APPLICATION OF FIBRE CEMENT IN GREEN BUILDING SYSTEM

Kim Chew Lim, Show Hing Ang, Shi Hao Yeong
Hume Cemboard Industries Sdn. Bhd.,
Lot 127220, Kawasan Perusahaan Kanthan, 31200 Chemor, Perak, Malaysia,
shyeong@humecemboard.com.my

ABSTRACT

Moving towards green building is no longer considered as luxurious and responsible construction, it is a need and necessity to build a sustainable future today. This paper shows how fibre cement contributing in Green Building system in the areas of energy efficiency, indoor environmental quality, materials & resources and site management.

Studies have been done to address thermal insulation which is one of the most effective ways to improve the energy efficiency of a building. This can be achieved by incorporating fibre cement sheets to roof, ceiling and wall systems that provide a better thermal insulation property (R & U values) to form the building envelop. Consequently, helping to minimize the heat transmittance in the building, improve comfort and energy saving.

KEYWORDS:

Fibre cement; green building system; thermal insulation.

INTRODUCTION

There has been an increasing concern about the environment and the renewability of our resources, with global warming and changes in our weather pattern of late. Sharing this concern for our world, most of the building & construction industries have been taking steps to lessen the carbon footprint and preserve the environment. In addition, environmental friendly and sustainable green building materials have gained fast traction in consumer attention and stringent expectations.

Green buildings are designed to save energy and make efficient use of resources, recycle materials and minimize the emission of hazardous substances throughout its life cycle. Green buildings harmonize with the local climate, traditions, culture and the surrounding environment and able to sustain and improve the quality of human life whilst maintaining the capacity of the ecosystem at local and global levels. Building green sends the right message about a company or organization that it is well run, responsible, and committed to the sustainability.

There are many green building rating systems or schemes been established to evaluate the building globally such as LEED (Leadership in Energy and Environmental Design) in United States, BREEAM (Building Research Establishment Environmental Assessment Methodology) in Europe, Green Star in Australia. GBI (Green Building Index) is Malaysia's construction industry recognized voluntary green building rating system which has been developed specifically for Malaysian tropical climate, whilst addressing the environmental and development contexts as well as cultural and social needs. With the objective of promoting to developers and building owners to design and construct green and sustainable buildings, the GBI rating tools focus on 6 key assessment criteria as below:

- Energy Efficiency
- Indoor Environmental Quality
- Sustainable Site Planning and Management
- Material and Resources
- Water Efficiency
- Innovation

Among these 6 key criteria, fibre cement as a board or panel can contribute scores in

- Energy Efficiency that covers reduction of energy consumption in buildings and thus reducing the CO_2 emission to the atmosphere and reduction on energy to keep indoor environment at satisfactory thermal comfort level.
- Indoor Environmental Quality which consists of sound insulation or noise control, good quality of construction, good indoor air quality with least emission of total volatile organic compound (TVOC) and formaldehyde.
- Sustainable Site Planning and Management which promote on Industrial Building System (IBS) and reduce on-site construction reduce material and construction wastage to landfill and land pollution.
- Material and Resources which demand on building products that incorporate recycled content materials and manufactured from regional materials

Thermal conductivity, k value is a measure of the rate of heat flow through a material subjected to a temperature gradient. Fibre Cement sheet has low k value which range from 0.20 to 0.30 W/mK deeming it as a good insulation material. Table 1 listed the k value of various building materials.

Table 1: Thermal Conductivity of various building materials:

Material	Fibre Cement	Brick	Concrete	Wood	Glass	Plaster	Steel
k value (W/mK)	0.20 to 0.30	0.7 -1.0	0.7 – 1.5	0.04 - 0.4	1.0 – 1.3	0.5 – 0.8	12 - 45

Figure 1 show typical buildings envelop in Malaysia. Fibre cement sheet can be used at roof, eaves & gable end, ceiling, external wall and screening.

Figure 1:

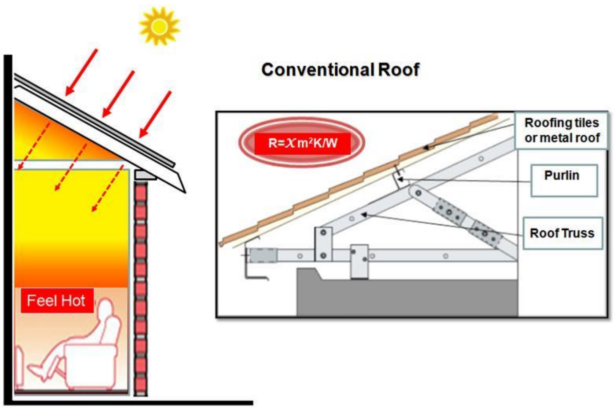
Typical Building Envelope in Malaysia

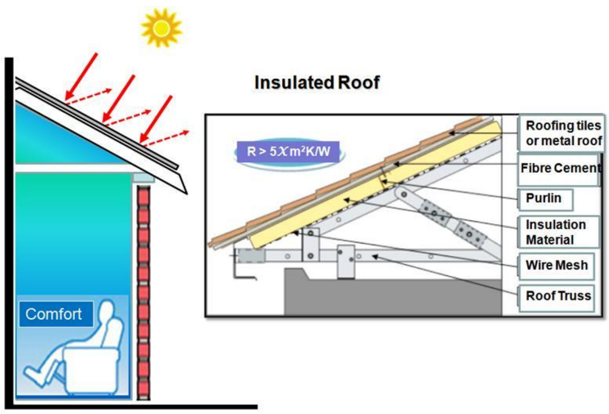
Component	Description
Roof	A **roof** is the covering on the uppermost part of a building. A roof protects the building and its contents from the effects of weather.
Fascia, Gable End & Eave Lining	Generally Fascia & Eaves are the external component that attached to roof. Gable End is the triangle wall between the edges of a sloping roof
Ceiling	A **ceiling** is an overhead interior surface that covers the upper limit of a room. It is generally not a structural element, but a finished surface concealing the underside of the floor or roof structure above.
External Wall	A **wall** is a usually solid structure that defines and protects the building against weather and safety.
Window (Glass)	A **window** is a transparent or translucent opening in a wall or door that allows the passage of light and, if not closed or sealed, air and sound.
Screening	A component that shade or hide the inner side of the building.
Shading	A building component provide protection from the effects of direct sun light.

Fibre cement sheet can be a roof sarking board to assist on the roof thermal insulation. Refer Figure 2 & 3 below. The thermal resistance or resistivity, R value can be increased many times after applying the sarking system.

