Study on Materials for Building Envelope Considering Energy

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ABSTRACT: There are plenty of alternative building materials introduced to construction industry in order to save energy. Although typical materials are used for construction, there is a trend to use alternative materials as sustainability has become an important topic in construction industry. But still there is confusion between energy and cost for selecting material for a building envelope while maintaining basic functions of the building envelope. Therefore, this study evaluates the different building materials in terms of life cycle energy and cost for local conditions. Ferro cement panels with coconut fibre filler is used as an alternative material, together with common building materials for the comparison. Proposed configuration has the lowest lifecycle energy and it is the most cost effective material. Also analysis implies that not only embodied energy but also operational energy is varied with use of different materials for building envelope.

1 INTRODUCTION

Building envelope is a physical separator between conditioned and unconditioned environment. Thermal comfort, visual comfort and acoustic comfort can be identified as basic functions of building envelope. When considering energy, space cooling has the highest share (40% to 60%) from total energy consumption and there is an increasing demand of this share in the building sector. Therefore materials that provide more thermal comfort can save more energy. Energy used in operational stage is not the only energy that a material uses in its life cycle. But also embodied energy, which is the energy required to produce, transport and fabricate, is an important part of its life cycle energy. All the energy consumed by a material in its life cycle is represented by the following equation.

$$LCE = EE_I + EE_{rec} + (OE * years)$$

LCE = the life-cycle energy
EE_i = the initial embodied energy of material
EE_{rec} = the recurrent embodied energy
OE = the total annual operational energy
Year = building life time (Utama & Gheewala, 2008)

It was thought until recently that the embodied energy content of a building was small compared to the energy used in operating the building over its life. Research by CSIRO has found that the average house contains about 1,000GJ of energy embodied in the materials used in its construction. This is equivalent to about 15 years of normal operational energy use. For a house that lasts 100 years this is over 10% of the energy used in its life. (Adams et al, 2006)

Cost of the materials is another important factor that should be considered together with energy. In practical situation if material is very expensive it is not suitable to be selected for a building envelope. This research will provide a comparison of commonly used materials and some innovative materials for building envelope by life cycle energy analysis and life cycle cost of the materials.

2 METHODOLOGY

Various materials use for building envelope that are available locally and internationally and their properties were obtained from the literature review. So that materials which are commonly used and innovative materials which consume less energy were selected for the comparison.

Embodied energy of each material was found from the literature. Then cooling load was determined by simulating materials in Design Builder software to compare materials in terms of operational energy. Then life cycle energy analysis was carried out for the selected materials using obtained embodied energy and operational energy and also the cost of the materials was compared.

2.1 *Selected building envelopes for comparison*

There are several typical attempts to save energy used in buildings. Among them selecting alternative material is one good option as it can save a lot of energy which is used to produce material (Embodied Energy) and the energy used in operational stage for cooling or heating etc. Many studies have been carried out about energy used for alternative building materials locally and internationally. However, with time new and innovative materials are introduced to the industry and further studies are needed with time.

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Bricks, Concrete hollow blocks, Cement Stabilized Earth Block (CSEB), Tempered glass, Cement Stabilized Rammed Earth (CSRE) and Ferro cement sandwich panels filled with coconut fibre are the selected materials for the comparison. Bricks and cement blocks are the most commonly used materials for walls. Bricks are used in different ways such as with or without plaster and different bond patterns such as English bond, Rattrap bond and sketcher bond which perform in different ways in terms of energy. CSEB Block, light weight bricks and concrete hollow blocks are popular with their good thermal properties. As most of the buildings use tempered glass for facades, study was carried out also for the tempered glass.
Composite material made out of Ferro cement and coconut fibre is found out as an innovative material for the walls. Cross section of it is shown in Figure 1.Alavez-Ramirez, et al (2012) have carried out research on this material in terms of thermal properties. Results have shown very low thermal conductivity when compared to other materials which mean operational energy for this material can be low. Also it is mentioned that the sandwich panels provide an economic method of providing structural requirements and thermal insulation. The faces of the sandwich panel provide protection to the core material and withstand the imposed loads acting as tension and compression elements

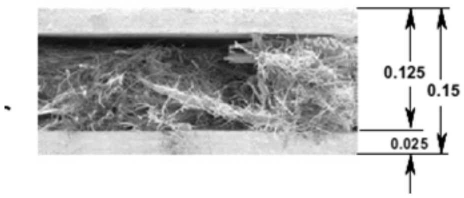

Figure 1: Cross section of ferrocemnt composite envelope (Alavez-Ramirez et al, 2012)

2.2 *Embodied energy of alternative materials*

Embodied energy of the basic building materials are used to calculate Embodied energy of selected materials. These data are obtained from the literature and presented in Tables 1 and 2.

