A preliminary study of hygrothermal performance of autoclaved aerated concrete blocks under hot humid climate of Thailand

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ABSTRACT

This paper reports field investigation of the hygrothermal performance of autoclaved aerated concrete blocks (ACC) compared to other wall construction materials. The study was conducted under the tropical climatic conditions of Thailand where this debatable issue had not been yet seriously investigated. To this end, three small houses were built. The dimensions of each were 2.4 m x 2.4 m x 2.3 m. Every house was built using a different commercial material namely red clay brick, AAC block and lightweight concrete (LC) block with a plastering layer and no painting in both internal and external sides. The well insulated roof was built with grey colored concrete tiles and gypsum ceiling. The inclination of the roof was 30º to the horizontal plane. Tests were conducted with closed windows and doors. The effect of ambient humidity was simulated by using sprinkles spraying water at the four sides of each house. Experimental observation demonstrated that measured temperatures and humidity profiles were different among three sample houses. The red-brick wall had the highest temperature difference compared to the AAC and LC walls. The inter-penetrated moisture's level existing inside each room was insignificant during normal weather condition. However, tests under high humid condition indicated good moisture prevention was observed at the AAC house. Within the AAC wall, the heat gain reduction into building is significant noticed that it is greater than LB and LC walls. The AAC block encourages the thermal comfort from studied experimentally.

1. INTRODUCTION

The investigation of moisture transfer in building materials (Freitas et al., 1995) is extremely important for the behaviors in connection with thermal performance, water-proofing, degradation of appearance and durability. The problem of moisture in buildings has always generated great interest. However, the scientific explanation for the many ways it may occur has frequently been extremely difficult due to the complexity of the problem. Moist or humid humid materials (Rode et al., 1998) have higher thermal conductivity than similar dry materials. The reason is that moisture replaces air in the pores of the material, and the thermal conductivity of moisture is higher than of air. Moisture also enhances the thermal contact between the solid grains of porous material. Under tropical climate of Thailand (Khedari et al., 2000) heat accumulation in modern building is the main problem for inhabitants. Thus residents are obliged to use mechanical obliged to use mechanical devices to satisfy their comfort. In the past three decades and due to the high economic grow rate of the country, air-conditioning was widely used. Today, due to increased awareness on environment and energy cost, the government tries to reduce energy usage in buildings and industries as well. In the past, the Thai style house was built from hard wood and made the openings at the top of the walls for increasing natural ventilation. However, it has been abandoned due to the high construction cost and forest reservation. Nowadays, houses are built using red bricks, cement-based materials, which can retain heat. Moreover, modern style houses are reproduced following western trend and design, which are not suitable for the tropical climate of Thailand. The problem of humidity penetration through the walls of the residential houses have been widely studied in many international institutions. Unfortunately and to the best of our knowledge, accurate study of this issue has never been done in Thailand. Therefore, the purpose of this paper is to study the humidity penetration through the plastered red clay brick laid wall, autoclaved aerated concrete (AAC) wall and lightweight concrete (LC) wall construction materials, which are widely used in the local market.

2. METHODOLOGY OF EXPERIMENT

Three small houses were built by using the most common construction materials available in the local market. The roofs were made by grey CPAC concrete tiles whereas every house walls were built using a different material, namely Autoclaved Aerated Concrete (AAC), Lightweight Concrete (LC) and Red clay Bricks (RB) (Fig. 1). The ceiling was made from gypsum board. Each house had a volume of about 13 m^3 (Fig. 2), 2.4 x 2.4 m base surface area and 2.3 m height. A small window (1.07 x 0.66m) was located at the west wall and a door on the east facade. The temperatures of walls, rooms dry and wet bulb temperatures and ambient air were measured at different positions using Type K (range: 0-1,250 ºC, accuracy ± 0.5ºC) thermocouples as shown in Figure 2. The thermocouples were connected to a portable hybrid recorder (Hioki, Model 8422-51, range: 0-1250ºC, accuracy ± 0.8%). Solar radiation was measured using solar radiation meter (type CM 10sensitivity: 4.83 x $^{-6}$ V/W.m^2 made by KIPP & ZONEN HOLLAND). Heat fluxes (EKO Heat flow meter, MF-140, range: -20ºC to 120ºC, Error ± 5%) were used to measure heat flow though the wall at 1 position. Tests were conducted at the factory of Superblock Public Co., Ltd, Singburi province, during January - February 2005. Data were recorded 24 hours a day. They included the temperature at inner and outer surfaces of the south wall, the room temperature at three positions as shown in Figure 3, the temperature of the surroundings, the heat flux through the south wall. The test has been divided into 2 steps: First all 3 houses were tested under normal weather condition during various days. Next the houses were tested under high humid wet weather condition simulated by using a special system we built to spray water around the houses (the simulated situation of high humidity weather condition has been shown in Fig. 1). The moisture content of ambi-