Figure 2: Conventional Roof without insulation

Figure 3: Roof Sarking system with fibre cement as sarking board



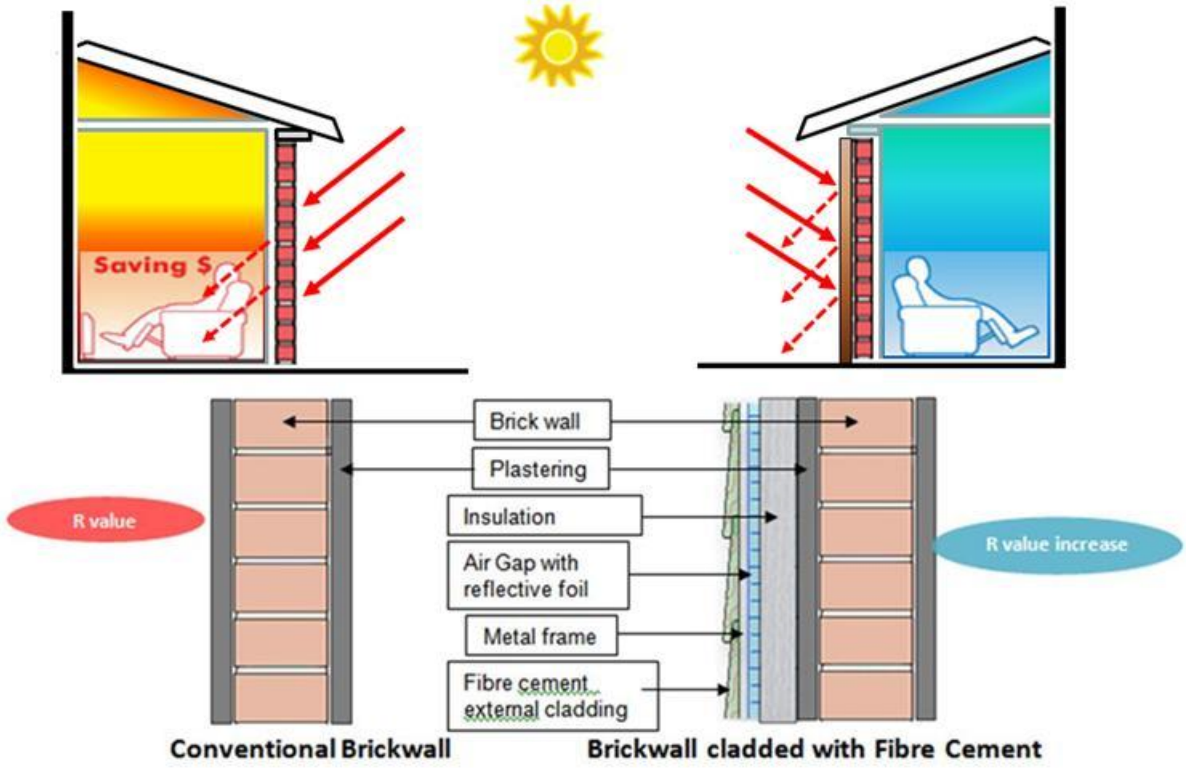


The R value is a guide to indicate the insulation performance – the higher the R value, the greater insulating effect. R value measures the resistance to heat transfer whereas U value, the reciprocal of the

R value, U=1/R measures the heat transfer through a material or building element (thermal transmittance). R value is equal to thickness/ k value and thus it can calculated if the thermal conductivity, k value of the materials known.

As part of the external cladding of building, fibre cement sheet can improve the R value of the conventional wall by cladding onto the brick wall which brick wall system is widely available in the residential housing in Malaysia, refer Figure 4.

Figure 4: External Wall Insulation

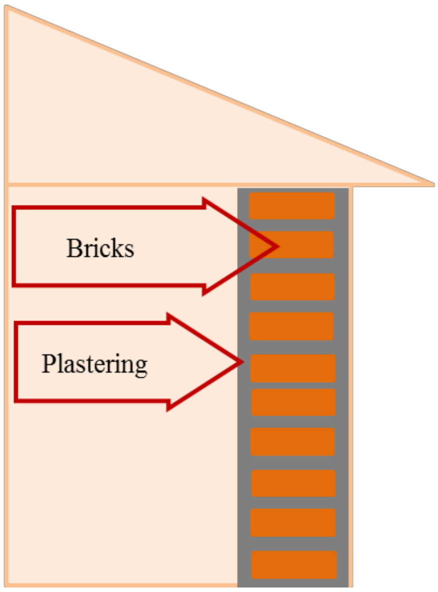
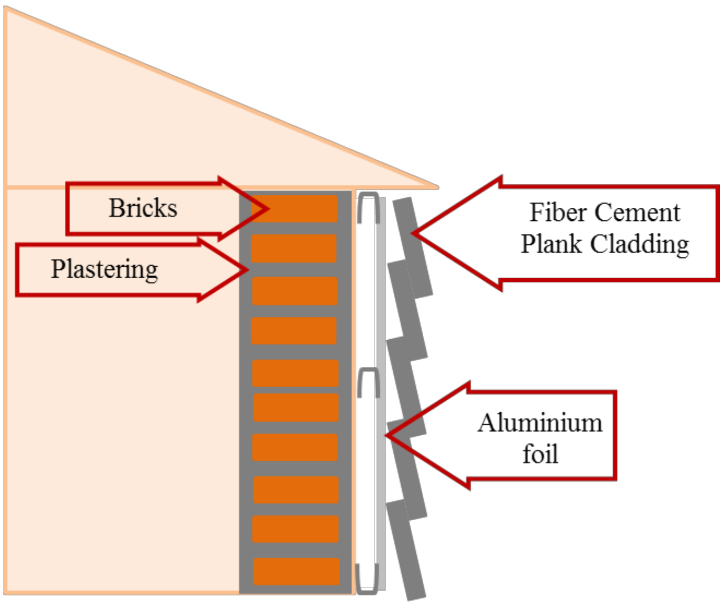


