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Study the Heat Transfer Potentiality of a Building Envelope Integrated with Elt at Foundation

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Abstract: The aim of this paper is to investigate the heat transfer potentiality of a building envelope integrated with ELT (end-of-life tyres) at foundation. A hazardous waste, ELT or massive scraped tyre waste created environmental load to the local environment. Today, when researchers think of the environmental impacts of tyres, they mostly focus on the management of tyres at the end of their useful lives. From Global perspective it is found that one billion tyres reach the end of their useful lives annually, out of which about four billion ELTs are currently in landfills and as stockpiles worldwide. Study revealed that most of the developing countries currently are not experienced with the disposal method of ELT. Besides, developed countries from Europe, USA, Japan and Singapore have framed specific law or regulation to the disposal of ELT. Recently it is obvious that should find out alternative ways as to reduce the load of massive ELT waste. Furthermore, this study has been designed to manage ELTs massive waste, experimentally. This research followed by an effective experimental set up to observe the real phenomena of ELT for passive cooling in hot humid and tropical climate and make comparison with conventional construction materials and systems.

Key words: ELT · Heat Transfer · Heat Sink · Building Envelope · Tropical Climate and Passive Cooling

INTRODUCTION

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

Most of the scrap tyres, annually generated in developing countries, are dumped in open or landfill sites. The scrap tyres is bulky and do not degrade in landfills. Therefore, open dumping of scrap tyres occupied a large space, presents an eyesore and causes potential health and environmental hazards [1]. Moreover, [2] stated that scrap tyres contain oily chemicals that are flammable and tyre fire increased hazards. Burning tyres released hazardous chemicals into air, water and soil. This is difficult to extinguish and expensive to clean up. Because of their shape, scrap tyres can also store water and debris, which provided an efficient breeding and feeding place for insects and rodents carrying diseases. These are also a source of dirt, dust, moisture and mold. Environmental issues continue to be a driving force behind ELT recycling. So, in developing countries, at present it is an emerging issue to find out alternative uses and alternative end of life pathways.

But the tyre is made of rubber materials (polybutadiene, styrene-butadiene rubber and polyisoprene or natural rubber), carbon black and some

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fibrous materials, reviewed by [2]. It has a high content of volatile compounds and fixed black carbon with a heating value higher than that of coal. This makes old tyres a good raw material for thermo chemical processes. Besides for thermo physical properties of rubber [3 - 4], tyres can be 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. For many days researchers have been trying to find out alternative construction materials to ensure thermal comfort and increase heat release in tropical buildings which is wide reviewed in [6]. But, the effort to use hazardous scrap tyres as alternative building construction material is not much and it is still an investigation concern for built environment researchers.

Nowadays, in hot tropical regions it is one of the most complicated and arising issue to ensure thermal comfort in buildings by means of passive way. Tropical climate greatly affects the indoor thermal environment of buildings. Here buildings are overheated during the day due to solar heat gain through the building envelope [7] and release the stored heat towards indoor when night begins. From a thermal comfort point of view it requires lowering of indoor temperature below the outdoor temperature, [6] and drain out the indoor excessive heat by using building envelope, by construction materials and by passive or active systems. Techniques for such thermal modification have been widely addressed at [7]. However, 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. Nevertheless, a range of passive design techniques need to be employed to help minimize or avoid this reliance.

The purpose of this study is to do experiment on hazardous ELT waste to find out efficient and effective end of life pathway that will positively increase the recycling and legal disposal rate of this massive waste which interns minimize the illegal dumping in land fill sites.

The aim of this study is to study the thermal impact of massive ELT waste material to building. And the objectives are to study the the heat transfer rate from a building envelope integrated with ELT waste together with compare its heat transfer and heat sink potentiality with a conventional foundation material as like sand.

MATERIALS AND METHODS

To do experiments on ELT to observe the heat flow character its thermal impact on indoor thermal environment, we build an experimental setup by using three different types of foundation materials (Figure 2). We have used ELT and polystyrene as alternative foundation materials from waste and sand as a conventional foundation material.

Location of Experimental Set-up: The Experimental setup is located inside the (Figure 1) at International Islamic University Malaysia (IIUM) campus, Gombak, Kuala Lumpur, Malaysia. IIUM is located at latitude 3.253o N and longitude 101.7375oE.