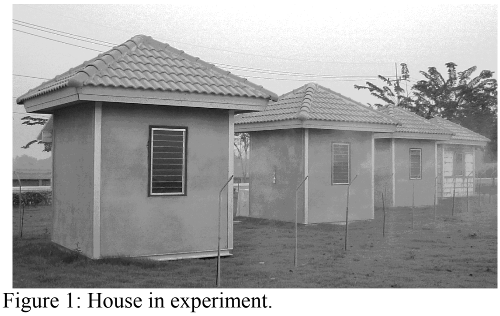

Figure 1: House in experiment.

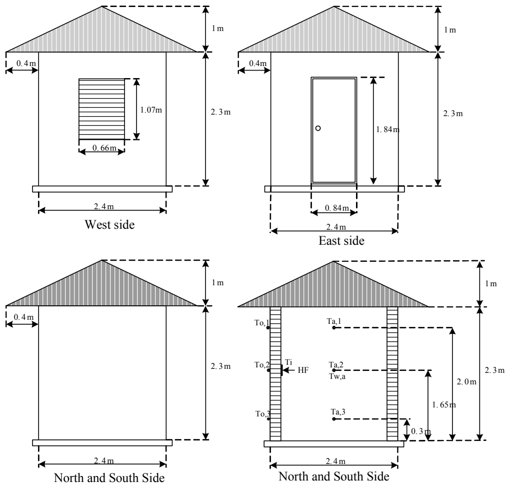

Figure 2: Dimensions of the test houses and positions of temperatures measurement (not to scale).

ent and rooms was then calculated using psychometric equations.

3. RESULTS AND DISCUSSION

3.1 Test conducted under normal weather condition

Figure 3 shows the hourly temperature variations of inner and outer surfaces of south wall, ambient and average dry and wet bulb temperature of room air. It can be seen that the temperature difference between the outer and inner surface areas is much higher (8°C) for the AAC and LC walls than the red clay brick wall (2°C) which confirmed their high heat insulation efficiency. That also explained why the temperature of the house built with red clay brick is more elevated than the two others. The analysis of moisture can be better illustrated using the moisture ratio and relative humidity plotted in Figure 4. It can be observed that the relative humidity of ambient did not vary that much and was practically constant. This is due to the fact that solar intensity was relatively low (see Fig. 5) and ambient dry and wet bulb temperatures were close each other. The moisture or humidity ratio variation varied following the

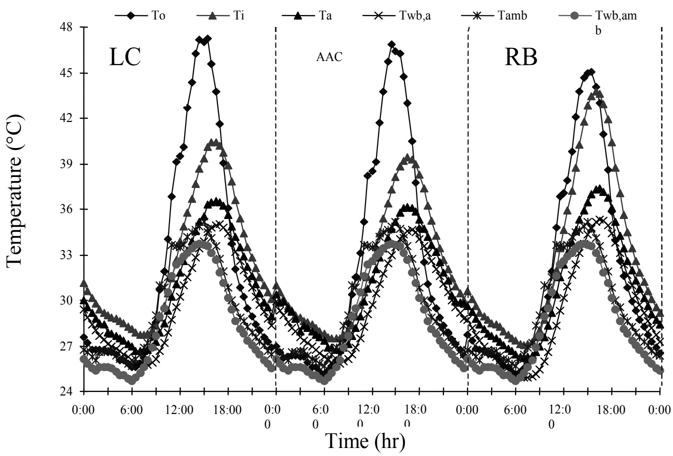

Figure 3: Air and wall temperature variations of the three houses under normal weather condition (29/01/2005).

