behavior in buildings also will enable the management and control of building conditioning process to be conducted efficiently.

Time lag also exists between the external temperature and the internal temperature. For a material of high thermal diffusivity, the time lag increases but the amplitude (or swing about the mean) of heat flow is reduced or damped. The increase in time lag and damping effect is related to the heat storage effect, *i.e*. the thermal capacity of the material [4].

Experimental and theoretical investigation of effects of wall's thermophysical properties on time lag and decrement factor demonstrates the thermal inertia of the internal space and wall system. Transient heat transfer through insulated walls behave differently if the insulation is on the outside or the inside surface [5-7].

Experimental Setup

Two experiments were carried out. The first one is for measuring the temperature effects on a building material due to solar radiation. The second one is for evaluating the temperature effects for a cross ventilated built space.

Temperature Effects on a Building Material

Figure 2 shows a simplified diagram of the experimental set-up. The sample is placed on two supports (bricks). Pyranometer measures the solar radiation (S) while the thermocouples T1, T2, T3 and T4 measure the air temperatures above, on the top, bottom and below the sample, respectively. These measurements were logged onto a data logger (Hydra, Fluke, USA). T1 and T4 were measured at a distance of 2cm above and below the sample, respectively.

Evaluation of Temperature Effects for a Cross Ventilated Built Space

In this experiment, temperature micro sensors with embedded data logging memories (Hobo H08-006-04, USA) were employed at placed at various locations inside and outside the built space.

Experimental Results

Influence of Solar Radiation on Concrete Surface

In this experiment, a standard concrete slab and an insulated concrete slab were employed as samples. The results in Figures 3 and 4 show that

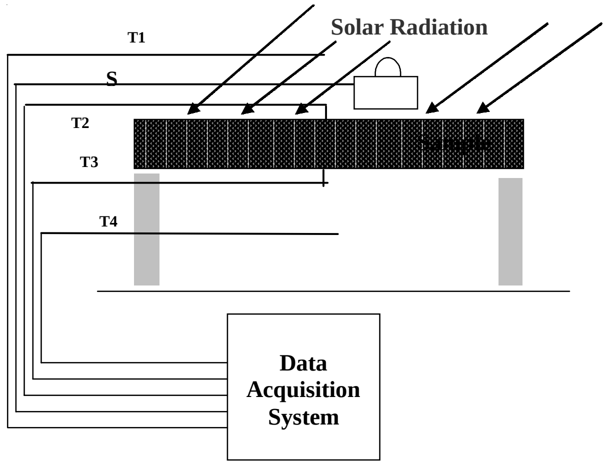

Figure 2: Experimental Set-up for the Experiment

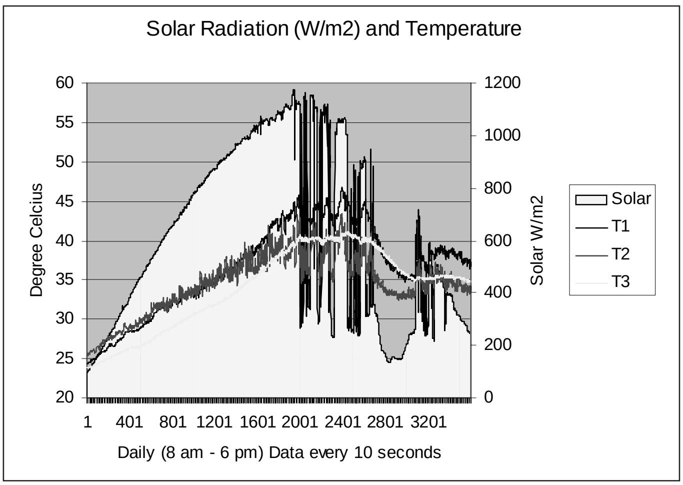

Figure 3: Temperature Profile for Various Locations in an Insulated Concrete Slab

the surface temperature varies in response to the changing solar radiation for both insulated and un-insulated concrete slab. The variation of the surface temperature changes was in parallel with the solar radiation.

