UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF ECO FRIENDLY CONSTRUCTION BRICKS FROM POLYETHYLENE TEREPHTHALATE (PET) PLASTIC WASTE AND ITS CARBON FOOTPRINT

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BY

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Thesis submitted in fulfilment of the requirement for the degree of Bachelor Science (Environmental and Occupational Health) from the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.

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ABSTRACT

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Single use plastics are plastic that only can be used once before being recycled or thrown away. The single plastic used has become a main problem for disposal. The aim of this study is to develop an eco-friendly construction bricks that incorporate single use plastic polyethylene terephthalate (PET) plastics as a solution to reduce the disposal issue. The bricks were prepared by using cement and sand with proportion of 4%, 8% and 12% of PET. The bricks were assessed for it compressive strength, water absorption and white precipitation. Carbon footprint was calculated for all the bricks. The results indicate that has highest compressive strength was conventional bricks (12.4 N/mm^2) followed by bricks that contain 5% of plastic (11.6 N/mm^2), 10% (5.96 N/mm^2) and 15% (2.98 N/mm^2). This is because plastic cannot bind well with other mixture in the bricks. Next, more water is absorbed with the increased of PET. Bricks with less plastic contain (4%) have the lowest percentage of water absorption which is 21.88% as compared 8% (25.14%) and 12% plastic (29.82%). Plastic does not intact well with the other mixture. The efflorescence test showed a positive result as all the bricks with PET does not have any white precipitation on the surface. Presence of white precipitation on the bricks would leads to serious problem because it can cause dry rot of woodwork, disintegration of masonry, decay and crumbling of plaster. The carbon footprint for the bricks reduced with the increased of PET. The result of compression strength, water absorption, efflorescence and carbon footprint was discussed and reviewed. It can be concluded that the compression strength are reduced and percentage water absorbed are increase, due to the incorporation of plastic waste into the brick mixture. However, efflorescence and carbon footprint showed a positive result.

Keyword: Polyethylene Terephthalate (PET), brick, Compressive strength, Water absorption test and Efflorescence test

ABSTRAK

PEMBUATAN BATU BATA MESRA ALAM DARI SISA PLASTIK POLIETILENA TEREFTALAT (PET) DAN PENGELUARAN KARBON

SITI SOFIA BINTI KAMAL AZAM

Plastik sekali guna adalah plastik yang hanya boleh digunakan sekali sebelum dikitar semula atau dibuang. Plastik tunggal yang digunakan telah menjadi masalah utama pembuangan. Tujuan kajian ini adalah untuk membina bata bata yang mesra alam yang menggabungkan sisa plastik polietilena terephthalate (PET) sebagai penyelesaian untuk mengurangkan masalah pembuangan. Batu bata disusun dengan menggunakan simen dan pasir dengan kadar PET 4%, 8% dan 12%. Batu bata dinilai untuk kekuatan mampatan, penyerapan air dan pemendakan putih. Jejak karbon dikira untuk semua batu bata. Hasil kajian menunjukkan bahawa kekuatan pemampatan tertinggi adalah batu bata konvensional (12.4 N / mm2) diikuti oleh batu bata yang mengandungi 5% plastik (11.6 N / mm2), 10% (5.96 N / mm2) dan 15% (2.98 N / mm2). Ini kerana plastik tidak dapat bergabung sebati dengan baik dengan campuran lain di batu bata .. Namun, lebih banyak air diserap dengan peningkatan PET. Batu bata dengan kurang plastik mengandungi (4%) mempunyai peratusan penyerapan air terendah iaitu 21.88% berbanding 8% (25.14%) dan 12% plastik (29.82%). Plastik tidak sebati dengan campuran lain. Uji efloresensi menunjukkan hasil yang positif kerana semua batu bata dengan PET tidak mempunyai pemendakan putih di permukaan. Kehadiran pemendakan putih pada batu bata akan menyebabkan masalah serius kerana boleh menyebabkan kayu kering reput, pecahnya batu, plaster akan mengalami kerosakan dan pecah. Jejak karbon untuk batu bata berkurang dengan peningkatan PET. Hasil kekuatan mampatan, penyerapan air, perbungaan dan jejak karbon dibincangkan dan dikaji. Dapat disimpulkan bahawa kekuatan mampatan dikurangkan dan peratusan air yang diserap meningkat, disebabkan oleh memasukkan sisa plastik ke dalam campuran bata. Walau bagaimanapun, ujian efloresensi dan jejak karbon menunjukkan hasil yang positif.