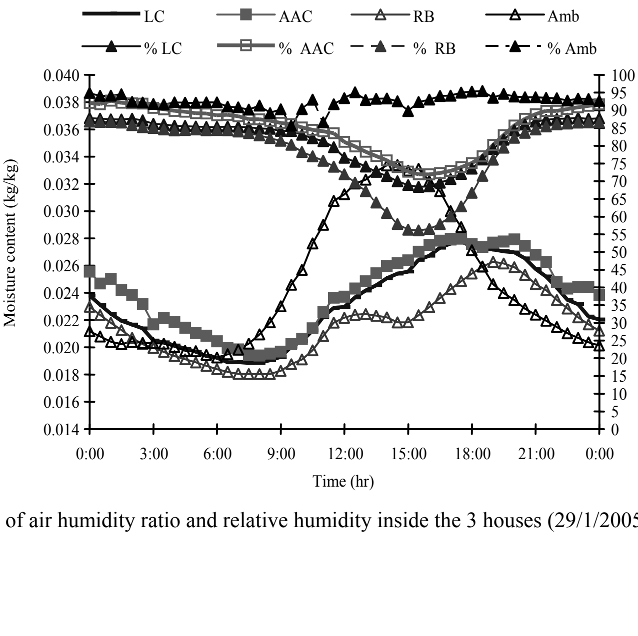

Figure 4: Comparison of air humidity ratio and relative humidity inside the 3 houses (29/1/2005).

ambient conditions; it in increased during daytime due to nature water evaporation and decreased at night due to condensation. The moisture ratio of the LC and AAC houses was slightly higher than the red clay brick house. The higher relative humility of the AAC and LC are due to the lower room temperature compared to the red clay brick house. These observations indicated that the AAC acts like a "vapor barrier" as moisture transmission through the walls is less important than the LC and clay brick houses. This effect will be more clarified in the next section where high humility surroundings is simulated. Figure 5 confirms the excellent insulation efficiency of AAC wall as heat flux transmitted through the AAC wall is about 50% and 40% lower than those measured through the red clay brick wall and LC respectively.

3.2 Test conducted under high humid weather condition

Figures 6 to 8 show the hourly temperature variations of the three houses at different position during three consecutive days. Here too the observations made in the previous section are the same. The effect of high ambient humidity on the performance of the construction material used can be depicted using the plots of Figures 9 to 11 which give the variations of relative humidity, moisture ratio and moisture ratio difference of the AAC and LC houses compared to the reference red clay brick respectively. It can be observed that during daytime, the moisture or humidity of the AAC house is the lowest one whereas at night it is slightly higher (Fig. 9). This confirms the observation we made earlier that AAC has the lowest vapor transmission rate. (Laboratory measurements are under going

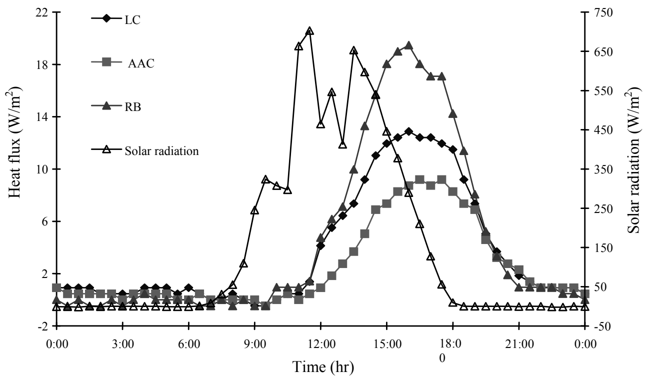

Figure 5: Heat flux comparison through the south wall of the 3 houses (29/1/2005).