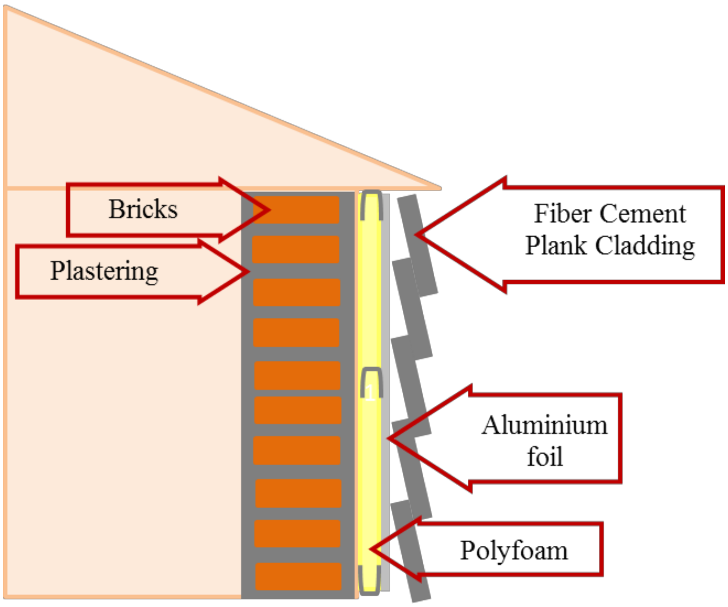
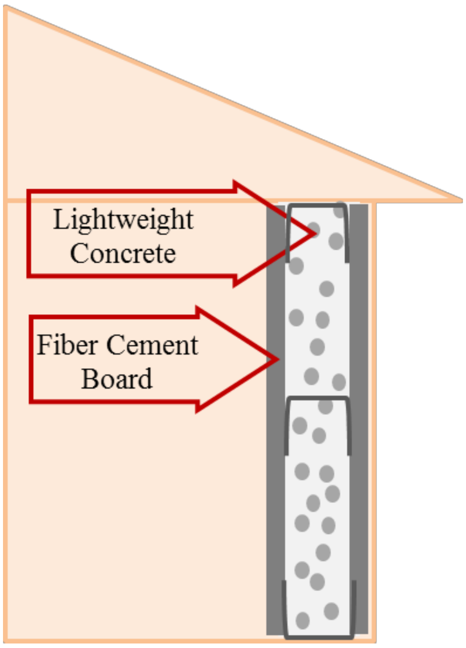
In this paper, we focus on the cool wall system. The thermal performance of a few wall systems was evaluated to find out the effective ways to improve the energy efficiency of a building. Consequently, helping to minimize the heat transmittance in the building, improve comfort and energy saving.

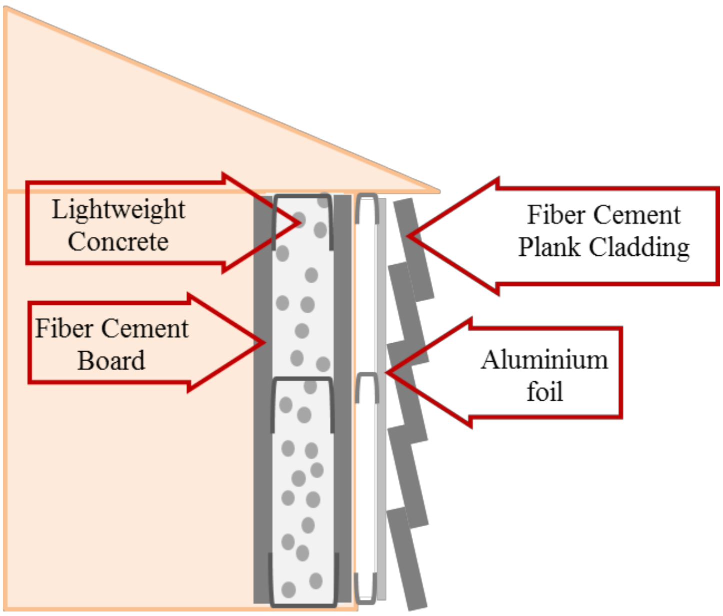
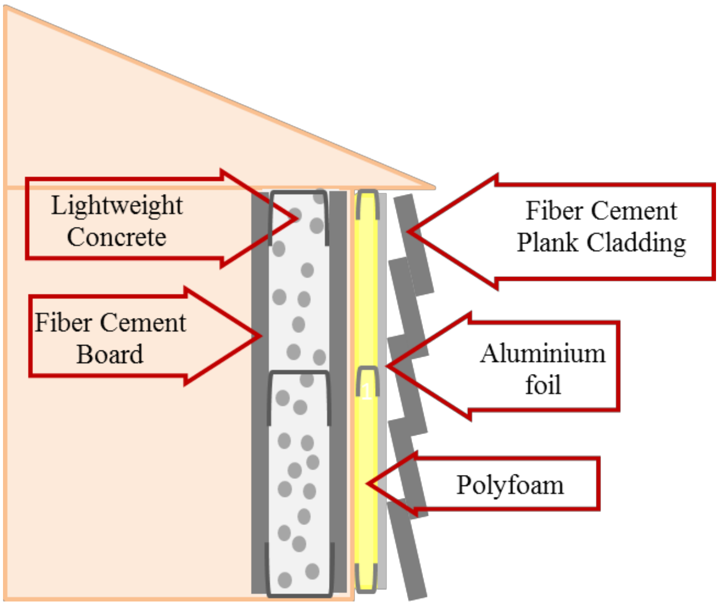
METHODOLGY

There are various types of building systems being designed and constructed to suit for its architecture intention and functional requirements. Brick wall and concrete wall systems are conventional type and normal type of building systems in many countries. . The building industry in some of the developed countries including Malaysia slowly evolved and there have this call Industrial Building System (IBS) which either made from pre-cast panels or cast in-situ panel wall systems. The objective of the study here is to evaluate the thermal transmittance properties of the building systems which comprise of fibre cement sheet panels (IBS) in comparison with conventional brick wall system. Besides, it is interested to know fibre cement (FC) that deems to be green building material, is able to improve the thermal insulation for a building. There are seven types of building systems mock up were evaluated in this study, namely, System A – Brick Wall, System B –

Brick Wall with FC Cladding, System C –Brick Wall with FC Cladding & Insulation, System D – Solid Wall, System E – Solid Wall with FC Cladding, System F – Solid Wall with FC Cladding & Insulation and System G – Dry Wall. The detail description of these wall systems are as follow:

System A -Brick Wall - A mock up house made of brick wall size 1.2m width x 2.4m length x 2.0m height with total wall thickness 150mm (100mm thick brick wall with 25mm plastering at both sides).	
System B – Brick Wall + FC Cladding - A mock up house made of brick wall size 1.2m width x 2.4m length x 2.0m height with thickness 150mm (100mm thick brick wall with 25mm plastering at both sides) and with fibre cement plank 7.5mm cladding at external side. Total wall thickness is about 222mm	

System C – Brick Wall + FC Cladding + Insulation - A mock up house made of brick wall size 1.2m width x 2.4m length x 2.0m height with thickness 150mm (100mm thick brick wall with 25mm plastering at both sides) and with fibre cement plank 7.5mm cladding at external side, insulated with Polystyrene foam (Polyfoam) 50mm and Aluminium foil. Total wall thickness is about 222mm.	
System D - Solid Wall - A mock up house made of solid wall size 1.2m width x 2.4m length x 2.0m height with total wall thickness 104mm - Solid Wall is a wall made from Fiber cement board 6mm at both sides and 92mm thick lightweight concrete in between.	

