STUDY THE THERMAL IMPACT OF MASSIVE WASTE MATERIAL TO BUILDING

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ABSTRACT

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

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

In that reason we needed to set up an experiment to observe the role of ELT for thermal comfort in tropical climate and that compare with conventional construction materials and other waste. The experimental setup has been installed in IIUM- Gombak campus, Malaysia. This contribution mainly focused on the literature and a proposed methodology.

Keywords: Recycling of massive waste materials, ELT, indoor thermal environment, energy consumption, Heat transfer, Building material and Tropical climate.

INTRODUCTION

The disposal of used automotive tyres has caused many environmental and economical problems in most of the developing countries. And most these countries currently are not experienced with the disposal of ELT with 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 should find out alternative ways as to reduce the massive ELT waste.

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 occupies a large space, presents an eyesore, causes potential health and environmental hazards, **Korenova, Z et al. (2005)**. Moreover, **Georgia department of community health (2010)** stated that scrap tyres have oily chemicals that are flammable and tire fires create injury hazards. Burning tyres also release hazardous chemicals, such as polycyclic aeromatic 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 issues continue to be a driving force behind ELT recycling. So, in developing countries, it is an emerging issue to find out alternative uses and alternative end of life pathways of annually generated massive ELT volume.

But dumping scrap tyres in landfill sites or stockpiling or open burning is a major waste of valuable energy resource. It is well known that the tyre is made of rubber materials (polybutadiene, styrene-butadiene rubber and polyisoprene or natural rubber), carbon black and some fibrous materials, **Korenova, Z et al. (2005)**. 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, 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 in tropical buildings with less energy consumption. But, the effort to use scrap tyres as alternative building construction material is not much and it is still an investigation concern for built environment researchers.

Nowadays energy issue is one of the most sensitive and complicated issues in the world. Fossil fuel which is the main source of energy are depleting and rising anxiety around the world about their negative effect on the atmosphere and the environment, **Gan and Li (2008)**. Energy is the key input in the development and economic growth. Malaysia has experienced strong economic growth through the last decade, **Saidur et al. (2007) and Hasanuzzaman et al. (2008)**. Malaysian economy grew at a rate of 5 % in 2005 and the overall energy demand is expected to increase at an average rate of 6 % per annum, **Saidur et al. (2009)**. Another study showed that among 2000 and 2005 energy consumption grew at a fast rate of 5.6 % to achieve 38.9 Mtoe in 2005. The final energy consumption is expected to reach 98.7 Mtoe in 2030, nearly three times the 2002, **APERC (2006).**

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 study the thermal impact of massive ELT waste material to building. And the objectives are to study the current ELT management scenario in Malaysia. Next to uncover the challenging issues to ensure thermal comfort in tropical building. Then study the techniques to modify the indoor thermal environment by building construction materials and finally to do an experiment on the ELT waste material to observe its real impact on a building indoor thermal environment.

MATERIALS AND METHODS

1. Library research on the ELT management scenario in Malaysia along with the thermal impacts of building materials to increase thermal comfort in tropical buildings.
2. Experiment

1) LIBRARY RESEARCH

A) 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, **WBCSD (2008)**. As stated **by Sandra & Thiruvangodan (2006)**, about 60% of the waste tyres are disposed via unknown routes. Waste tyres in Malaysia are neither categorized as solid waste or hazardous waste. It is generally considered as business or trade waste, **Sandra & Thiruvangodan (2006)**. Hence currently, there is no specific law or regulation, which governs waste tyre management. At present, there is no institutional move toward managing waste tyre as a resource in Malaysia. Existing companies operate solely on business ethics, with profit being the conclusion. Without a policy and management structure in place, it is costly and difficult for the recycling companies to get a steady supply of waste tyres, **Sandra & Thiruvangodan (2006)**.

Sandra & Thiruvangodan (2006), also uncovered that, In Malaysia landfill is the easiest and a legal avenue to dispose waste tyres, the gate fee for waste tyres disposal is considered expensive by many private rubbish collectors. Private rubbish collectors collect waste tyres from the dealer's premises together with other rubbish: thus they charge a minimum extra fee. On the other hand, a high gate fee at the landfill deters the private rubbish collectors from dumping waste tyres at the landfill. Left with little choice they have to find alternative places within their budget to dispose the tyres. The adverse environmental impacts due to improper management of waste tyres, was deduced from field observations and "ad-hoc" data from interviews with municipal health inspectors and landfill operators. There is a serious lack of producer responsibility for waste tyre management in Malaysia. Tyre producers or manufacturers are not concerned about the final disposal of their product at the end of its life. They leave it solely to their dealers to tackle this issue. The lack of producer responsibility in managing the waste makes the management of waste tyres a more difficult task. 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 tyres. Lack of consistent and available information/data about waste tyre generation and management hinders the understanding of current management scenarios, which is critical to formulate pragmatic solutions, **Sandra & Thiruvangodan (2006).**