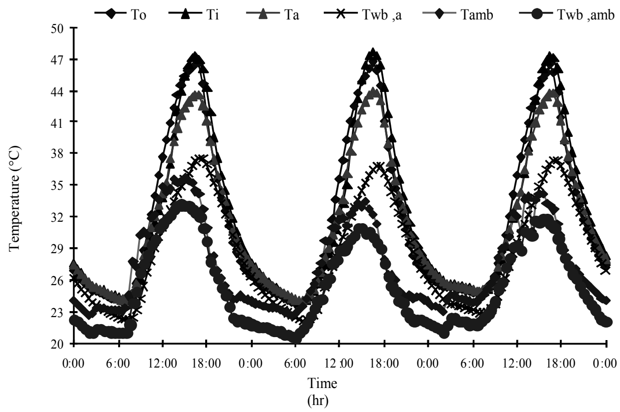

Figure 6: Hourly variation of air and wall temperatures of the house with red brick wall tested under high humid weather condition.

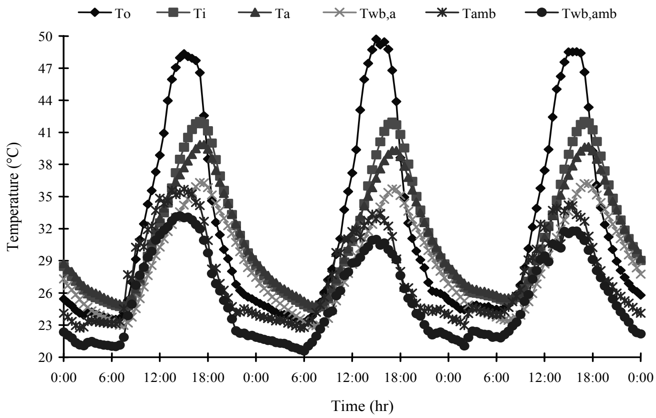

Figure 7: Hourly variation of air and wall temperatures of the house with LC wall tested under high humid weather condition.

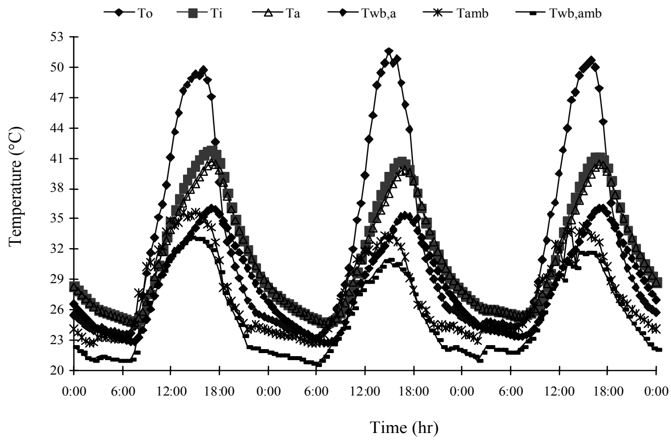

Figure 8: Hourly variation of air and wall temperatures of the house with AAC wall tested under high humid weather condition.

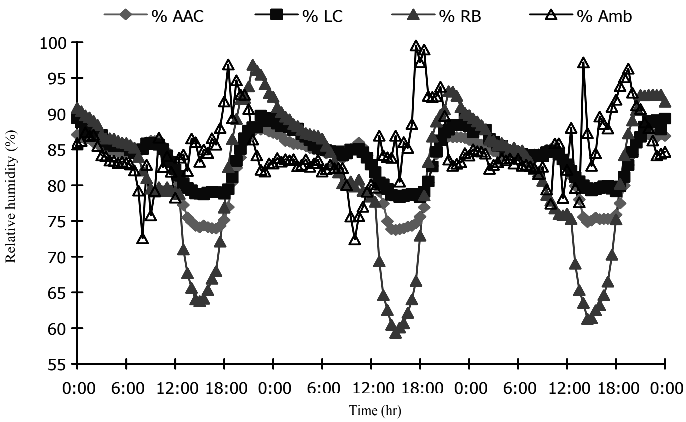

Figure 9: Comparison of the air relative humidity inside the three houses tested under high humid weather condition.