Table 1: Embodied energy of basic building materials (Jayasinghe,, 2013)

Building Material	Embodied energy for production (MJ/kg)	Embodied Energy for Transportation (MJ)	
		50km	100km
Cement	5.85	50	100
Steel	42.0	50	100
Lime	5.63		
LP	2.33		
Aluminium	236.8		
Glass	25.8		

Table 2 : Embodied energy for transportation (Jayasinghe, 2013)

Building Material	Embodied energy for production (MJ/m^3)	Embodied Energy for Transportation (MJ/m^3)	
		50km	100km
Sand/ Soil	0	87.5	175
Crushed aggregate	20.5	87.8	175
Burnt bricks	2550	200	200

Using the embodied energy of basic materials, embodied energy for the selected envelopes was calculated and summary of it is presented in Table 3. Embodied energy for finishes was obtained from the literature (Jayasinghe, 2013).

Table 3: Embodied energy for selected building envelope

Envelope	Embodied energy/m^2		
	Material	Finishes	Total
Brick-sketcher bond	279	185	464
Brick-rat trap bond	567		567
Brick-English bond	661	185	846
Concrete hollow block	202	94	296
CSEB	228	85	313
Ferro cement composite	228		228
Tempered glass	890		890
CSRE (6%)	95		95
CSRE (10%)	149		149

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2.3 Operational energy

In order to compare operational energy of different materials, cooling load of the material was used. Cooling load was found out by simulating each material in Design Builder software. To validate the results obtained from the software, actual model buildings of different materials were used as shown in Figure 2. Ambient temperatures and surface temperatures of those models were obtained from the data-logger for three weeks.

Figure 2: Actual Models

Then carried out computer modelling with these materials and obtained temperature data for each model. By comparing actual data and results obtained from the software for a brick model, validated the results that were obtained from the software. And thermal properties of the Ferro cement composite material were obtained. Using these thermal properties and properties obtained from literature, cooling load of each model was determined using Design Builder software as shown in Figure 3.

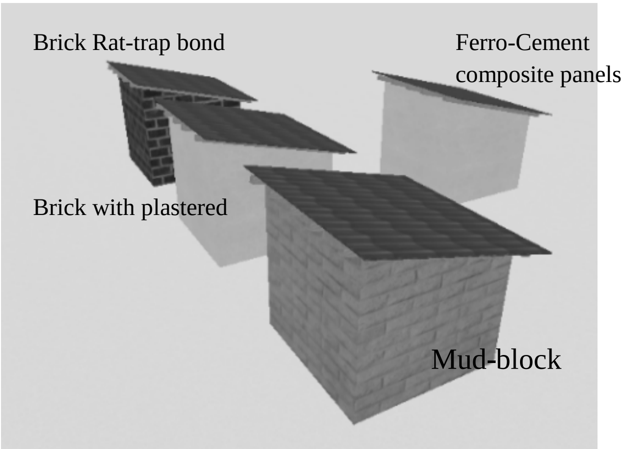

Figure 3: Simulated models in design builder

RESULTS AND DISCUSSION

First brick masonry model was simulated in Design Builder by using thermal properties of bricks which were found from literature. Then compared the results with the results obtained actually to validate the results of Design Builder software. Comparison of the actual data and results obtained from the software are presented in Figure 4. As the results obtained from the software and from actual measurements are almost same it can be concluded that the results obtained from the software are calibrated.