B) 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 23.5o N) and the Tropic of Capricorn (latitude 23.5o S). Occupying about 40% of the land surface of the earth, the tropics are the home to almost half of the world's population. There are variations in climate within the tropic. However 90% of the tropical zones embody hot and humid climatic regions, whether permanent or seasonal. The remaining 10% is dessert like, and characterized as hot and dry climate, **Baish (1987)**. 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, **Paul & Dieter (1993)**. According to **Paul & Dieter (1993)**, the main climatic factors affecting human comfort and relevant to construction are: air temperature, its extremes and the difference between day and night, and between summer and winter. For building design principle, **Paul & Dieter (1993)** stated that minimize heat gain during daytime and maximize heat loss at night in hot seasons and minimize internal heat gain in the hot seasons are the main points to consider when designing a tropical responsive building.

The Tropics regarded as a region where the human evolved and comfort has often been taken for granted, built environments are increasingly becoming issues of public concern, **Ossen et al. (2008).** The demand for comfort conditions in buildings are significantly increased as a result of exposure to uncomfortable outdoors, **Ahmed (2003).** 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, **Ossen et al. (2008).**

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. To ensure thermal comfort, it requires lowering of indoor temperature below the outdoor temperature by building construction elements and by passive or active systems. Techniques for such thermal modification have been widely addressed at **Givoni (1994).**

So, building design for tropical warm climatic conditions would attempt to exclude major heat loads arising due to the existing ambient temperature and the intensity of solar radiation. If ambient temperature is higher than the room temperature, heat enters the building through building envelope. The efficient way to cool a building, therefore, is to minimize the heat gain by building envelope or increase the heat loss from building envelope to the maximum level. Incorporation of energy efficient passive cooling techniques into the building design wherever possible to reduce cooling load and energy consumption by building is the main challenging issues in tropical buildings.

C) Modification of the indoor thermal environment by building materials

Rising concerns regarding global warming stand the building industry with a challenge to cut its energy consumption. Countries as like in the UK and in the US, for example, the building sector consumes of order 40-50% of the total delivered energy, **DTI (2003) & EPA (2004).** Of this, climate control systems, namely ventilation, cooling and heating can account for as much as 70% of the total energy use, **BRESCU (2000).** This 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. **Chenvidyakarn (2007)** 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. Nevertheless, a range of passive design techniques need to be employed to help minimize or avoid this reliance.

In hot climates, materials for building envelopes and the immediate surfaces should help reduce heat gains into the buildings. A survey, **Leaurungreong (2005),** shows that many traditional buildings in hot humid climates use lightweight materials along with relatively permeable constructions, such as wooden walls with ventilation gaps and woven bamboo strip flooring, to allow the interiors to cool rapidly in the evening following the outside air temperature, and achieve a relatively comfortable environment during sleeping hours. These materials have low thermal insulation value. However, such uses of 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, **Chenvidyakarn (2007).**

From literature, it is obvious that building materials always play a vital role in tropical buildings to minimize thermal impact. For example, **Chenvidyakarn (2007)** reviewed that foam or glass fiber can cut effectively conductive heat transfer through building envelope which receives strong solar radiation. In addition, reflective material, such as aluminium foils, to help block radiative heat transfer*;* 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*;* a concrete block from oil palm fibres and bagasse; and sandwich walls from rice straw and rice husks. 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, **Chenvidyakarn (2007).**

So, further research and experiment are required to make out more of such high-potential materials especially from massive waste materials and build up them for wider marketable use. Concentration should be given in particular to the ability of the material's thermal insulation performance and heat release potential to increase indoor thermal comfort level.

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	

Source: *The Engineering Tool Box (2012), Hypertextbook (2012)*

2) EXPERIMENT

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

A) Location of experimental set-up

The Experimental setup is located inside the premise of Mahallah Ameenah (Fig -1) at International Islamic University Malaysia (IIUM) campus, Gombak, Kuala Lumpur, Malaysia. And IIUM is located 0.1 kilometer away from Iiu Main Rd; 0.2 kilometer away from Islamic Revival Faculty Rd; 0.3 kilometer away from Female Colleges Rd; 0.4 kilometer away from Main Building Rd; 0.4 kilometer away from Health Centre Rd; University Islam Antarabangsa (UIA) is geographically located at latitude (3.253 degrees) 3° 15' 10" North of the Equator and longitude (101.7375 degrees) 101° 44' 14" East of the Prime Meridian on the Map of Kuala Lumpur, *Pagenation (2012).*

