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Study the Thermal Impact of Massive Waste Material To Building Construction

Muhammad Abu Eusuf, Ph. D[1, a] & Abdullah Al- Hasan[2, b], and Sharonee Sidek[2, a]

[1]Faculty of Architecture and Environmental Design, International Islamic University Malaysia

[2]Post-graduate Student, Built Environment, International Islamic University Malaysia

[a]eusuf2005@gmail.com/ abueusuf@iium.edu.my, [b]abdullah_al_hasan@yahoo.com, sharonee@limkokwing.edu.my

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Abstract: This study focuses on the recycling of massive waste materials and their thermal impact to buildings, which then adapt the indoor thermal environment. It is observed that the role of construction materials modify the building interior and consequently regulates the indoor thermal environment and focus on the reduction of energy consumption at large.

The rapid growth of energy consumption has raised concerns in worldwide. This has caused mainly the exhaustion of energy resources. Efficient employs of energy play a vital role in minimizing the energy usage. Having in mind the aim to seek for contextual alternative building material from waste to obtain continuing improvement in building energy performance, then this study has been designed to do experiments on locally available massive waste material (end-of-life tires, or ELTs) and investigate its thermal impact on indoor energy management strategy.

For that reason, it is needed to set up an experiment to observe the role of ELT for thermal comfort in a tropical climate as compared to conventional construction materials and other waste. This contribution mainly focuses on the literature and a proposed methodology.

Introduction

The disposal management of used automotive tires has caused many environmental and economical problems in most developing countries, and most of these countries currently are not experienced with the disposal of ELT on the framing of a specific law or regulation to the disposal of ELT management. Hence ELT created a massive waste in management system, which interns modified our environment. Recently, it is obvious that we should find alternative ways to reduce the massive ELT waste.

From the literature, it is evident that most of the scrap tires, annually generated in developing countries, are dumped in open or landfill sites. The scrap tires are bulky and do not degrade in landfills. Therefore, open dumping of scrap tires occupies a large space, presents an eyesore, causes potential health and environmental hazards, [9]. Moreover, GDCH [6] stated that scrap tires have oily chemicals that are flammable and tire fires create injury hazards. Burning tires also release hazardous chemicals, such as polycyclic aromatic hydrocarbons, volatile organic compounds, and toxic metals, into air, water, and soil. Tire fires are difficult to extinguish, and are expensive to clean up. Because of their shape, scrap tires can also collect water and debris, which creates a breeding and feeding habitat for insects and rodents carrying diseases such as West Nile Virus. Scrap tires are also a source of dirt, dust, moisture, and mold. Environmental management issues continue to be a driving force behind ELT recycling. So, in developing countries, it is an emerging issue to find alternative uses and alternative ELT pathways of annually generated massive ELT volume.

Dumping scrap tires in landfill sites or stockpiling or open burning is a major waste of valuable energy resource. It is well known that tires are made of rubber materials, carbon black and some fibrous materials [3]. They have a high content of volatile compounds and fixed black carbon with a heating value higher than that of coal. So, old tires are good raw material for thermo chemical processes. Besides for thermo-physical properties of rubber, tires can performed as a high-quality heat sink and can be used an alternative construction material for tropical building to ensure the indoor comfortable thermal environment. Researchers have been trying to find alternative construction materials to ensure thermal comfort in tropical buildings with less energy consumption. But, the effort to use scrap tires as alternative building construction material is not much and it is still being investigated.

Recently, energy consumption is one of the most burning issues in the world. Fossil fuel which is the main source of energy is depleting and raising anxiety around the world about their negative effect on the atmosphere and the environment [5]. Malaysia has experienced strong economic growth through the last decade [7]. Studies show that between 2000 and 2005 energy consumption grew at a fast rate of 5.6% to achieve 38.9 Mtoe (million tonnes of oil equivalent) in 2005. The final energy consumption is expected to reach 98.7 Mtoe in 2030, nearly three times that of 2002.

The purpose of this study is to identify the current scenario and factors of massive ELT waste generation in Malaysia, its disposal practices, as well as to do experiments on this massive ELT waste to find out the alternative end of life pathways, that will positively increase the recycling and legal disposal rate of this massive waste.