Kata kunci: Polietilena Tereftalat (Pet), batu bata, kekuatan mampatan, penyerapan air, pemendakan putih

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LIST OF ABBREVATIONS

PET	Polyethylene Terephthalate
SDG	Sustainable Development Goal
RICS	Royal Institution of Chartered Surveyors
HDPE	High-Density Polyethylene
LDPE	Low-Density Polyethylene
PP	Poly-propylene
PVC	Polyvinyl chloride
PS	Polystyrene
US EPA	United State Environmental Protection Agency
N	Newton

CHAPTER 1

INTRODUCTION

1.1 Background

Plastic waste generation has become big environmental issue that worries many developed and developing country. About 50% of plastics are produced into disposable single-use application which means they are only used once and is used in a short time. Some example of single used plastic waste is food packaging, plastic shopping bag and plastic bottles (Mwanza et al., 2018). The main reason why single used plastic bag become the main environmental issue is due to its characteristic that can take up to thousands of years to decompose, contaminating soil and water, and it also affecting animals on land as well as in the ocean as plastic waste can cause choking, entanglement hazards and entanglement hazards to the animal (Giacovelli, 2018). According to Malaysia Plastics Manufacturer Association (2011), data from 2008 to 2010, Malaysia produced 43% of the plastic production is for packaging, followed by electrical and electronic (26%), household (10%) automatic (11%) and others.

Packaging is the main source of waste plastics which is 43%, but it is clear that other sources such as electrical and electronic waste are becoming significant sources of waste plastics and are in fact extremely durable, and therefore the majority of polymers manufactured today will persist for at least decades, and probably for centuries if not millennia (Kamble & Karad, 2017).

There are multiple of attempt and idea by researchers to incorporate waste in construction materials to protect the environment and sustainable development (Zhang, 2013). Eco-friendly bricks are one of appropriate method to reduced plastic waste in the environment. The main idea of this eco-friendly bricks was incorporating plastic waste as one of the component in the bricks. The plastics that were used are generated by people. Moreover, construction industry are continuously growing day by day, therefore by incorporating plastic waste into construction material might play big role because it could help in reducing the usage of earth based materials (Kamble & Karad, 2017).

1.2 Problem Statement

According to Parker (2019), the production of single used plastic is rising very quickly and this has become major problem in the environment. This is because the amounts of plastic that are produce are way more than earth can handle. We can see African and developing Asian countries suffer from these plastic pollution the most due to plastic waste is not being properly managed. Even in Malaysia, the generation of plastic waste is about 18 000 per day and it is expected to rise up to 2% every year(Webb et al., 2013). Not all of the wasted are collected and disposed at the suitable place. It has been stated that only 5% of wastes generated at Kuala Lumpur are recycled, while others dumped to landfills (Jereme, Siwar & Alam, 2014). Gayer et al. (2017) stated that in 2015, 6400 metric tonnes of plastic waste being generated and only 9% of plastic waste has been recycled and the rest of it ends up in landfills or waterways or on the landscape in the world. Lack of plastic waste being recycled surely becoming big problems.

According to National Geographic (2018), it is quite hard to identify whether plastic waste affect human. There is possibility that the chemical such as phthalates can leach into the environment. Human can indirectly affected with it by the water we drink in the bottle, seafood that we consumed and clothes that we wear. This chemical are recognised as endocrine disruptor which it can disturb our normal hormone function. Other health problem that may cause by this chemical is birth defects, impaired immunity and cancer (Rustagi, Singh & Pradhan, 2011).

Every type of plastics that we used in our daily life has its own characteristics and composition (Wong, 2017). A total of 7 types of plastics can be recycled which include Polyethylene Terephthalate (PET or PETE or Polyester), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDPE), Polypropylene (PP) and Polystyrene (PS) (Merrington, 2007). Polyethylene terephthalate (PET) has a characteristics that are light, strong, have low gas permeability, chemically and thermally stable and it is also easily handled and processed (Chhazed et al.2019). That is why PET are commonly chosen by researcher to incorporate into construction materials (Tapkire, Patil, & Kumavat, 2014).