System E - Solid Wall + FC Cladding - A mock up house made of solid wall size 1.2m width x 2.4m length x 2.0m height with thickness 104mm and cladded with fibre cement plank 7.5mm at external side. Total wall thickness is about 176mm - Solid Wall is a wall made from Fiber cement board 6mm at both sides and 92mm thick lightweight concrete in between.	
System F - Solid Wall + FC Cladding + Insulation - A mock up house made of solid wall size 1.2m width x 2.4m length x 2.0m height with thickness 104mm and cladded with fibre cement plank 7.5mm at external side, insulated with Polystyrene foam (Polyfoam) 50mm and Aluminium foil. Total wall thickness is about 176mm. - Solid Wall is a wall made from Fiber cement board 6mm at both sides and 92mm thick lightweight concrete in between.	

System G - Dry Wall

- A mock up house made of dry wall size 1.2m width x 2.4m length x 2.0m height with total wall thickness 124mm

- Dry Wall is a wall made from Fiber cement board 12mm at both sides and 100mm thick mineral wool in between.

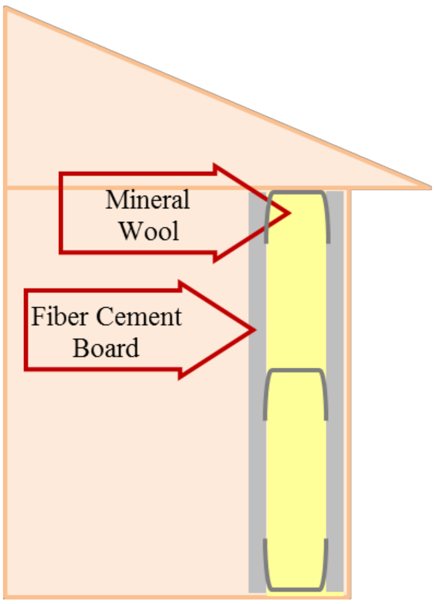


Figure 5 shows one of the mock up house specimen (one of the longitudinal side of the wall). The lightings as the heating elements were set up as shown in Figure 6 & 7. Total 18 bulbs were used in which 9 bulbs each were positioned to shine onto each longitudinal side of the wall of the mock up house (Figure 8& 9). The wall was mark with 15 points for temperature measurements (Figure 5 & 6). The lights were positioned in such way that the external wall temperature can reach 40 °C in maximum 2 hours' time for the brick wall system. This was set by putting the brick wall system under the natural sunlight and gauge the maximum temperature can be reached during two hours time. Then, the distance between the lights and panel was determined and used for all the wall systems. The distance for the experiment was 75cm, refer Figure 9.

Figure 5: Mock Up House

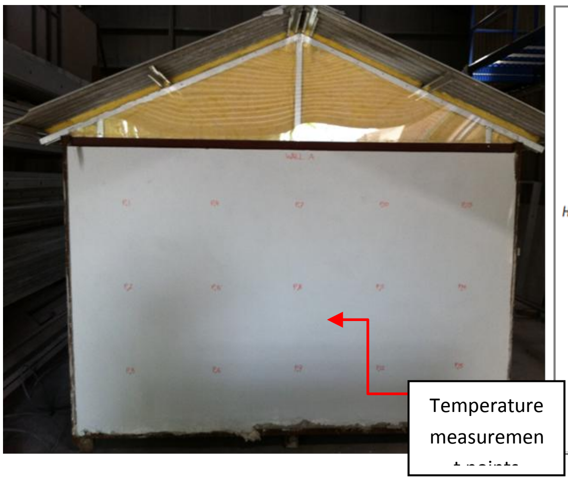
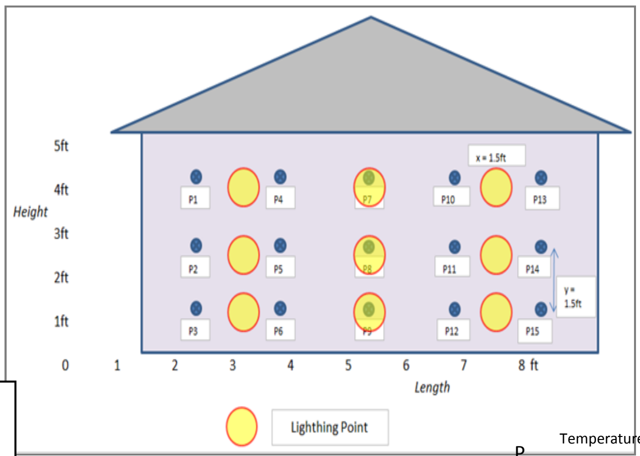