The aim of this study is to identify the thermal impact of massive ELT waste material to buildings and the objectives are to study the current ELT management scenario in Malaysia to uncover the challenging issues to ensure thermal comfort in tropical building.

Materials and Methods

ELT Generation and their disposal in Malaysia

In Malaysia, there is a steady increase in ELT generated annually in the country. The number of ELT generated annually in the country is estimated to be 14 million, [14]. Researchers [12] revealed that about 60% of the waste tires are disposed via unknown routes. Waste tires in Malaysia are neither categorized as solid waste or hazardous waste. It is generally considered as business or trade waste. Hence currently, there is no specific law or regulation to govern waste tire management and lack of institutional move toward managing waste tire as a resource in Malaysia. Without a policy and management structure in place, it is costly and difficult for the recycling companies to get a steady supply of waste tires [12]. In Malaysia landfills are the easiest and a legal avenue to dispose waste tires, the gate fee for waste tires disposal is considered expensive by many private rubbish collectors. Private rubbish collectors collect waste tires from the dealers' premises together with other rubbish. The adverse environmental impacts due to improper management of waste tires, was deduced from field observations. Tire manufacturers are not concerned about the final disposal of their product at the end of its life. This issue is tackled by tire- dealers. Generally, there is a lack of awareness and concern among the industry and the public on the environmental and health impacts due to improper management of waste tires. Lack of consistent and available information/data about waste tire generation and management hinders the understanding of current management scenarios, which is critical to formulate pragmatic solutions [12].

Building in Tropics (climate, design principles and thermal comfort)

Generally the tropical zone is the area of land and water between the Tropic of Cancer (latitude 23.5^o N) and the Tropic of Capricorn (latitude 23.5^o S). Occupying about 40% of the land surface of the earth, the tropics are the habitat to almost half of the world's population. There are variations in climate within the tropic. However 90% of the tropical zones represent hot and humid climatic regions, whether permanent or seasonal. The remaining 10% is dessert like, and characterized as hot and dry climate. Local conditions may also differ substantially from the prevailing climate of a region, depending on the topography, the altitude and the surroundings, which may be either natural or built by humans. The presence of conditions like cold air pools, local wind, water bodies, urbanization, altitude and ground surface can all influence the local climate strongly, [11]. Accordingly, the main climatic factors affecting human comfort and relevant to construction are: air temperature, its difference between day and night, and between summer and winter. For building design principle, a study [11] stated that heat gain must be minimized during daytime and heat loss must be maximized at night in hot seasons and internal heat gain must be minimized in the hot seasons; which are the main points to consider when designing a tropical responsive building.

The Tropics are regarded as a region where the humans evolved and comfort has often been taken for granted, built environments are increasingly becoming issues of public concern. The demand for comfort conditions in buildings are significantly increased as a result of exposure to uncomfortable outdoors [1]. Overheated outdoor environment of the city has contributed to a growing preference for a lower comfort temperature indoors. This in turn has put an immense pressure on the energy demand in the cities. Local climate significantly affects the indoor thermal environment of buildings. In tropical climates, buildings are overheated throughout the day for solar heat gain through the building envelope.

Modification of the indoor thermal environment by building materials

Rising concerns regarding global warming pose the building industry with a challenge to cut its energy consumption. The massive energy consumption can be reduced considerably by employing passive environmental solution as a replacement for mechanical ones. Because passive design allows buildings to become accustomed more appropriately to their local climates and take better advantage of natural energy resources, such as thermal buoyancy, to help condition their interior environments. Research [4] stated that achieving thermal comfort through passive means in tropical and hot humid climate is not always easy. Characterized by relatively high temperatures, these climates usually require cooling. Even with the best effort to reduce heat gains, cooling requirement may not be eliminated. These difficulties lead to many buildings relying completely on air-conditioning. In hot climates, materials for building envelopes and the immediate surfaces should help reduce heat gains into buildings. However, traditional materials may no longer be appropriate today, particularly in urban areas, due to increased pollution levels and population densities, along with the diminished availability of traditional materials, among other things [4].