Webb et al., (2013)states that wildlife is deeply affected when this plastic wastes are not dispose correctly. Plastic waste can be carried away by river stream to the sea and causes the ocean to be heavily polluted with plastics. These could affect the ecosystem in the ocean. The chemical that are present in Polyethylene Terephthalate are Ethylene glycol which is a colourless liquid obtained from ethylene while dimethyl terephthalate is a crystalline solid obtained from xylene (Encyclopaedia Britannica, 2020).

Beside bricks, plastic waste can also be recycled to various of product such as shopping bag, t-shirts, sleeping bags, sweaters and carpet (Geyer, Jambeck, & Law, 2017). The production of conventional bricks requires the usage of environmental resources as the main material in bricks and it causes other problem which is environmental degradation. There are many parts in the earth where the natural source already deteriorates due to produce the conventional bricks. Environmental degradation is where the environment resources such as sand, clay and soil deteriorate due to the exploitation by human (Shakir & Mohammed, 2016). From the previous research it can be seen that there are multiple attempt to produce bricks from waste materials, however it is not commercialized and produced widely. Eco-friendly bricks are not well accepted by public and industry because they are not familiar with it (Zhang, 2013). A study conducted by Wahid, Rawi, & Desa, (2015) states that the addition of plastic reduce the amount of water absorb by the bricks and also the soluble salt content of the bricks are not affected by the addition of plastic waste.

There are multiple advantages of eco-friendly bricks. First of all, the production of the eco-friendly plastic bricks could help in reducing the amount of plastic waste in the environment and also prevents the contamination of the environment (Mwanza et al., 2018). Other than that, according to Antico (2017) the production of the bricks using waste material is cost effective because basically wastes are used as one of the component in the bricks. Eco-bricks are lighter than conventional bricks up to 40% due to the properties of plastics that is lightweight (Bhushaiah, Mohammad, & Rao, 2019). In tern of the benefit to the environment, the production of eco-bricks can make the air quality become better; this is due to less of plastics being burnt in incinerator. Carbon footprint also reduced, because of the used of plastic waste in bricks replacing metal. This is due to 5% of greenhouse gases comes from the production of conventional bricks (Kognole et al., 2019).

According to Zhang (2013), bricks that are produced contain high carbon footprint because cement or clay are burnt in high temperature.. Carbon footprint is defined as greenhouse gases or specifically carbon dioxide that is produced by manufacturing of a product, vehicles and human activities. That is why is important to quantify carbon footprint of the bricks so that the potential impact to the environment can be assessed (Kumbhar et al., 2014). However, there are limited studies found on the amount of carbon footprint released by eco-friendly construction bricks from polyethylene terephthalate (PET) plastic and how to reduce carbon footprint. Therefore, this study was designed to develop an eco-friendly construction bricks from polyethylene terephthalate (PET) plastic and the carbon footprint its produced.

1.2 Research Justification

This study aims **to** develop an eco-friendly construction bricks from PET plastic waste and to calculate its carbon footprint. Zhang (2013) stated that by recycling plastic waste by incorporating it in the bricks it could help in increasing the percentage of recycling in the world and also can become one of the effort to protect the environment and help to have a sustainable development.

According to Shakir and Muhammad (2016) , depletion of natural resources are cause by the exploitation of industry and human to produced bricks. Therefore, by incorporating plastic as the component in the bricks can help reduce the use of natural resources such as sand, clay and soil. Beside that plastic is one of the materials that can be work on easily. This is due to its properties that are lightweight and durable. Plastics is also can be easily obtained and it is also inexpensive (Hopewell, Dvorak, & Kosior, 2009).

Large manpower and high processing cost needed to do recycling of plastic, therefore most of the plastic waste end up in landfills and environment. Here author suggested the use of these plastic bags pieces in a concrete as a plastic fiber to improve the properties of concrete. Use of plastic has a dual advantage cost of material is low also it solve the problem of disposal of plastic up to some extent (M & Wardha, 2012). By incorporating plastic the bricks, it helps keeping plastic out of the ecosystem and prevents the contamination of the environment (Antico et al., 2017)

1.3 Conceptual Framework

Figure 1.4 shows the conceptual framework of this study. Municipal solid waste is divided by two which is inorganics and organic waste. There are 3 types of inorganic waste which are plastics, card board and paper. Plastics waste has been chosen for this study. The type of plastic waste that is used is Polyethylene Terephthalate (PET). The PET plastic waste is recycled as one of the component in the eco-friendly bricks. Three tests were carried out for the bricks which are compressive strength test, water absorption test and efflorescence test. From the bricks, environmental risk which is carbon footprint of the bricks will be assessed. This study can become the optimum method to achieve SDG 14 by reducing the plastic waste in the environment. The independent variable for this study is the eco-bricks while the dependant variable is compressive strength, water absorption and efflorescence test.