Figure 6: Lighting positions & Points of °C Measurements



P Temperature measurement points

Figure 7: Lights as heat simulation shine onto the wall

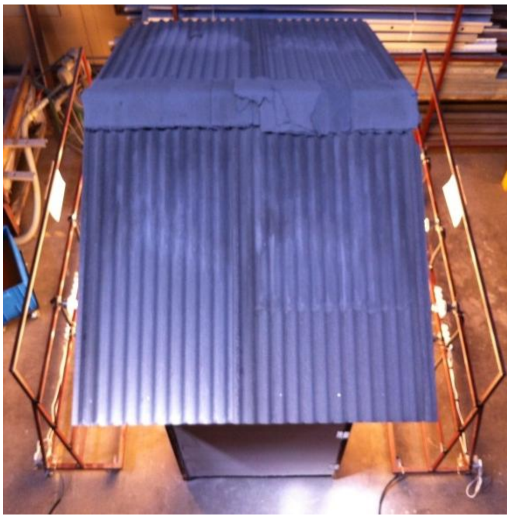


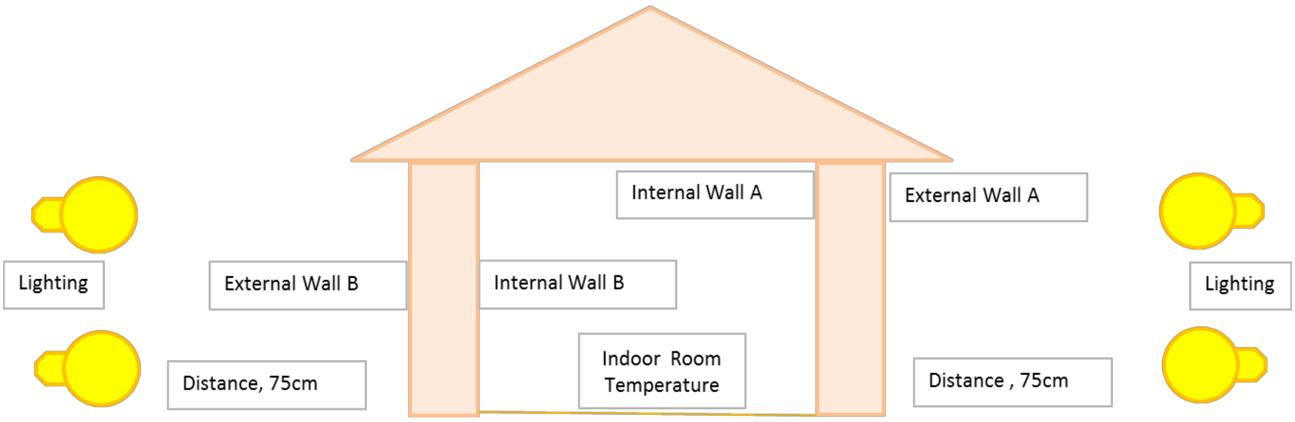
Figure 8: Top view of the mock up house

The experiment was conducted in indoor environment to avoid the fluctuation of temperature due to the external environment factors.

Temperature measurements were done on External Wall A & B, Internal Wall A & B, and Indoor Room as shown in Figure 9 After turning on the lights to heat up the external wall surface, the timing was recorded and temperature on external and internal wall surface and indoor room were hourly recorded. To simulate the typical Malaysia day time from 8am to 5pm, the lights was on for 9 hours. The lights were off at 9th hour of heating and temperatures of subsequent hours were recorded until 15th hour. Average temperature of each section was calculated and a chart of average temperature versus time was plotted. Besides, the temperature difference between external wall surface, internal wall surface and indoor room for each wall systems will be calculated and compared.

The temperatures of wall surfaces were measured hourly using infrared thermometer and for indoor room temperature, a thermometer was used.

Figure 9: Location of Temperature Measurements



RESULTS AND DISCUSSIONS

Figure 10: Charts showing the External – Internal Wall Surface and Indoor Temperatures of the Wall Systems