It is obvious that building materials always play a vital role in tropical buildings to minimize thermal impact. For example, foam or glass fibre can cut effectively conductive heat transfer through building envelopes which receive strong solar radiation, [10]. In addition, reflective material, such as aluminium foil help block radiative heat transfers, [13]. Besides, a number of innovative materials usually from local raw and waste materials have been explored in hot humid climates. Examples comprise particleboards from a mixture of rice straw and rice husks and *vetiver* grass; insulation boards from cassava and corncobs; a composite concrete from a combination of durian peel, coconut fibre and coconut coir; a brick from a combination of soil and coconut coir; a cement board from coconut coir [2]; a concrete block from oil palm fibres and *bagasse*; and sandwich walls from rice straw and rice husks, [13]. Some of these materials, such as the cement board from coconut coir, have lower thermal conductivities than those of conventional materials such as bricks and concrete, and in this regard is more appropriate for construction in hot climates [4]. Obviously, further research is required to find a suitable way to develop an effective recycling process of massive waste materials ELT for wider use.

Table 1: Describe the physical and thermal properties of Rubber, Sand and Earth

No	Material	Porosity	Density [kg/m3]	Specific Heat [kj / kg K]	Thermal Conductivity k – [W/(m.K)]	Emissivity (ε) [On 30°C]
1	Rubber	Non-porous	801	2.01	0.13	0.94
2	Sand	Porous	1281 (sand, dry)	0.8	0.15 - 0.25 (dry sand)	0.76
			1922 (sand, wet)		0.25 – 2 (moist sand)	
					2 – 4 (saturated sand)	
3	Earth	Porous	5513	1.26	1.5	

Source: [8]

Experimental set-up

To do experiments a set-up is developed with three different types of foundation materials, which are given in Fig. 1 and Fig. 2. Here ELT and polystyrene are used as alternative foundation materials from massive waste and sand as a conventional foundation material. The Experimental setup is located inside the (refer to Fig. 1) at International Islamic University Malaysia (IIUM-3.253^{o} N and 101.7375^{o}E).

Figure 1: Location plan of experimental set-up

Picture 1: Image of experimental set-up

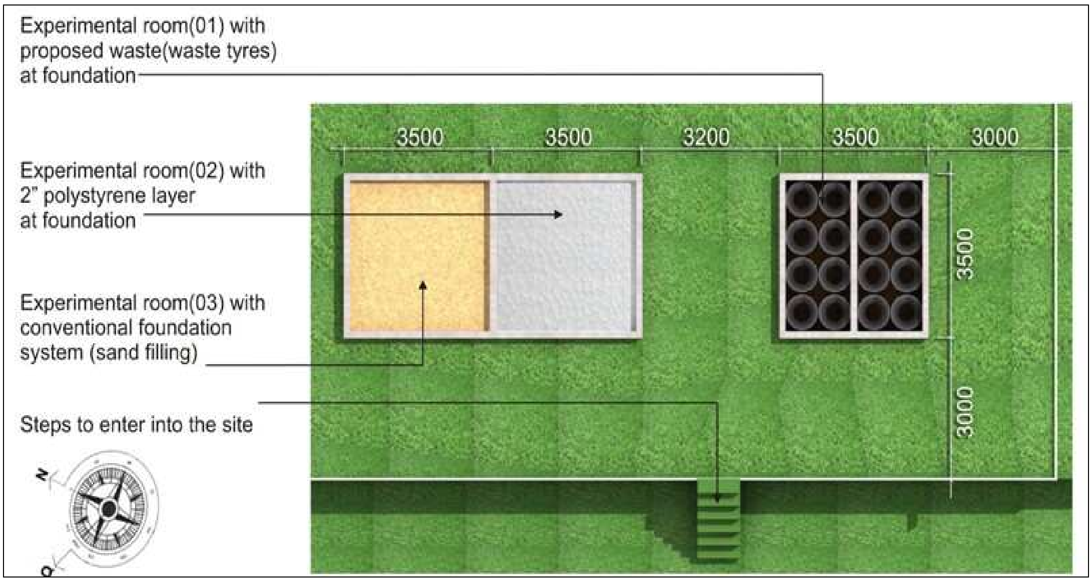


Figure 2: Plan of experimental set-up

We have started the planning and designing process of experimental set-up on 7th April 2011. And the construction started on 23rd June 2011 and finished on 05th January 2012 and finished the set up of equipments on 15th January 2012 and then data acquisition started.

