# Thermal Behaviour Studies on Building Walls based on Type and Composition of the Materials

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**Abstract.** Controlling the thermal behaviour of buildings is very important because it affects the energy use in the buildings and impacts the thermal environment of the area. Thermal behaviour of the building is determined by the type and composition of the building material. This paper shows the thermal behaviour of several types and composition of commonly used building wall materials, i.e. brick, aerated concrete, laminated wood with glass wool insulation, and gypsum with glass wool insulation. For the thermal behaviour measurements, we used wall models exposed to halogen lamps of 2000 watts for 4 hours heating and 4 hours for cooling with a measurement interval of 5-15 minutes. Data retrieval using 8 thermocouples mounted on the surface and inserted inside the wall. The observed thermal behaviour phenomena are the heat flow on the walls, the time delay, and the heat capacity. The results show different maps of the thermal behaviour on the walls and indicating the need for additional thermal insulation material to control the heat release to the outside and inside of the building.

**Keywords:** thermal behaviour, building material, thermal insulation

## 1. Introduction

Many experts claim that the building has a negative effect on energy use and environmental damage such as the urban heat island (UHI) phenomenon. The negative effects of the building are mainly due to the material properties used, especially the role of the building envelope [1]. Currently, in major cities in the world, there is a phenomenon of increased air temperature due to heat dissipation effects of buildings.

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The material properties that play a major role in this phenomenon are the ability to save or Specific heat and release heat or IR emissivity. The use of brick, concrete in the building and asphalt on the road body reported giving the greatest warming effect on city air [2]. The building materials have a large specific heat so that when exposed to sunlight throughout the day will store large amounts of heat. The intensity of sunlight received is influenced by a number of factors namely the orientation of buildings, seasons, weather and location of a latitude of the location.

This phenomenon is difficult to control because the materials attached to the building cannot be replaced easily and cheaply. Some experts claim that the effect of shadowing can reduce the rate of heating the building so that the effects of caloric release are also reduced. Differently, other experts claim that the replacement of glass material can reduce the effects of energy use in buildings. But both ways can not optimally control the recovery and release of heat. One of the more effective ways is to add thermal insulation materials on the walls of the building, but the addition of insulation requires a thermal behavioural review of commonly used building materials.

This paper presents the results of an experimental study on the commonly used thermal properties of building materials. The result of this research is to formulate requirement insulation for improvement of thermal behaviour of building envelope wall [3-13].

## 2. Materials and Methods

The study of the thermal behaviour of buildings due to sun exposure is carried out in the laboratory or indirectly. Exposure to sunlight in buildings is modelled by exposure to light from two halogen lamps @ 1000 Watt. The exposure process is carried out for 4 hours then followed by a cooling process for 4 hours. The duration of exposure is similar to the sun irradiation period at 08.00-12.00 on the wall facing east then cooling when the position of the sun is inclined westward at 12.00 to 16.00.

The thermal behaviour of the buildings is represented by the east and west walls of the buildings which are made from various possibilities of popular building wall materials namely; 1) multiplex and glass-wool, 2) gypsum and glass-wool 3) aerated concrete, 4) brick. Comparison of the four wall materials of the building is carried out in a 1x1 m model. This study method was adopted from Aversa et al. [14].

Each wall model is exposed to a halogen lamp with a distance of 65 cm. The temperature measurement is carried out every 15 minutes using a Type K thermocouple with an accuracy of 0.2% + 1 ° C and an infrared (IR) camera from the outer and inner surfaces (Figure 1).

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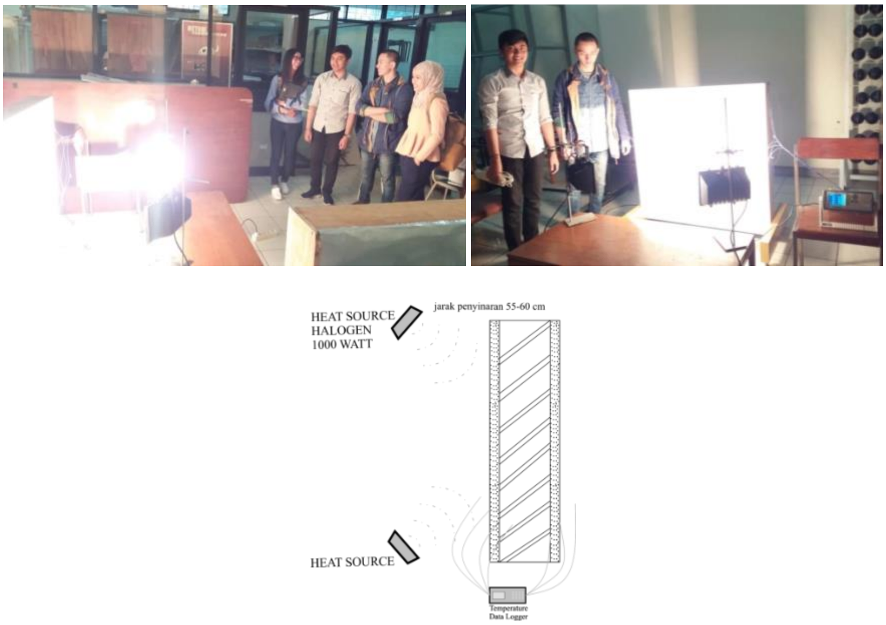