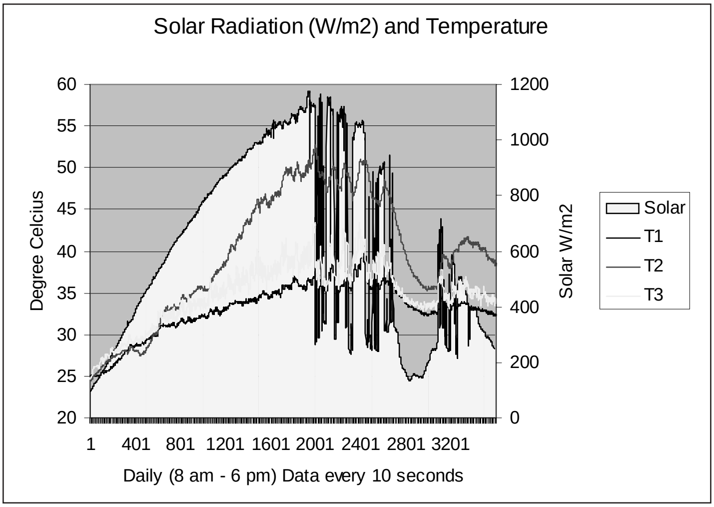

Figure 4: Temperature Profile for Various Locations in an Uninsulated Concrete Slab

Figures 5 and 6 show that the insulated concrete slab gets hotter quicker on the upper surface. For the lower surface, the temperature of un-insulated surface gets hotter faster. Here, it could be observed that insulating the concrete slab will increase the thermal resistance but will also increase the temperature of the external surface. An increased in external surface temperature will also increase the heat that diffuse through the concrete, though overall reduction in heat flow will still dominate and a net reduction of heat transfer through the concrete wall could still be observed with the insulation.

The temperature signal at certain point in the building material will indicate the thermal diffusivity of the material. With proper formulation, the signal can be used to measure the thermal diffusivity of the building material. Surface temperature, either external or internal surface will be dependent on the solar radiation while another dependent parameter is the thermal system which will indicate the property of the surface and the thermal diffusivity. How the internal surface response will depend on the thermal capacity, thermal conductivity and material density.

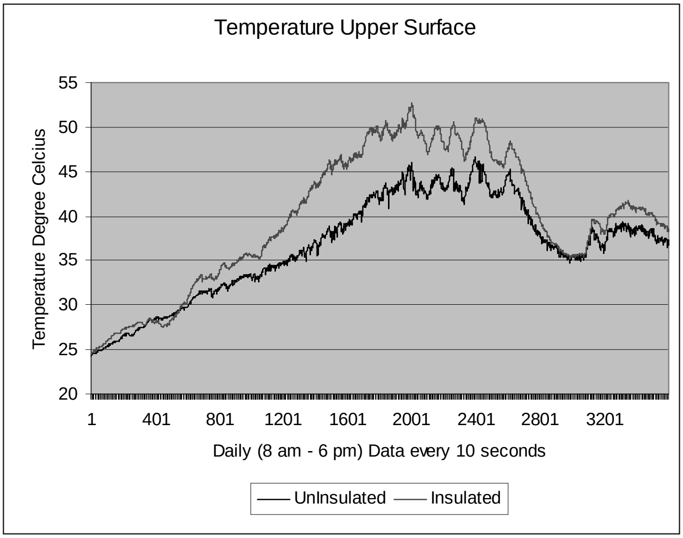

Figure 5: Upper Surfaces Temperature Effects on Insulated/un-insulated Concrete Slab