Results and Discussions

For discussion and analysis purpose we presented here only the data of ELT foundation based on experimental room and compared its performance and impact on the indoor thermal environment with the conventional sand filling foundation based experimental room.

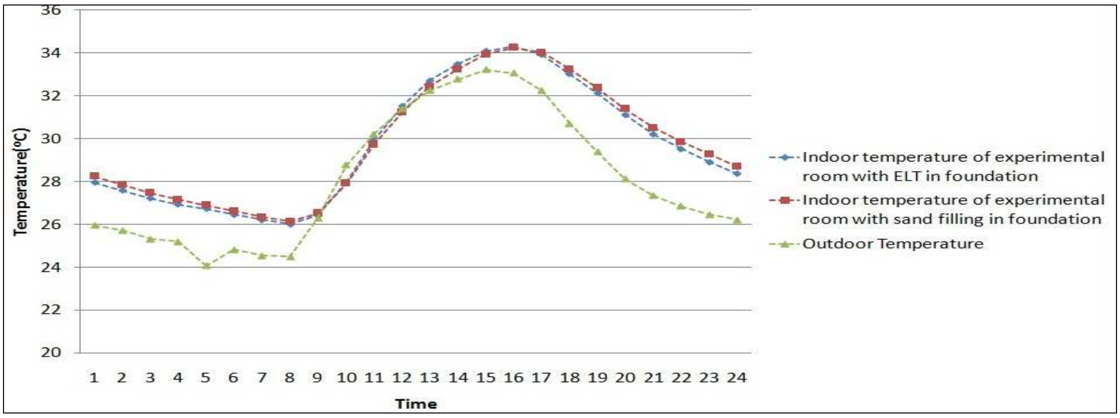
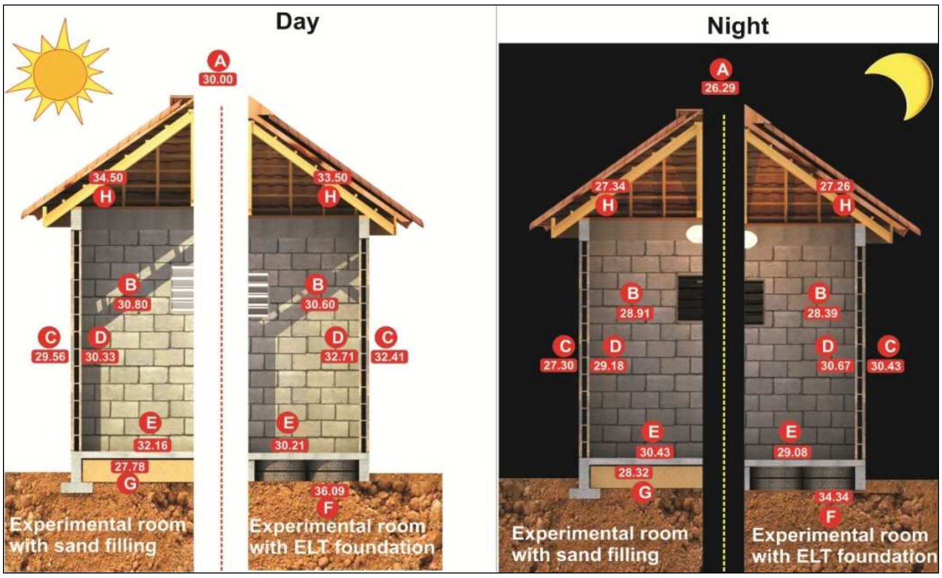


Figure 3: Indoor and Outdoor temperature variations (February 2012)



- A,B= Outdoor and indoor air temperature (°C);
- C,D= Outside and inside wall surface temperature (°C);
- E= Ground floor slab top surface temperature (°C);
- F= Temperature below tire (°C);
- G= Temperature below slab (°C) and
- H= Inside roof surface temperature (°C).