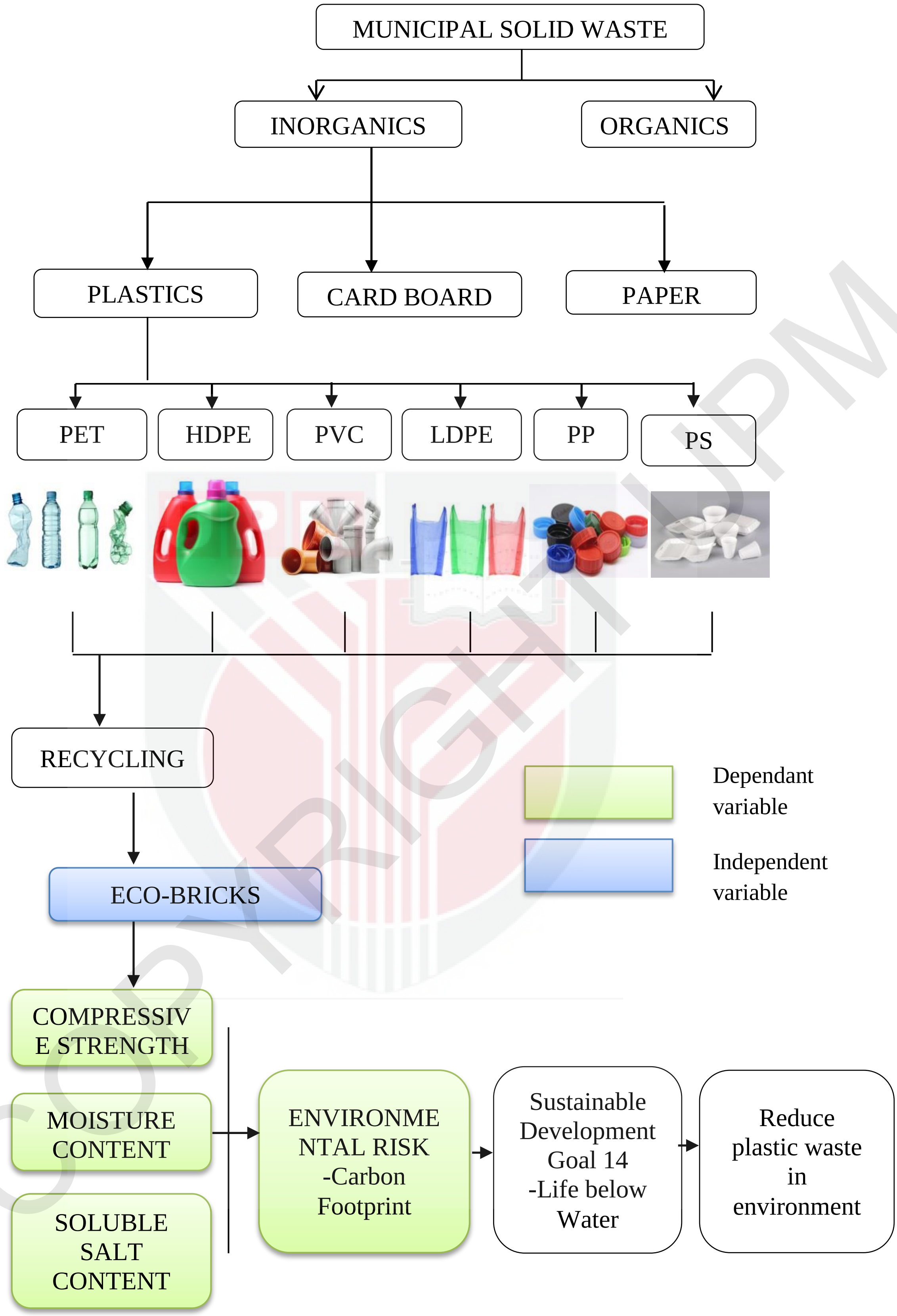

Figure 1.3: Conceptual Framework

1.4 RESEARCH QUESTION

1. What is the extent of compressive strength, water absorption, soluble salt content and carbon footprint of eco-friendly construction bricks with different proportion (4%, 8% and 12%) of PET plastic?