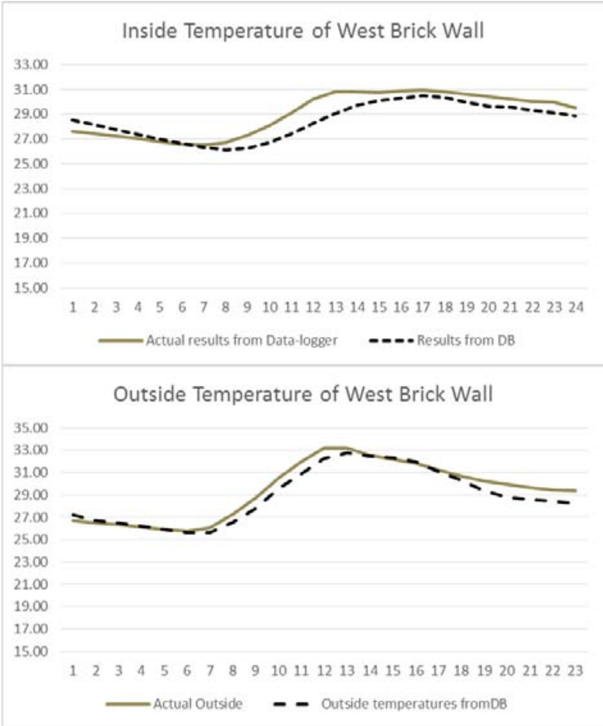

Figure 4: Comparison of actual and simulated temperature data of brick envelope

Then simulated the actual temperature data of Ferro cement composite and rat-trap brick bond envelopes and obtained the thermal properties and cooling load of them.

Also other building envelopes were simulated by using thermal properties determined from literature and calculated the cooling load for each building envelope as shown in Figure 5. U values and cooling load of the selected materials are presented in Table 4 and Table 5 respectively. Then life cycle energy and cost for each building envelope were determined and the results are tabulated in Table 6.

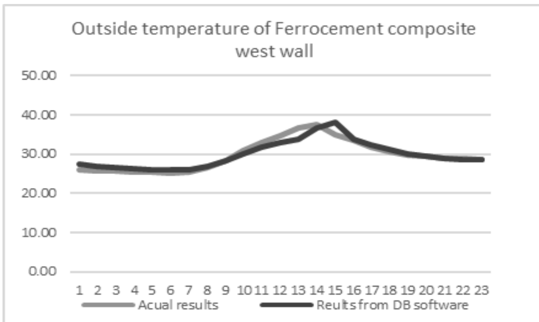

Figure 5: Comparison of actual and simulated temperature data of Ferro cement composite material envelope

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Table 4: U-Value of materials obtained from simulation

Building Envelope	U value
Ferro cement composite	1.42
brick-sketcher bond	3.39
brick-rat trap bond	1.81
brick-English bond	2.22
concrete hollow block	1.96
CSEB with mud plaster	2.05
CSEB without plaster	2.04
Tempered glass	5.62

Table 5: Cooling Load

Building Envelope	Cooling load (kWh/h)	Cooling load for 10 year
Ferro cement composite	0.01	126
brick-sketcher bond	0.04	504
brick-rat trap bond	0.02	252
brick-English bond	0.03	378
concrete hollow block	0.01	126
CSEB with mud plaster	0.02	252
CSEB without plaster	0.02	252
Tempered glass	0.13	1638

Table 6: Life cycle energy and unit cost

Building Envelope	Life cycle energy for 10 years	Cost/m^2 (Rs.)
Ferro cement composite	356	1300
brick-sketcher bond	968	1750
brick-rat trap bond	819	2600
brick-English bond	1224	3100
concrete hollow block	422	1740
CSEB with mud plaster	565	1700
CSEB without plaster	477	1500
Tempered glass	2528	4500

3 CONCLUSION

According to the results shown in Table 6, Ferro cement composite material shows good performance in terms of cost and life cycle energy. It can save about 30% of lifecycle energy when compared to brick masonry. Concrete hollow block (without plaster) shows lowest embodied energy.

Concrete hollow block has low life-cycle energy after Ferro cement composite material. But it has higher cost than Ferro cement composite material. Although tempered glass is popularly used for facades it shows very much poor performance in terms of both cost and energy.

Also it is recommended that the operational energy should be taken into account for the life-cycle energy because, operational energy has shown a significant contribution for life cycle energy of each material.

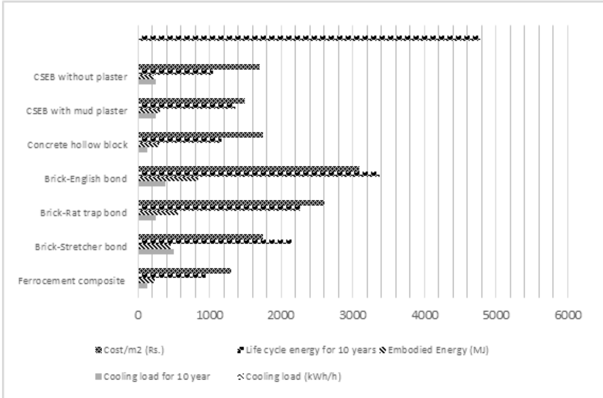

Figure 6: Comparison of building envelopes

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