Figure 4: Experimental room set-up

From previous studies it is found that in tropical climates, buildings are overheated throughout the day due to solar heat gain through the building envelope. So, to ensure and improve thermal comfort, it requires lowering of indoor air temperature to be less than the outdoor air temperature and increase heat loss through building envelope by using building elements and by passive or active systems. But the control of indoor thermal environment is directly related to the large amount of energy consumption. In tropical climate, it is a very important and challenging issue to minimize or avoid the reliance on air conditioning. This reliance on air conditioning and energy consumption can be reduced significantly by employing passive solutions such as alternative contextual construction materials and construction techniques.

Through literature it is evident that tire contain almost 43% rubber. It is observed that, for physical, mechanical and thermal properties of rubber (refer to Table-1), ELT can enhance heat sink and drain out the excess heat from indoor environment. Moreover, for the thermal storage capacity of the earth, the daily and even the annual temperature fluctuation keeps on decreasing with increasing depth below the ground surface. Studies have revealed that at a depth of 15 m, the earth has a constant temperature of 10°C. The level of water table plays an important role here.

From figure 4, it is found that envelope (ground floor slab, wall and roof) of experimental room integrated with ELT at the foundation is much cooler than the envelope (ground floor slab, wall and roof) of experimental room with conventional sand filling foundation. At day time ELT integrated ground floor slab it is almost 1.95°C cooler than the sand filling based ground floor slab and during night time it is 1.35 ^{o}C cooler. This clearly represents the high rate of heat released to the earth of the ground floor slab integrated with ELT. Similarly, the wall and roof of experimental room integrated with ELT at foundation is cooler than the wall of experimental room with conventional sand filling foundation. This has happened because ELTs are performing as a heat sink here because of their physical and thermal properties. For high specific heat value (refer to Table-1), ELT always keeps itself cool. As a result large amount of heat from above ground floor slab is absorbed by ELTs and immediately release heat to the earth because of its low density and low thermal conductivity and keep the above ground floor slab remain cool. And for high porosity, high thermal conductivity and high specific heat value (refer to Table-1), earth continuously absorbs heat from ELTs and retains the absorbed heat.

On the other hand, from this experiment it is revealed that the ground floor slab with conventional sand filling based foundation rarely transfers heat to the sand. It continuously absorbs heat from the sand (refer to Fig. 4) and keeps heating. The main reason behind this reverse heat flow from the sand to the above ground floor slab is for the variation of physical and thermal properties of sand (refer to Table-1). For high porosity, low specific heat value and high thermal conductivity, the sand absorb heat from its above ground floor slab but all the heat retains in its volume and remains hotter than its above ground floor slab. As a result the ground floor slab with conventional sand filling foundation is remaining hot as compared to the ground floor slab integrated with ELT at foundation.

And as a result, indoor air temperature is affected due to the heat gain, heat store and heat release character of envelope (wall, roof and ground floor slab) of experimental rooms. Figure 3 and 4 has been depicted the day time temperature variation, where ELT foundation room is 0.2^{o}C cooler than the other samples. Hence at nocturnal condition, the indoor environment of the experimental room with ELT foundation is more comfortable than day time and temperature gradient is reduced by 0.5 ^{o}C.

Conclusions

In tropical climates, improving the indoor thermal environment of buildings together with exploiting the energy efficiency is a multifaceted task that involves a high degree of integration in design, construction materials and construction technique. Therefore, the best results are generally achievable in new tropical buildings where energy and contextual considerations can be incorporated. And ELT heat sink can be performed as a key passive cooling method by increasing the heat loss from building as well as cooling loads reduced by addressing the building envelope together with reducing grid-electricity consumption. Though, ELT is a massive waste material in Malaysia and for its cheap price and availability it can be used as a contextual alternative construction material which interns can minimize the massive waste load of ELT. Strong and effective legislation is required and then that rules should be imposed on the minimization of ELT waste. Our next attempt is to investigate the heat sink potentiality of ELT in multi storied buildings.

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