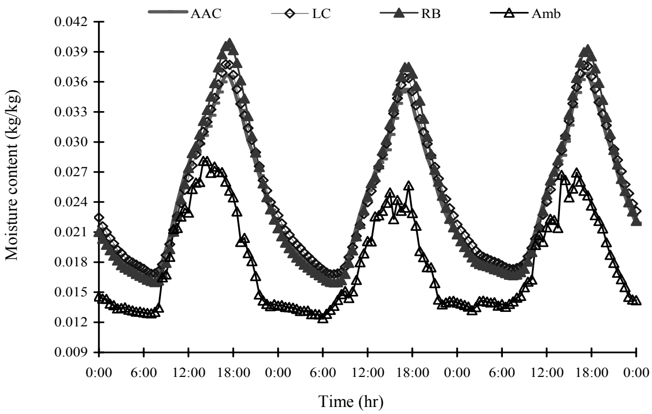

Figure 10: Comparison of the air moisture ratio inside the 3 houses tested under high humid weather condition.

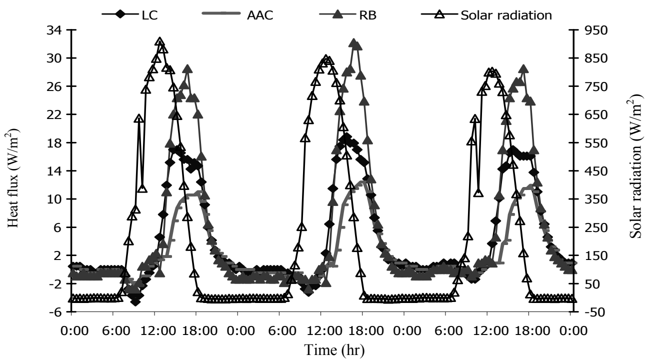

Figure 11: Heat flux comparison of the south wall of the 3 houses tested under high humid weather condition.

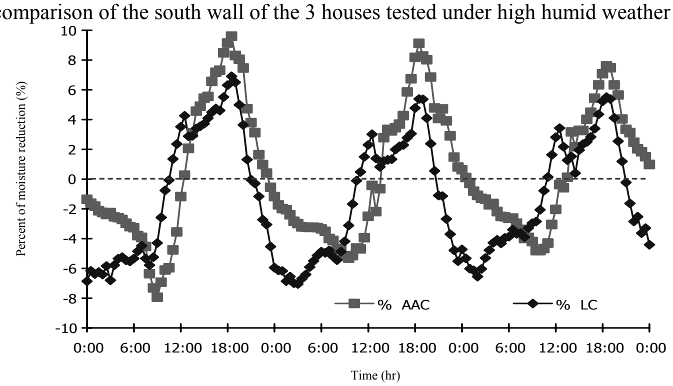

Figure 12: Percent reduction of moisture ratio between the houses built with autoclaved aerated concrete (AAC) and lightweight concrete (LC) compared to the reference clay brick house.

to confirm observation). Figure 11 demonstrated that the percentage of air moisture ratio reduction is high during daytime for the AAC house while at night, the opposite is observed. This finding is quite interesting as it confirmed that AAC construction material could be used in tropical climate while offering an additional advantage as moisture barrier. Finally, Figure 11 confirmed again the excellent properties of the AAC wall material as heat flux transmission reduction is much more important under high humid condition compared to the LC and clay brick walls.

4. CONCLUSION

A field comparative study of three houses built using different kind of materials that are available in the local market but manufactured in different manners was reported. These materials are autoclaved aerated concrete produced following an advanced cost-expensive modern standard process, lightweight concrete and red clay brick which have an uncomplicated less expensive production cost. The focus of this study was aimed at assessing material performance incurred in the hot and humid climate where high rain and hot summer are prevailing weather conditions. The tests revealed that autoclaved aerated concrete has the best performance as it can act like an excellent heat insulation and prevent moisture penetration. These features are much more enhanced when high humidity surrounding, simulated using water sprayed continuously, is prevailing. Due to these features, ACC can help to save the energy consumption from using the air conditioning system.

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NOMENCLATURE

Ta:	air room temperature, C
Ti:	Internal wall temperature, C
To:	External wall temperature, C
Tamb	Ambient temperature, C
Twb, a:	Wet bulb temperature in door air, C
Twb, amb:	Wet bulb temperature of ambient, C

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