Figure 1: Experimental Setup

The irradiation is directed to the center of the wall, where the thermocouple is placed on the outer side (Tso), the inside of the outer layer (Tm1), the center of the wall (Tm2), the inside of the indoor layer (Tm3) and the indoor surface (Tsi) (Figure 2).

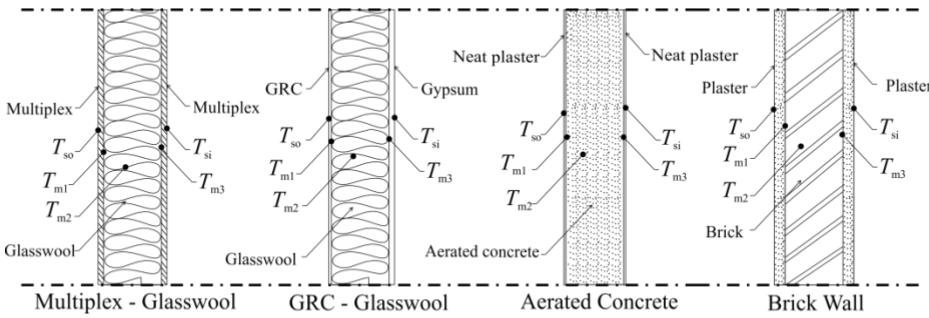


Figure 2: Type of wall material and thermocouple position

The multiplex and GRC walls represent the type of sandwich while the walls of aerated concrete and brick represent the block type. On the sandwich wall the type of material and composition in general are:

- 15 mm multiplex on the outside and inside with 4-inch glass wool insulation (density 16 kg/m$^3$) in the centre. On the outside is given a layer of waterproofing and weather shield paint, while the inner multiplex is given a layer of ordinary wall paint.
- 4 mm GRC on the outside and 9 mm gypsum on the inner side with 4-inch glass wool insulation in the middle. The outer and inner layers are the same as multiplex walls.

While the type of block walls, types of materials and compositions that are commonly used are:

- 12cm thick aerated concrete wall. The outer and inner layers are the same as multiplex walls.
- Brick wall with 1.5cm cement mortar plaster on the outer and inner surfaces. Finishing on the outer and inner layers is the same as the multiplex wall.

## 3. Results and Discussion

The measurement results show the heating and cooling profiles on the four walls (Figure 3). On the sandwich wall, the outer surface temperature is relatively stable after 90 minutes of heating, while in the block wall type the wall temperature continues to increase during the heating period. While the surface temperature in the sandwich wall tends to be stable, while in the block wall type the temperature continues to increase with a linear gradient. The difference in thermal behaviour in the two types shows the role of glass-wool which significantly inhibits the heat flow from the outside. In the block system, aerated concrete and brick materials tend to continue heat from outside to inside. In the block system, the difference between outside and inside temperatures continue to increase during the heating period while the on the sandwich system the different temperature is relatively stable.