1.5 RESEARCH OBJECTIVE

<u>General objective:</u>

To develop an eco-friendly construction bricks from PET plastic waste and to calculate its carbon footprint.

<u>Specific objective:</u>

1. To develop eco-friendly construction bricks by using different percentage of plastic bottles waste as one of its component.
2. To compare the compressive strength, water absorption, and white precipitation of eco- friendly construction bricks with different percentage (4%, 8% and 12%) of PET plastic and conventional bricks.
3. To identify the relationship between the water absorption with percentage (4%, 8% and 12%) of PET plastic and conventional bricks in the eco- friendly construction bricks.

4. To calculate carbon footprint of the bricks using formula.

1.6 Research Hypotheses

1. There is significant difference of water absorption of eco- friendly construction bricks with different percentage (4%, 8% and 12%) and conventional bricks..
2. There is a significant relationship between the water absorption with proportion (4%, 8% and 12%) of PET plastic with conventional bricks.

1.7.1 Conceptual Definition

i. Eco-friendly

Eco-friendly means earth-friendly or to have little harm or does not cause harm to the environment (Cambridge Dictionary, 2020)

ii. Brick

A brick is a material that is used in the construction of building. Typically used to make pavements, walls and other element in masonry construction (Merriam-Webster, 2020)

iii. Polyethylene terephthalate (PET) plastic

Semi-crystalline polymer, Polyethylene terephthalate (PET) is a type of plastic used widely as packaging material for drinking water. This is due to its characteristics that light and strong (Webb et al., 2013).

iv. Recycling

Recycling is the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products (United States Environment Protection Agency, 2017)

v. Carbon footprint

A carbon footprint also known as embodied carbon is historically defined as the total greenhouse gas emissions that are produced directly or indirectly that are caused by human activities, or product, and typically expressed as carbon dioxide equivalent (Jiménez, Domínguez, & Vega-Azamar, 2018)

1.7.2 Operational Definition

i. Eco-friendly

Usually refers to product that will help in reducing the usage of resources for example water and energy which then will contribute to green practices or living.

ii. Bricks

Bricks can be made from various types of material such as soil, cement, clay and sand. There are also many bricks ratio can be used depending on the usage of the bricks.

iii. **Polyethylene terephthalate (PET) plastic**

This is one type of plastic that can be recycled. It is commonly used for food packaging and beverages packaging such as mineral water bottles.

iv. Recycling

It is an operation whereby reprocessing waste materials into something that useful whether in its original form or other purposes.

v. Carbon footprint

Carbon footprint or embodied carbon can be calculated from cradle-to-gate, cradle-to-site, and cradle-to-end of construction, cradle-to-grave, or even cradle-to- cradle. Various formula are established to calculate carbon footprint and it is commonly expressed in kilograms of CO_2e per kilogram of product or material (Jiménez et al., 2018).

CHAPTER 2

LITERATURE REVIEW

2.1 Plastic

Plastics are human made materials that are being used on daily basis. Plastic can be moulded into any objects because they consist of materials that are pliable which is wide range of synthetic or semi-synthetic organic compounds (Geyer et al., 2017). There are multiple of different plastics has been invented to fill human everyday needs. . Plastic is a synthetic polymeric material that has a high molecular weight. Organic compounds that are used to make plastic include vinyl chloride, vinyl acetate, ethylene, vinyl alcohol and many more (Ilyas et al., 2018). Due to its properties that is lightweight, cheap, strong, durable, thermal and electrical insulation, design capability, resistant toward corrosion and can be moulded into various type of product make plastic become the best choice for wide application (Thompson et al., 2009).

Each of the plastics has its own composition and characteristics (Wong, 2017). Hopewell et al. (2009) states that only 7 types of plastic can be recycle which are Polyethylene Terephthalate (PET or PETE or Polyester) labelled as number 1 which is plastic that are clear and tough and mostly used for drink and food packaging, High-Density Polyethylene (HDPE) labelled as number 2 is a common and white plastic usually used as the grocery bag, opaque milk, juice container, shampoo bottles, and medicine bottle, Polyvinyl Chloride (PVC) labelled as number 3 label as is a high rigid clear plastic and it is used in toys, blister wrap, cling wrap, detergent bottles, loose-leaf binders, blood bags and medical tubing, Low-Density Polyethylene (LDPE) labelled as number 4 is a soft and flexible plastics widely used for bags (grocery, dry cleaning, bread, frozen food bags, newspapers, garbage), plastic wraps; coatings for paper milk cartons and hot & cold beverage cups; some squeezable bottles (honey, mustard), food storage containers, container lids , Polypropylene (PP) labelled as number 5 is a flexible but hard plastic and typically used in hot food containers like thermos, Polystyrene (PS) labelled as number 6 is a brittle and rigid plastic food containers, egg cartons, disposable cups and bowls, packaging, and also bike helmet and other plastic is for all other plastics beside number 1-6 and also plastics that are probably layered or mixed with other types of plastics, for examples bioplastics are labelled as 7.