Picture 1*: image of experimental set-up (Copyright by others)

Figure 1*: Location plan of experimental set-up

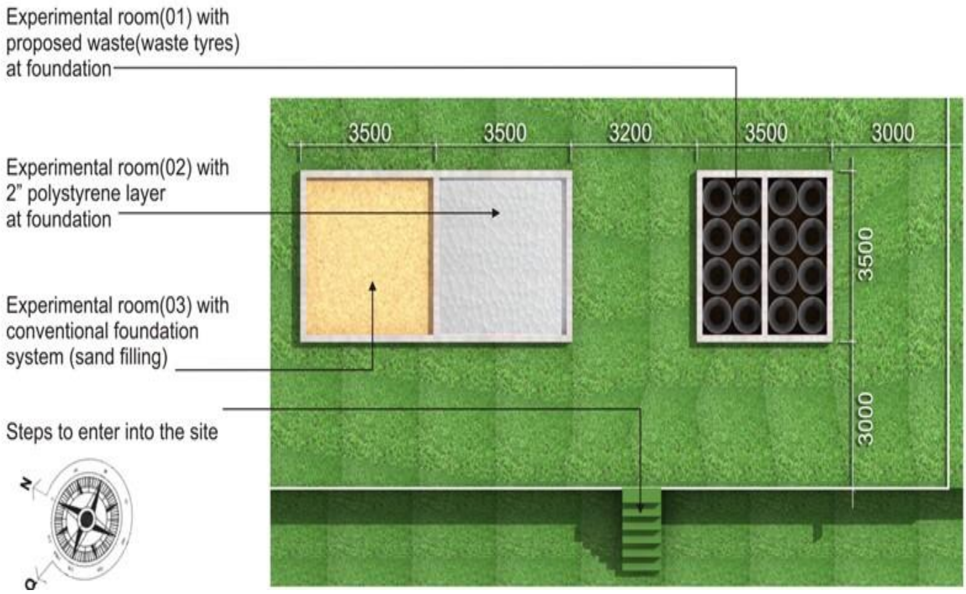

Figure 2*: Plan of experimental set-up

B) Construction period of experimental set-up:

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.

C) Experimental output:

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

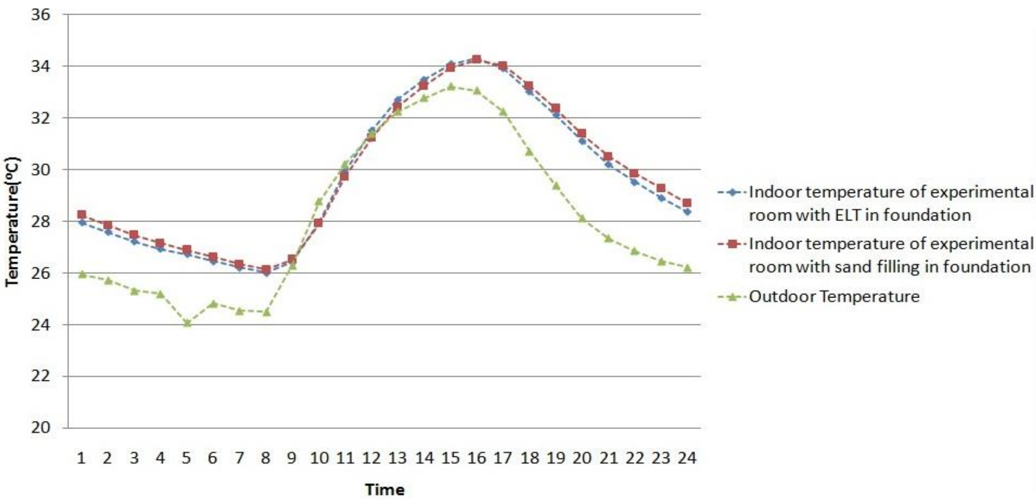

Figure 3*: Indoor temperature of experimental rooms in relation with time and Outdoor temperature from 1st – 28th Feb 2012