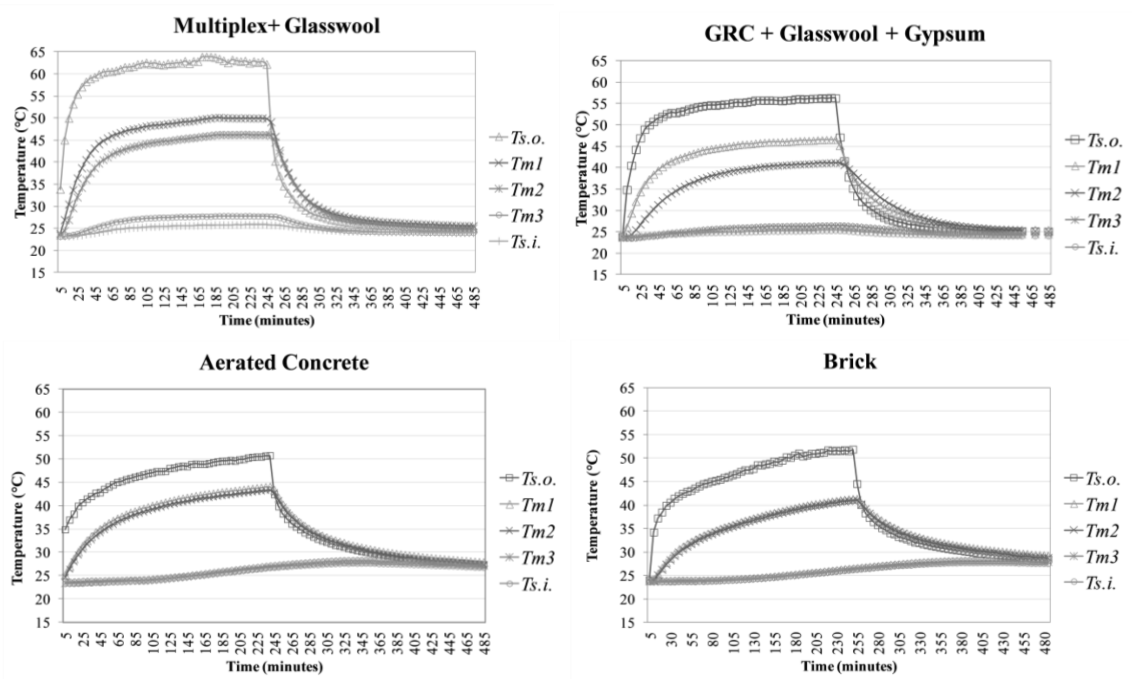


Figure 3: Wall temperature profile during heating and cooling on: a) multiplexed walls, b) GRC walls, c) aerated concrete walls, d) brick walls

In the cooling process, the outer surface of the sandwich wall quickly cools to lower than the middle temperature of the wall. On the block wall, cooling runs slower even though the surface temperature is still rising in the cooling period. This shows the block wall works as a thermal mass.

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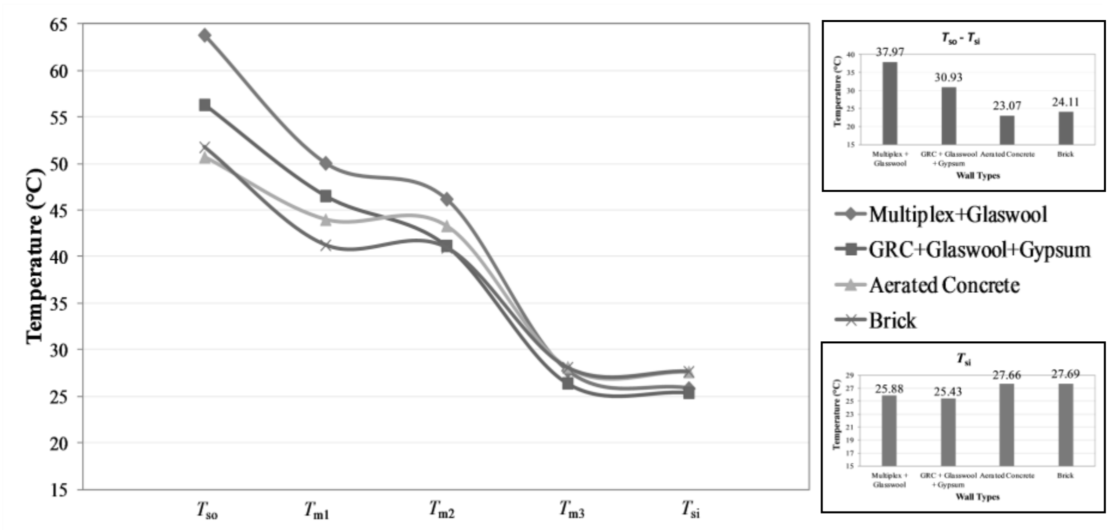


Figure 4: Wall temperature profile in maximum heating

In Figure 4, the wall temperature profile shows that the sandwich wall with glass wool insulation can hold the heat flow well enough so that the difference between the outer and inner surface temperatures is greatest. But the temperature of the outer surface of the sandwich wall increases rapidly to a temperature of 65 ° C, adversely affecting the thermal outdoor environment. The role of surface properties needs to be considered in the use of this sandwich wall.

Unlike the block wall, the surface temperature does not soar when exposed to sunlight, because it requires a lot of heat energy to increase the temperature. Block walls have a large thermal capacity compared to sandwich walls.