Figure 10.1

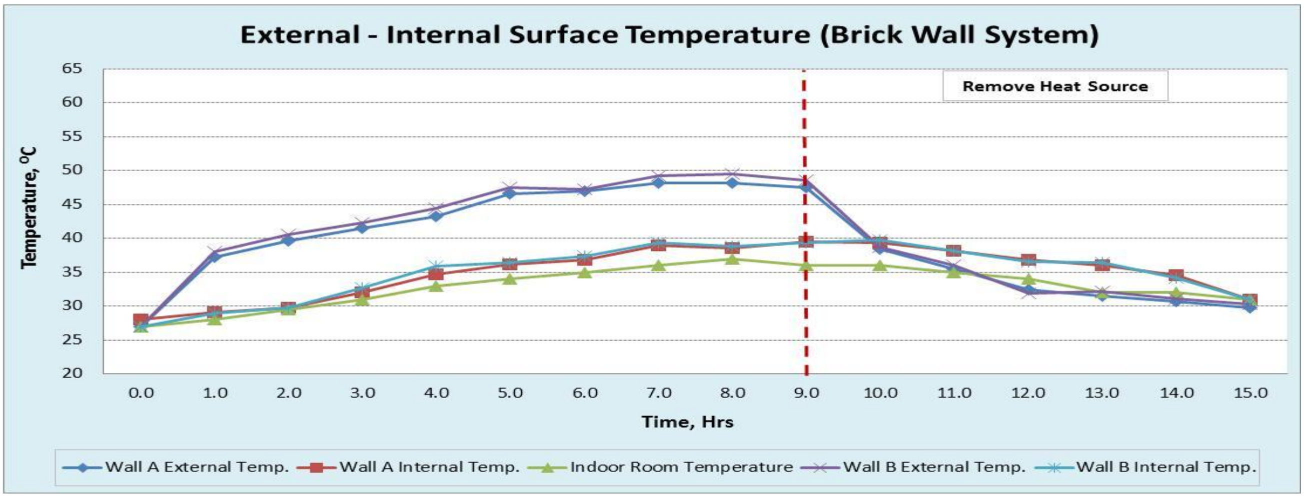


Figure 10.2

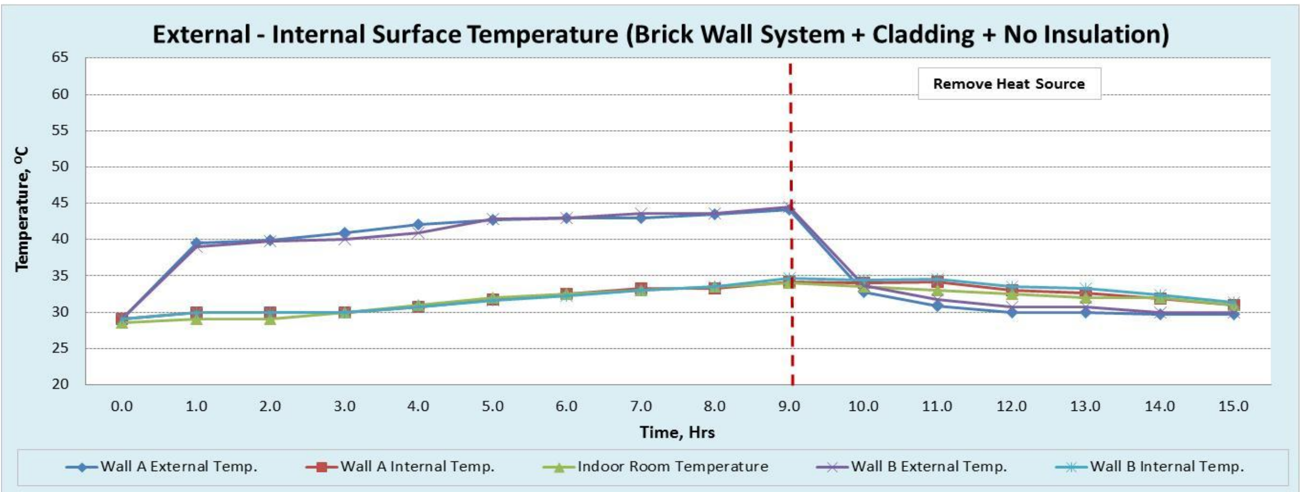


Figure 10.3

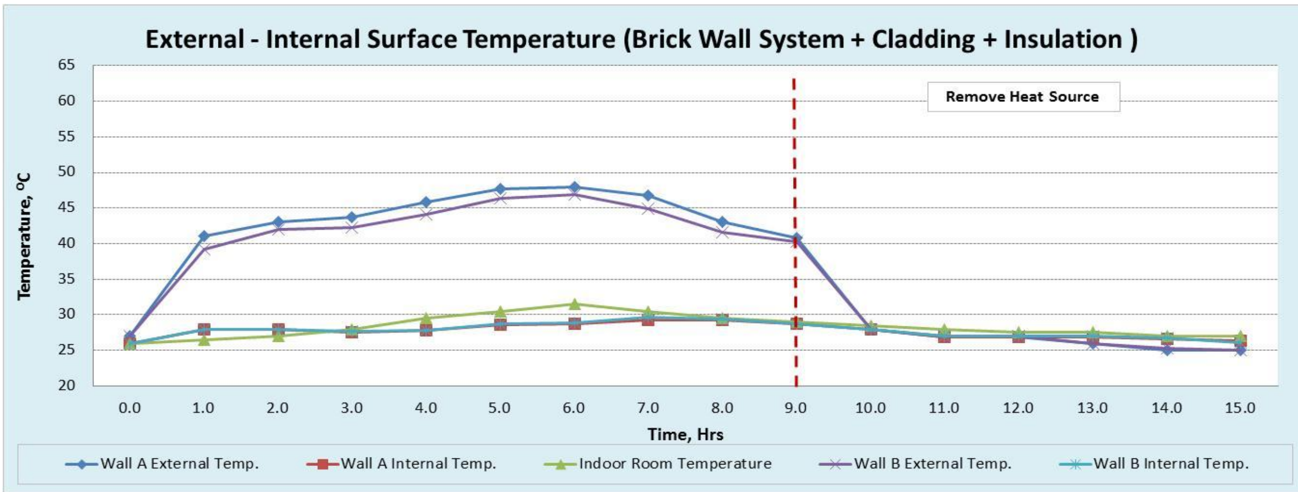


Figure 10.4

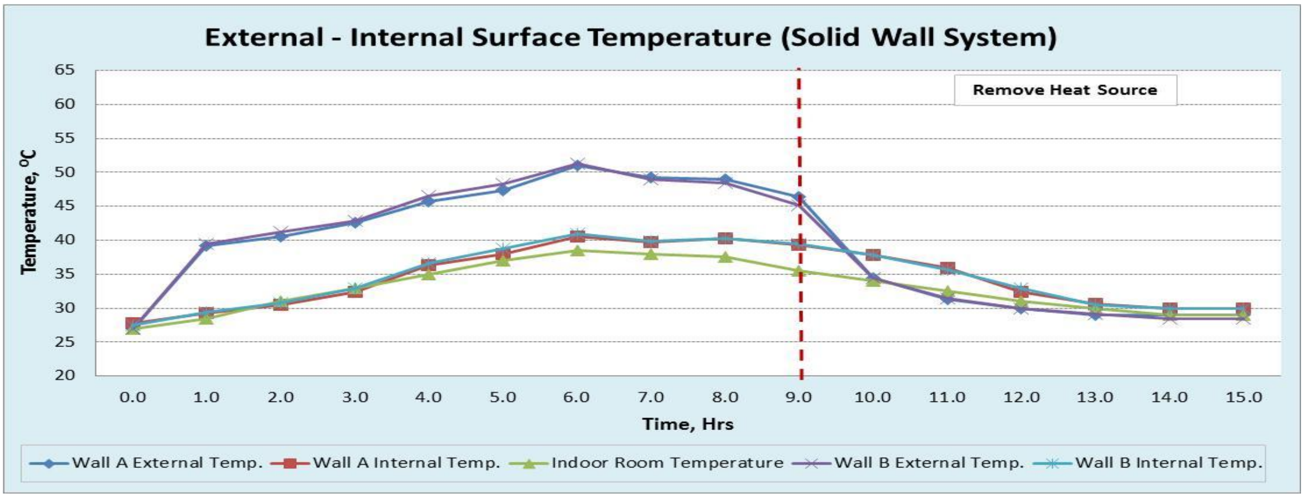


Figure 10.5

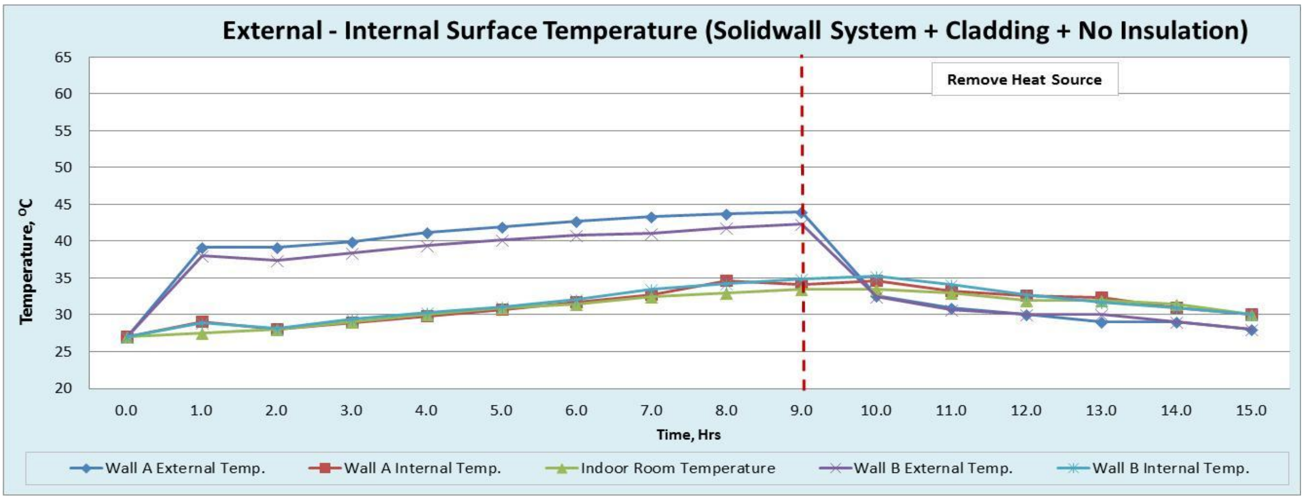


Figure 10.6

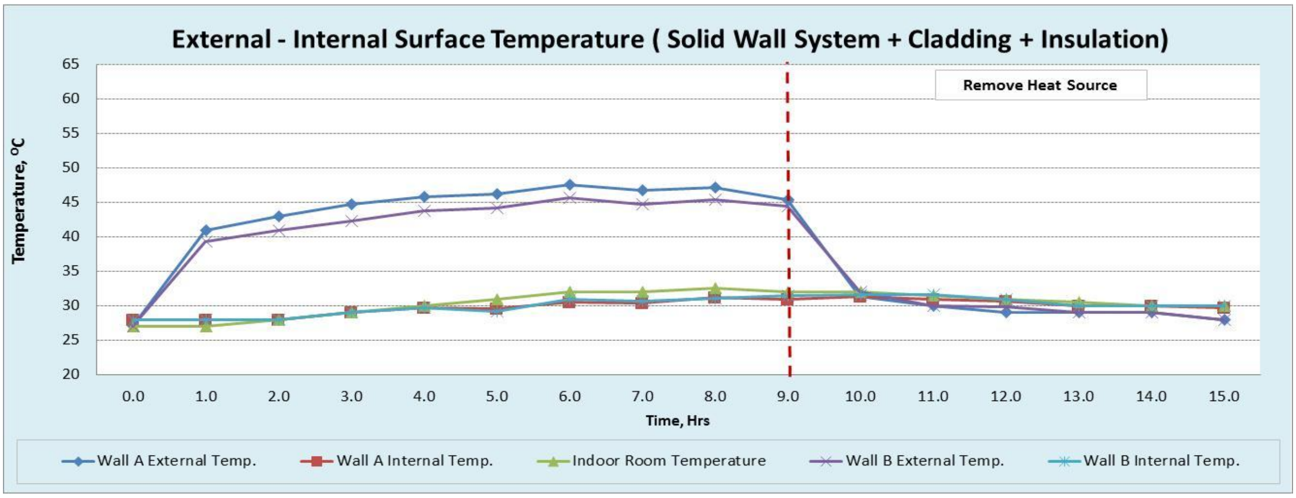
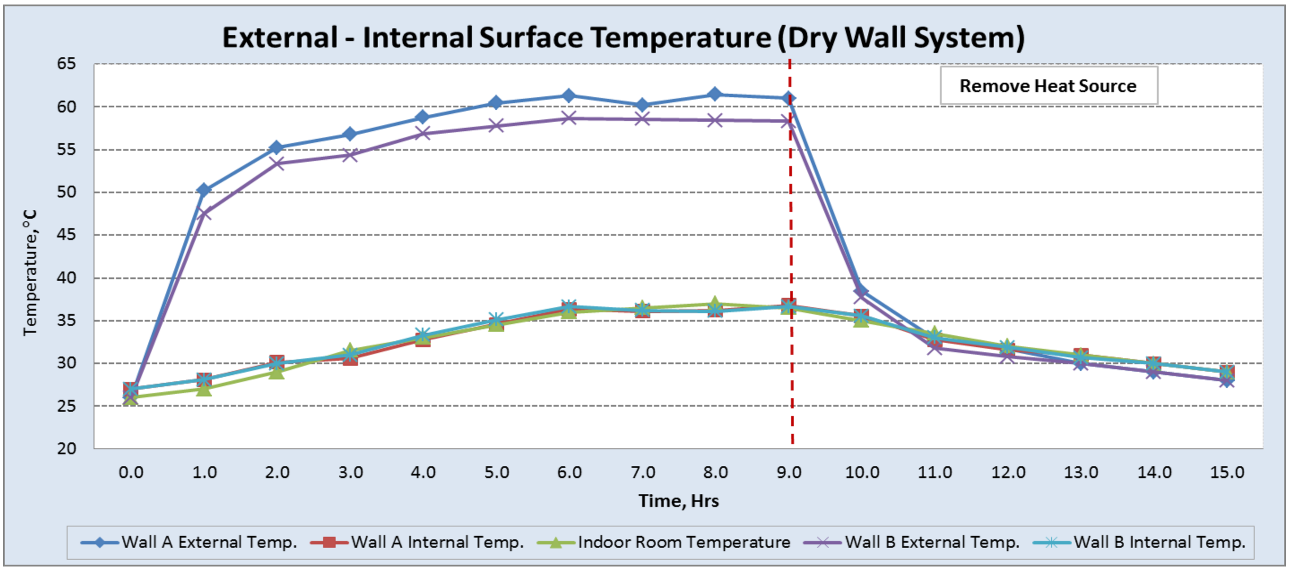


Figure 10.7



Referring to the temperature versus time charts above, it was found that the temperature changes reacting differently based on the wall system. Internal Wall temperature increased when the External Wall temperature increased and it was clearly seen for Brick Wall (System A), Solid Wall (System D) and Dry Wall (System G) systems where there were no cladding and insulation on the walls. Refer to Table 2, the Brick Wall and Solid Wall systems with Fibre Cement cladding and Polystyrene foam insulation appeared to be the best systems in controlling the rising of Internal Wall and Indoor Room temperatures. The temperature rising of these clad and insulated systems was less than 5 °C for the internal & indoor room temperatures during the 9 hours heating time whereas for those unclad and not insulated system, the internal wall temperature can be increased more than 10 °C and subsequently the indoor temperature also increase about 9 – 10 °C. With fibre cement cladding without insulation, the internal wall and indoor temperature raised slowly comparing with the equivalent wall system without any cladding. Therefore, with addition of fibre cement plank cladding on the external wall did assist in thermal insulation to the building.

Comparing Brick Wall with Solid Wall and Dry Wall which the later two belonged to IBS wall systems and the wall panel are made from fibre cement, solid wall with light weight concrete infill reacted comparable as Brick Wall, whereas Dry Wall with mineral wool infill has a very high external wall temperature but less internal wall temperature. The external wall temperature for Dry Wall is the highest comparing to others might due to the mineral wool which contact direct with the fibre cement has a very low thermal conductivity which prevent the heat transmit through it and thus the heat accumulated in the external piece of fibre cement panel.