We started 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. We finished the set up of experimental equipments on 15th January 2012. From 16th January 2012 we started data acquisition. Data acquisition interval was only 10 seconds for micro scale observation. All construction materials and systems for all 3 experimental rooms are same except the foundation materials and system. So, physical and thermal properties of foundation materials including earth are listed in Table 1.

Construction Period of Experimental Set-up: Though, this study has been focused to the heat transfer rate from building envelop along with the thermal impact on indoor thermal environment, that's why we used 8 thermocouples for each experimental room to acquire the heat transfer data from building envelop (Figure 3). The ground floor slabs were drilled in 2 nearby positions and placed the thermocouples as per below positions. Yellow dots indicate the thermocouples positions. Thermocouples positions were as below:

- Thermocouple placed on floor slab surface of each experimental room.
- Thermocouple placed in 2.5" deep inside the floor slab of each experimental room.

Table 1: Physical and thermal properties of Rubber, Sand and Earth

No	Material	Porosity	Density (kg/m^3)	Specific Heat (Kj / Kg K)	Thermal Conductivity k - W/(m.K)	Emissivity Coefficient (ε) (On temperature 300 K)
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	5500	1.26	1.5	

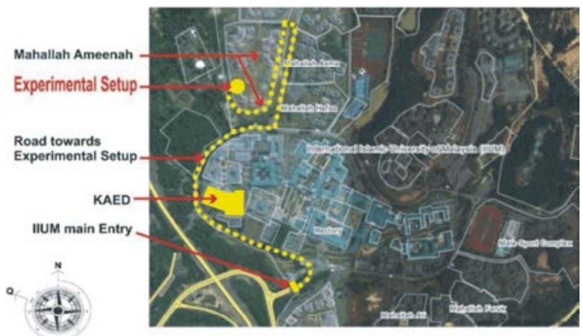

Fig. 1: Location plan of experimental set-up

Pic. 1: Image of experimental set-up

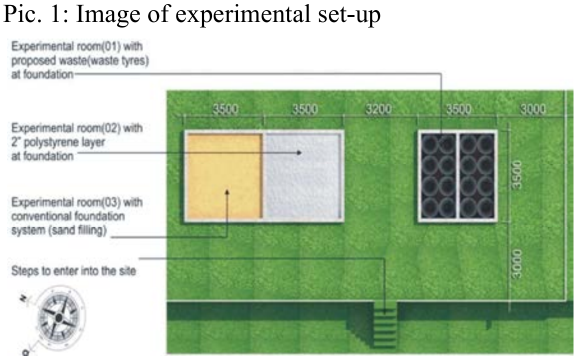

Fig. 2: Plan of experimental set-up

- For ELT based foundation 1 thermocouple touched the ground and for conventional sand filling foundation 1 thermocouple touched the top of sand surface.

Fig. 3: Position of thermocouple wires

- Thermocouple placed on outside wall of each experimental room.
- Thermocouples placed on inside wall of each experimental room.
- Thermocouple placed on inside roof of each experimental room.

RESULTS AND DISCUSSIONS

From data observation and analysis it is revealed that envelope (ground floor slab, wall and roof) of experimental room integrated with ELT at foundation is much cooler than the envelope of experimental room with conventional sand filling foundation (Table 2). 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°C cooler. This clearly represents the less heat storage nature of the ground floor slab integrated with ELT at foundation. Same as, wall and roof of experimental room integrated with ELT at foundation is cooler than the wall of experimental room with conventional sand filling foundation. From Table 3, it is observed that in case of ELT foundation system, wall (19.75 watt at day, 15.81 watt at night) and roof (5879.72 watt at day, 1444.73 watt at night) gain less heat than the wall (50.71 watt at day, 123.81 watt at night) and roof (7559.64 watt at day, 1545.52 watt at night) of sand filling foundation. And this is happened because ELTs are acted as a heat

Table 2: Comparison of indoor thermal comfort conditions of experimental rooms, Heat transfers from the envelops (wall, roof and slab) of experimental rooms, sand and earth