Table 2.1: Type of plastic that can be recycled

Symbol	Common uses	Properties	Example
	Packaging for drink and food	Lightweight, durable and clear	 Figure 2.1.1 [Polyethylene plastic bottle](2019). Retrieved from https://waste4change.com/7-types-plastic-need-know/
	Packaging for detergent bottle, opaque milk and medicine bottle.	Tough and stiff	 Figure 2.1.2 [Detergent bottle](2017). Retrieved from https://www.recyclingtoday.com/article/starlinger-
	Toys and blood bag, plastic piping	Can either be rigid of soft depend on the amount of plasticizers added	 Figure 2.1.3 [PVC piping] (2018). Retrieved from https://omnexus.specialchem.com/selection-guide/polyvinyl-chloride-

4 LDPE	Plastic bag and plastic wrap	Cheap, versatile and lightweight	 Figure 2.1.4 [Plastic bag](2019). Retrieved from https://waste4change.com/7-types-plastic-need-know/
5 PP	Hot food container (thermos), bottle lit	Effective barrier towards water, durable and resistant	 Figure 2.1.5 [Bottle cap] (2018). Retrieved from https://www.kempner.co.uk/2019/04/16/advantages-and-disadvantages-of-polypropylene-blog/
6 PS	Egg cartons, disposable cups and bowls, packaging	Easily disperse, lightweight and weak Structure	 Figure 2.1.6 [Polystyrene food container](2019). Retrieved from https://waste4change.com/7-types-plastic-need-know/
7 O	Water cooler bottles and fiberglass	Has various properties	 Figure 2.1.7 [Water dispenser bottle](2019). Retrieved from sswaterdispenser.com/wp/prod

2.1.1 Single used plastic

According to Giacovelli (2018), single-use plastics or usually called disposable plastics are things that only can be used once before we recycle or throw it away and single used plastics are used mainly as packaging. Example of single used plastic that we always used includes food packaging, grocery bags, straws, plastic bottles, cups, container and cutlery. In a study conducted by Geyer et al. (2017), the entire population of the word produces more than 400 million tonnes of plastics every single year and most of it comes from packaging. Based on the report, 47% from the total plastic waste comes from plastic packaging which half of it comes from Asia. Report released by United Nation Environment Programme (2018) state that, there are 9 billion tons of single used plastic have been created. However, only 9% of that plastic are being recycled and 12% has been incinerated and the rest of which is 79% of plastic waste end up in dumps, landfills or even worst in the environment.

2.1.3 Effect of Plastic on Environment

Non-biodegradable waste such as plastic waste generated from water bottles has become a main problem for disposal (New Straits Time, 2018). This leads to plastic pollution in environment and it causes of multiple hazardous and ecologically damaging effects. In 2008, 34 million tons of plastic was disposed in the United

States. Of this, 86% ended up in landfills. However, “disposal of plastics in landfills is ultimately unsustainable and diminishes land resources fit for other uses of higher societal value. Pollutants released from burning plastic waste in a burn barrel are transported through the air either short or long distances and are then deposited onto land or into bodies of water. A few of these pollutants such as mercury, PCBs, dioxins and furans persist for long periods of time in the environment and have a tendency to bio- accumulate, which means they build up in predators at the top of the food web.