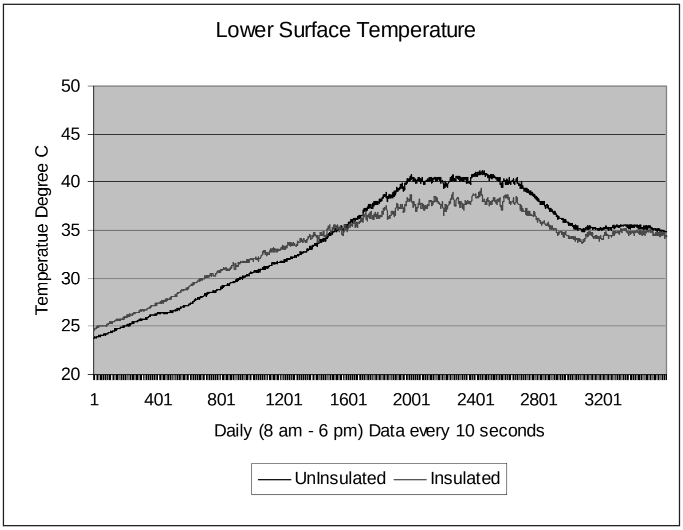

Figure 6: Temperature for Lower Surface

Temperature Effects for a Cross Ventilated Built Space

Figures 7 and 8 show the photos of the built space sampled in this experiment. Three very significant technologies were employed for this built-space. Firstly, insulated concrete slab was employed for the major walls surrounding the built space. Secondly, various ‘fins’ were used for the upper part of all internal walls. Lastly, thin and elongated holes were cut out in many parts of the ceilings.

Figure 7: Internal Ventilation through the Ceiling and Wall

Figure 8: The Holes Design to Facilitate Cross Ventilation

Figure 9 shows the average external temperature and temperatures at various locations inside the built space. This figure clearly shows that the three strategies above bring forth a remarkable improvement in the thermal effects inside the built space. From Figure 9, it could be observed that the external temperatures varies between 25 ^{o}C to 32 ^{o}C, while at the same time the temperature in the ceiling varies from 23 ^{o}C to 42 ^{o}C. Anywhere in the built space, the temperatures vary between 25 ^{o}C to 29 ^{o}C only.

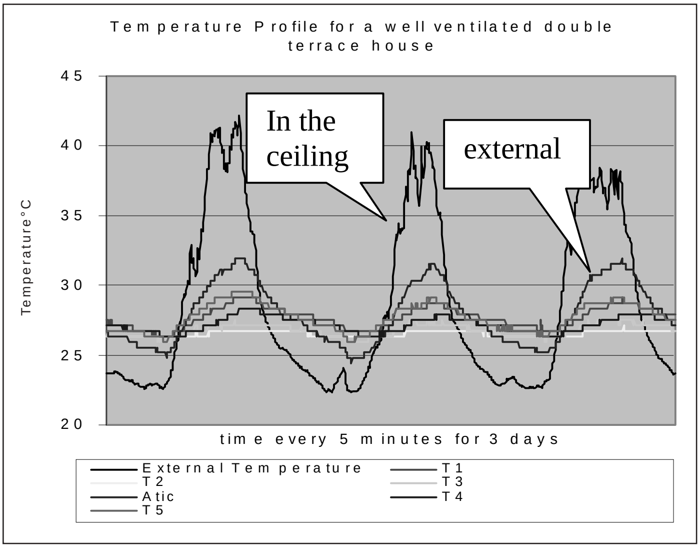

Figure 9: Temperature at Various Locations in the Built Space

Conclusion

This study shows that a simple set-up may be employed for direct evaluation of heat conduction in a building material and also for evaluating the temperature effects in a built space. A simple comparison between standard and insulated concrete slabs shows that by insulating the building material such as the concrete slab the temperature conducted to the inner surface of the material will be much lower than the outer surface which is exposed to solar radiation. Further, the application of the insulated concrete slab as built space walls, coupled with cross ventilation strategies managed to maintain the temperatures inside the built space at a low levels.

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