Position of thermocouple wire	Data acquisition period	Time	Average envelop/ indoor temperature (°C) of experimental room integrated with ELT foundation	Average envelop/ indoor temperature (°C) of experimental room with sand filling foundation	Temp difference (oC) of building envelop/ indoor {Sand filling experimental room-ELT integrate experimental room}
On floor surface	1st - 28th Feb 2012	(day)7:27 am - 19:27pm	30.21	32.16	+1.95
	1st - 28th Feb 2012	(night)19:28 pm - 7:26am	29.08	30.43	+1.35
2.5" deep inside the slab	1st - 28th Feb 2012	(day)7:27 am - 19:27pm	31.45	31.64	+0.19
	1st - 28th Feb 2012	(night)19:28 pm - 7:26am	29.65	30.13	+0.48
Touch the earth / sand	1st - 28th Feb 2012	(day)7:27 am - 19:27pm	36.09 (earth temperature)	27.78(sand temperature)	-8.31
	1st - 28th Feb 2012	(night)19:28 pm - 7:26am	34.34 (earth temperature)	28.32 (sand temperature)	-6.02
On inside wall surface	1st - 28th Feb 2012	(day)7:27 am - 19:27pm	32.71	30.33	
	1st - 28th Feb 2012	(night)19:28 pm - 7:26am	30.67	29.18	
On Outside wall surface	1st - 28th Feb 2012	(day)7:27 am - 19:27pm	32.41	29.56	
	1st - 28th Feb 2012	(night)19:28 pm - 7:26am	30.43	27.30	
On inside roof tile surface	1st - 28th Feb 2012	(day)7:27 am - 19:27pm	33.50	34.50	+1.00
	1st - 28th Feb 2012	(night)19:28 pm - 7:26am	27.26	27.34	+0.08
Indoor air temperature	1st - 28th Feb 2012	(day)7:27 am - 19:27pm	30.65	30.80	+0.15
	1st - 28th Feb 2012	(night)19:28 pm - 7:26am	28.39	28.91	+0.52

Table 3: Comparison of Heat loss and Heat gain by experimental rooms' envelope

Envelop type	Thermal transmittance value, U	Area (m^2) A	Temperature difference (°C)ΔT	Heat loss/gain(Watt) U.A.ΔT
Ground floor slab integrated with ELT at foundation	9.09	12.25	5.88 (day)	654. 75 (Heat loss)
			5.26 (night)	585. 71 (Heat loss)
Ground floor slab with sand filling foundation	9.09	12.25	4.38 (day)	487. 72 (Heat gain)
			2.11 (night)	234.95 (Heat gain)
Wall of experimental room integrated with ELT at foundation	5.88	11.2	0.3(day)	19.75 (Heat gain)
			0.24(night)	15.81 (Heat gain)
Wall of experimental room with sand filling foundation	5.88	11,2	0.77(day)	50.71 (Heat gain)
			1.88(night)	123.81 (Heat gain)
Roof of experimental room integrated with ELT at foundation	38.18	44	3.5 (day) used outside temperature from weather station data	5879.72 (Heat gain)
			0.86 (night) used outside temperature from weather station data	1444.73 (Heat gain)
Roof of experimental room with sand filling foundation	38.18	44	4.5 (day)) used outside temperature from weather station data	7559.64 (Heat gain)
			0.92 (night)) used outside temperature from weather station data	1545.52 Heat gain)

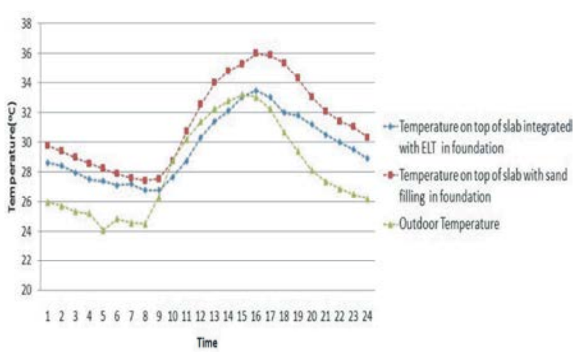

Fig. 4: Temperature on top of slab in relation with time and outdoor temperature from 1st - 28th Feb 2012

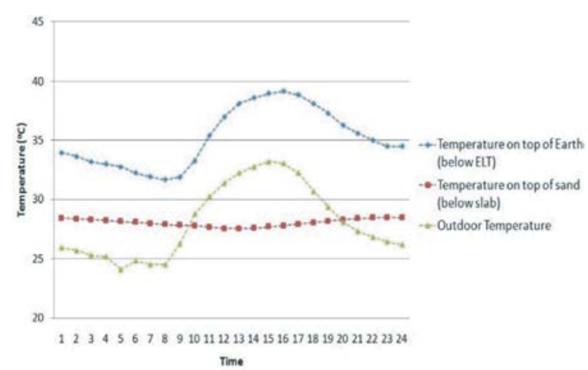

Fig. 5: Temperature of earth and sand below experimental rooms in relation with time and outdoor temperature from 1st - 28th Feb 2012

sink here. Heat gained by the wall and roof are sink by the ELT at foundation and drained out to the earth.