Table 2: Temperature Changes during 9 hours Heating Time

System	Temperature (°C) Variation During Heat Source On (From 0 till 9th hours of heating)		
	External Wall	Internal Wall	Indoor Room
Brick Wall	21 (27 - 48)	12 (27 - 39)	9 (27 - 36)
Brick Wall + Cladding	15 (29 - 44)	6 (29 - 35)	6 (28 - 34)
Brick Wall + Cladding + Insulation	14 (27 - 41)	3 (26 - 29)	3 (26 - 29)
Solid Wall	19 (27 - 46)	12 (27 - 39)	9 (27 - 36)
Solid Wall + Cladding	16 (27 - 43)	8 (27 - 35)	6 (27 - 33)
Solid Wall + Cladding + Insulation	18 (27 - 45)	3 (28 - 31)	5 (27 - 32)
Dry Wall	34 (26 - 60)	10 (27 - 37)	10 (26 - 36)

Table 3: Temperature at 6th hour

System	Temperature (°C) Recorded (at 6th hour)			Temperature Variation of external wall and internal wall (°C)	Temperature Variation of external wall and indoor room (°C)
	External Wall Surface	Internal Wall Surface	Indoor Room		
Brick Wall	47	37	38.5	10	8.5
Brick Wall + Cladding	43	32	32.5	11	10.5
Brick Wall + Cladding + Insulation	47	**29**	31.5	**18**	**15.5**
Solid Wall	51	41	38.5	10	12.5
Solid Wall + Cladding	42	32	31.5	10	10.5
Solid Wall + Cladding + Insulation	47	31	32.0	**16**	**15.0**
Dry Wall	53	34	33.0	**19**	**20.0**

Table 3 list the temperatures recorded at the 6th hour. A comparison was done at the 6th hour when the external temperature was almost the highest been observed in the charts.

For brick wall system with fibre cement cladding and insulation, the temperature variations of (a) external wall with internal wall and (b) external wall with indoor room showed higher values comparing to brick wall with fibre cement cladding but without insulation as well as solely brick wall system. The similar observation found on solid wall, solid wall with fibre cement cladding and solid wall with fibre cement cladding and insulation where the latest showing the biggest temperature difference. Dry wall system observed to have the highest temperature variation of external and internal wall, external wall and indoor room comparing with brick wall and solid wall. By having the fibre cement cladding and/or insulation, the indoor room temperature can be improved or become much more cooling, means temperature can be reduced about 6-7 ^{o}C comparing those wall without cladding and/or insulation (refer Table 3).

Table 4: Temperature Changes when Heat Source removed

	Temperature (°C) Variation After Removing Heat Source (from 9th to 12th hour)		
System	External Wall	Internal Wall	Indoor Room
Brick Wall	17 (49 - 32)	2 (39 - 37)	2 (36 - 34)
Brick Wall + Cladding	13 (44 - 31)	1 (34 - 33)	1 (34 - 33)
Brick Wall + Cladding + Insulation	14 (41 - 27)	2 (29 - 27)	1 (29 - 28)
Solid Wall	16 (46 - 30)	6 (39 - 33)	5 (36 - 31)
Solid Wall + Cladding	13 (43 - 30)	2 (35 - 33)	2 (34 - 32)
Solid Wall + Cladding + Insulation	15 (45 - 30)	0 (31 - 31)	1 (32 - 31)
Dry Wall	28 (60 - 32)	5 (37 - 32)	5 (37 - 32)

external wall temperature of brick wall show higher decrement compared with brick wall with fibre cement cladding and brick wall with fibre cement cladding and insulation. The similar trend was observed for solid wall as well. Dry wall showed a very drastic drop of external wall temperature comparing with other wall system, 28 ^{o}C within 3 hours cooling time.

For internal wall and indoor room temperatures changes, the temperature dropped slowly for brick wall comparing with solid wall and dry wall. Generally, from the finding, the solid wall and dry wall would release the thermal mass faster comparing with brick wall and kept the indoor room much cooler in shorter period. This is good for tropical climate countries. With cladding and/or insulation at external, the internal wall and indoor room temperatures of solid wall decrease in similar rate as brick wall. The initial temperature during heating time for these clad and/or insulated walls already quite low and thus not much change been observed although the heat source been removed.

The estimated R-Value and U-Value of the tested wall systems can refer to Table 5 below. These were calculated based on the thermal properties of the building components in the wall system.

Table 5: Estimated (based on calculation) R-value and U-value of the tested wall system

	R-Value (m^2k/W)	U-Value (W/m^2k)
System A (Brick Wall)	0.390	2.564
System B (Brick Wall + FC Cladding)	0.511	1.956
System C (Brick Wall + FC Cladding + Insulation)	1.761	0.568
System D (Solid Wall)	0.486	2.059
System E (Solid Wall + FC Cladding)	0.607	1.648
System F (Solid Wall + FC Cladding + Insulation)	1.857	0.539
System G (Dry Wall)	2.770	0.361

From Table 5, Dry Wall (System G, IBS) which has highest R-value tend to provide highest insulation effect followed by system F and C which have fibre cement cladding and insulation layer for solid wall and brick wall theoretically. However, the study showed system C and F are better. There is not much difference in thermal transmittance of Solid Wall (System D, IBS) with brick wall (System A, conventional wall) although the R-value of the solid wall is higher which been showed in the experiment above. In order to reach very good thermal insulation, the fibre cement cladding at the external wall did play the role which clearly showed by the increasing value of R, and the experiment here. Besides, by adding a layer of insulation between the cladding and wall, it increased further the thermal insulation properties for the wall system. This has been proven through the temperature measurement in the study.

CONCLUSION

Address thermal insulation would be one of the most effective ways to improve energy efficiency of a building. This can be achieved by incorporating ceiling, roof, wall and floor systems that provide better thermal insulation property (R value) to form the building envelope. Consequently, helping to reduce heat transmittance into the building especially in Malaysia and those tropical climate countries thus improving living comfort and energy saving.

In this experiment, it was clearly showed that the fibre cement cladding can help to improve the thermal insulation properties of the conventional brick wall. By adding the insulation material between the cladding and wall further improved the thermal insulation properties. However, there is no improvement showed by using Industrial Building system i.e. Solid Wall and Dry Wall with fibre cement as the wall panels.

For existing residential houses generally brick wall system in Malaysia if intend to achieve energy efficiency, one of the green building requirements, the fibre cement cladding can be considered.

Further study is required to evaluate the above discussed systems where improvement can be made in order to enhance the thermal insulation by evaluating on the coating technology.

REFERENCES NOTATION

1. Sustainable energy by Sustainable Energy Authority Victoria
2. Green Building Index by Malaysia Green Building Confederation
3. Insulated roof system, Ideal House by Sime Darby Malaysia