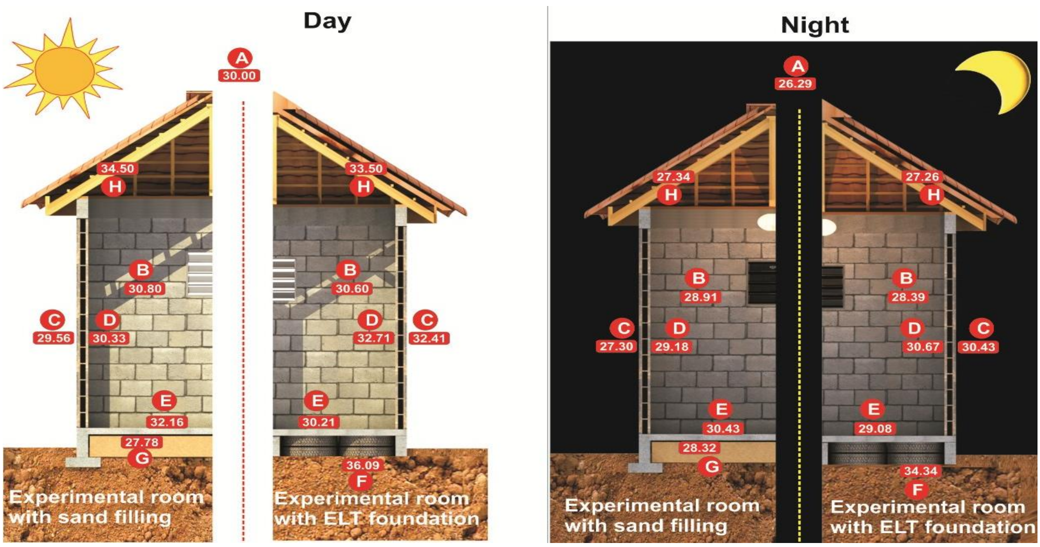

Figure 4*: Indoor temperature of experimental rooms in relation with time and Outdoor temperature from 1st – 28th Feb 2012

A= Outdoor air temperature (0C), B= Indoor air temperature (0C), C= Outside wall surface temperature (0C), D= Inside wall surface temperature (0C), E= Ground floor slab top surface temperature (0C), F= Temperature on top of earth (below tyre) (0C), G= Temperature on top of sand (below slab) (0C), H= Inside roof surface temperature (0C).

RESULTS AND DISCUSSIONS

From literature it is obvious 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 below the outdoor air temperature and increase heat loss through building envelop by using building elements and by passive or active systems. But the control of indoor thermal environment by active means as like air con is directly related to the large amount of energy consumption. In tropical climate it is 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 as like alternative contextual construction materials and construction techniques.

Next, from literature it is also found that major part of a typical car tyre is rubber, almost 43%, **WBCSD (2008)**. From **The Engineering Toolbox (2012) & Hypertextbook (2012)**, it is observed that, for physical, mechanical and thermal properties of rubber (Table-1), ELT can be performed as an enhanced heat sink and can be drained out the excess heat from indoor. 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, **Ossen et al. (2008)** has 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. In summer and particularly during the day, the ground temperature is much lower than the ambient air temperature. If a part of the building is earthbound, the building loses heat to the earth particularly The most ancient dwellings were often dug into the ground or covered with earth to take advantage by transferring the heat to the deep earth, **Rosangela (2002).**

From experiment, 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 (ground floor slab, wall and roof) of experimental room with conventional sand filling foundation (Fig-4). At day time ELT integrated ground floor slab it is almost 1.95^{o}C cooler than the sand filling based ground floor slab and during night time it is 1.35^{o}C cooler (Fig-4). This clearly represents the high rate of heat release 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 (Fig-4). And this has happened because ELTs are performing as a heat sink here because of their physical and thermal properties. For 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 by ELTs and Immediately release heat to the earth because of its low density and low thermal conductivity (Table-1) and keep the above ground floor slab remain cool (Fig-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 (Fig-4).

On the other hand, from experiment it is revealed the ground floor slab with conventional sand filling based foundation rarely transfer heat to the sand. It continuously absorbs heat from sand (Fig-4) and keeps itself heated. 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 absorb heat from its above ground floor slab but all the heat retains in its volume and always keep hotter than its above ground floor slab (Fig-4). Following the 1st law of thermodynamics, the hot sand continuously passes heat to the above ground floor slab. 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 (Fig-4).

And as a result for above heat gain, heat store and heat release character of envelop (wall, roof and ground floor slab) of experimental rooms, their indoor air temperature is also affected. From (Fig-3) and (Fig-4) it is observed that at day time the indoor air temperature of experimental room with ELT foundation is almost $0.2^{o}C$ cooler than the indoor air temperature of experimental room with sand filling foundation . But at night, the indoor air temperature of experimental room with ELT foundation is more comfortable than day time. At night the indoor air temperature difference is between two experimental room is more than $0.5^{o}C$ (Fig-4).

CONCLUSIONS

In tropical climate, improve 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 key passive cooling method by increasing the heat loss from building as well as cooling loads can be reduced by addressing the building envelope together with reducing grid-electricity consumption. Though, ELT is 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 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 multi storied buildings.

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