At day time, temperature profile inside the slabs (at 2.5" deep) are almost equal but during night time ELT integrated ground floor slab much cooler than sand f illing based ground floor slab (Table 2). After one month observation we found that at day time, inside (2.5" deep) temperature of ELT integrated ground floor slab is 0.19°C cooler than the sand filling based ground floor slab and during night time it is 0.49°C cooler. Because of high specific heat value (Table 1), ELTs always keep itself remain cool. As a result large amount of heat from above ground floor slab is absorbed (Table 3) by ELTs and Immediately release heat to the earth because of ELT's low density, low thermal conductivity and higher emissivity (Table 1) and keep the above ground floor slab remain cool (Table 2) and (Figure 4). And for high porosity, high thermal conductivity and high specific heat value (Table 1), earth continuously absorbing heat from ELTs and retains the absorbed heat (Table 2).

On the other hand, it is obvious from the experiment that ground floor slab with conventional sand filling based foundation never transfer heat to the sand. Rather it continuously absorbs heat from sand (Table 3) and keeps itself heated (Table 2). Main reason behind this reverse heat flow from sand to the above ground floor slab is for the physical and thermal properties of sand (Table 1). For high porosity, low specific heat value and high thermal conductivity, sand filling absorbs heat from its above ground floor slab but all the heat retains in its volume and always keeps hotter than its above ground floor slab (Table 2). And for 1st law of thermodynamics, the hot sand continuously passes heat to the above ground floor slab (Table 3). As a result ground floor slab with conventional sand filling foundation is always remaining hot as compared to the ground floor slab integrated with ELT at foundation.

Heat Transfer Potentiality of Ground Floor Slab Integrated with Elt at Foundation: For analysis purpose, here has been employed some numerical models to estimate the Heat storage and Heat release behavior of ground floor slabs integrated with ELTs and sand filling. The governing equation for heat transfer under the ground floor slabs is as stated by [8]:

$$Q_f \text{ (measured in Watts)} = U.A.\Delta T \quad (1)$$

The amount of heat that is lost (Q_f) through the building fabric depends on 3 things;

- The difference between the inside design temperature and the outside temperature (ΔT)
- The area of the different building elements exposed to the temperature differential (A)
- The rate at which heat flows through the different building elements exposed to the temperature differential, known as the U -Value (U)

A U-value is a measure of thermal transmittance. Heat flow through a material is usually expressed in terms of thermal resistance (R). Transmittance is the inverse of resistance and can therefore be expressed as the reciprocal of resistance:

$$\text{Thermal Transmittance (U-value)} = 1/\text{Thermal Resistance (R)} \quad (2)$$

The amount of resistance that a material offers to the flow heat through it depends on the thermal properties of the material and its thickness. It can be calculated from the following formula:

$$R = d/\lambda \quad (3)$$

- R is the thermal resistance of the material (m^2K/W)
- D is the thickness of the material (in metres)
- λ is the thermal conductivity of the material (W/mK)

[8] stated that thermal conductivity of cast concrete (dense 2000 kg/m3) is 1.13 W/mK.

- So, the R value (thermal resistance) for the ground floor slabs of experimental rooms is 0.125/1.13 = 0.11 (calculated by equation 3)
- So, the R value (thermal resistance) for the wall of experimental rooms is 0.1/0.58 = 0.17
- So, the R value (thermal resistance) for the concrete roof tiles of experimental rooms is 0.022/0.84 = 0.026

CONCLUSIONS

In hot humid tropical climate, exploit the efficient heat drain out from building envelope to improve the indoor thermal environment of a building is a multifaceted task that involves a high degree of integration in design, construction materials and construction technique. Besides, it is very important to control and minimize the indoor temperature and to minimize or avoid the reliance on air conditioning. And ELT heat sink can be performed as key passive cooling method by increasing the heat loss from building as well as an alternative construction material which interns can minimize the massive waste load of ELT. Strong legislation is required and law-rules should be imposed on the minimization of ELT waste. Our next attempt is to investigate the heat sink potentiality of ELT in multistoried buildings.

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