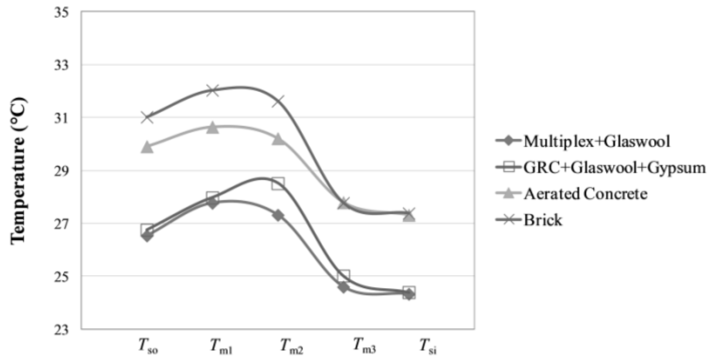


Figure 5: Wall temperature profile after cooling

In figure 5, it can be seen that the cooling process starts from the surface, both outside and inside surfaces. In the above conditions, it can be seen that the middle wall temperature is higher than the surface temperature.

Sandwich walls are lower than the wall block after 4 hours of cooling. Brick walls store the most heat compared to other walls, this shows the ability to store the largest brick wall heat. Negative effects of heat storage are seen at higher external and inner surface temperatures than sandwich walls. The temperature of the wall surface which is higher than the air temperature indicates the release of heat from the wall to the air which is felt as heating both indoors and outdoors. The phenomenon of warming outdoor space by buildings is known as the urban heat island, where accumulatively the buildings in the region release heat into the air so that the temperature of the region's air rises significantly.

Thus it has become clear that the use of heavy materials such as bricks is not suitable for future use. Likewise, aerated concrete material recommended as a substitute for bricks also shows thermal behaviour that is not good compared to sandwich walls.

This phenomenon requires the study of building materials in the future, where lightweight bricks and concrete that have large heat capacity must be repaired in several ways, namely; 1) reduce the heat capacity, 2) reduce the thermal conductivity.

Currently, mitigation technology is needed to improve the thermal behaviour of buildings [2] especially those using brick and concrete materials. New insulation material technology applied to the outer surface of the wall so that heat gain from the sun can be avoided.

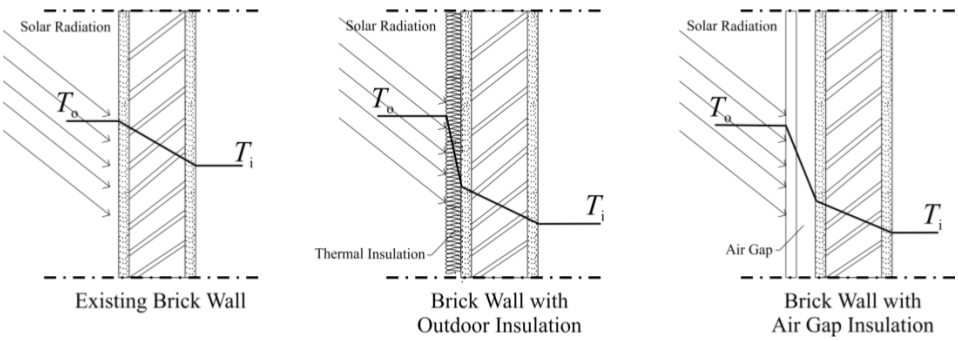


Figure 6: Thermal insulation material for envelope building wall

The study of the thermal behaviour of building materials shows the need for many studies of thermal insulation material technology suitable for the outer walls. This compatibility can be seen from the UHI effect parameters [2] and the material's weather resistance effect. Insulation material for application outside the wall requires water-resistant properties and deformation due to possible loads [6]. The use of natural and sustainable materials such as cellulose has enormous potential in Indonesia [7, 8, 9, 10, 15].

The behaviour of the thermal wall of the building affects indoor temperature and space occupants [16]. In the next study, it is expected that the role of the insulation of the outer walls in the outdoor and indoor environment can be well mapped.

## 4. Conclusions

Thermal behaviour of buildings is strongly influenced by its material properties. Physical environment parameters both outdoor and indoor can be a direction for the study of insulation material technology. Based on the study above, it was proven that aerated brick and concrete materials showed poor thermal behaviour for outdoor and indoor environments. To improve the thermal behaviour of the building, it is necessary to have appropriate insulation material on the outside of the wall.

It is necessary to study the thermal properties of the thermal insulation of these walls which are in accordance with the needs of the tropical environment where UHI parameters and thermal comfort are applied.

Sustainability parameters must also be considered, where the use of natural insulation such as cellulose is very potential in a tropical environment. But the cellulose material needs an in-depth study related to fire and water resistance.

## 5. Acknowledgements

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