2.1.4 Effect of plastic waste on Greenhouse Gas Emission

According to World Wildlife Protection (2019), most of plastics that produced today are derive from materials such as propylene and ethylene and this material usually come from fossil fuels that are mostly oil and gas. The process of extracting and transporting those fuels, then manufacturing plastic creates billions of tonnes of greenhouse gases. For instance, 4% of the world's annual petroleum produced is used to make plastic while another 4% gets burned in the refining process. According to report released by Centre for International Environmental Law (CIEL) (2019), the extraction and the transportation of these fossil fuels release a lot of carbon dioxide and it is estimated that in United Stated 12.5 to 13.5 million metric tons carbon dioxide released per year from this activity. Other than that, incinerating process of plastic waste also contribute to the release of greenhouse gases. Incinerating plastic waste causes the released of carbon dioxide (CO_2), air borne particulates, methane (CH_4) and nitrous oxide (N_2O). Besides that, incinerator also releases carcinogenic polycyclic aromatic hydrocarbon (PAHs) and dioxins (Proshad, et al., 2018).

2.1.5 Effect of plastic waste on life in water

This plastic waste that not been dispose correctly will possess bad effect to wildlife (Webb et al., 2013). Rivers carry plastic waste from deep inland to the sea, making them major contributors to ocean pollution. Those animals that live in the ocean are most affected by this plastic pollution. According to World Animal Protection (2017), marine species that are mostly affected by this pollution includes fish, whales, dolphins, sea turtles, seals and seabirds. Most of the plastic wastes never completely disappear; only the sizes of these plastic waste getting smaller that causes these marine species mistaken plastic waste as food; therefore these plastics may cause choking and also enter their digestive system and causes death. They also stated that in 2014, there were about 15 to 51 trillion microplastic particles were floating in the world's oceans and the weight are about 93,000 to 236,000 tonnes. No matter where the plastic waste ended up whether in an ocean, on land, or a river can stays in the environment for 100 years or more (UN Environment, 2020).

2.1.6 Effect of plastic on human health

The usage of plastic is the most preferable in industries. However, it can affect human health either directly or indirectly. National Geographic (2018) through its article entitled “We Know Plastic Is Harming Marine Life. What About Us?” states that it is quite hard to identify whether plastic waste affect human. However, there is possibility that the chemical such as phthalates can leach into the environment. Human are usually exposed to harmful chemical during manufacturing, sometime the chemicals leach into the food that are pack using plastic or water we drink in the bottle, seafood that we consumed and clothes that we wear. There many health effects that could be cause from the chemical of the plastics. This includes birth defects, impaired immunity, cancer, endocrine disruption and many more (Rustagi, Singh & Pradhan, 2011). There are many chemical that present in plastic which are bisphenol A (BPA), phthalates, antiminitroxide, brominated flame retardants, and poly-fluorinated (Halden 2010). However, there are two chemical that are commonly used and popular in plastic industry which are bisphenol A and phthalates. The substance or chemical that are harmful to human named phthalates or phthalate esters are esters of phthalic acid. The substance commonly used as plasticizers to increase the flexibility of plastic (Kumar, 2018). Phthalates can enter human body by ingesting material that are contaminated with it. This include contaminated food, food that have come contact with plastic food packaging (Halden, 2010). Other than that, the other chemical that can affect human health is BPA. Bisphenol A (BPA) are usually used as polycarbonate plastics monomer building block. Besides that, BPA are also commonly used as an additive to plastic (Verma et al., 2016). BPA molecules can leach from food and beverage container into food and drink overtime if the container are repeatedly washes or when the container are stored in acidic or basic condition (Proshad et al.,2018). Both BPA and phthalates can cause birth defects because it can enter newborn body through pregnancy, through fetal and also by breastfeeding. According to Halden (2010), it is crucial to remember that all kind of plastics container contain BPA and phthalates.

2.2 Polyethylene Terephthalate

2.2.1 Properties

Semi-crystalline polymer, Polyethylene terephthalate (PET) is a type of plastic used widely as packaging material for drinking water. This is due to its characteristics that light, strong, have low gas permeability, chemically and thermally stable and it is also easily handled and processed (Webb et al., 2013)). Atoms that are presence in Polyethylene Terephthalate (PET) are only Carbon, oxygen and hydrogen. When PET plastic being burn, it will generates water and carbon dioxide. Thus, there will be no emission of harmful gas (Maneeth et al., 2014)

2.2.2 Chemical structure

Condensation reaction between dimethyl terephthalate and ethylene glycol form PET (Smith, Inomata & Peters, 2013). Ethylene glycol is a colourless liquid obtained from ethylene while dimethyl terephthalate is a crystalline solid obtained from xylene (Encyclopaedia Britannica, 2020). For each ethylene-terephthalate monomer unit added to the polymer, one mole of methanol is as by-product. The only atomic species present in PET are therefore hydrogen, oxygen, and carbon.

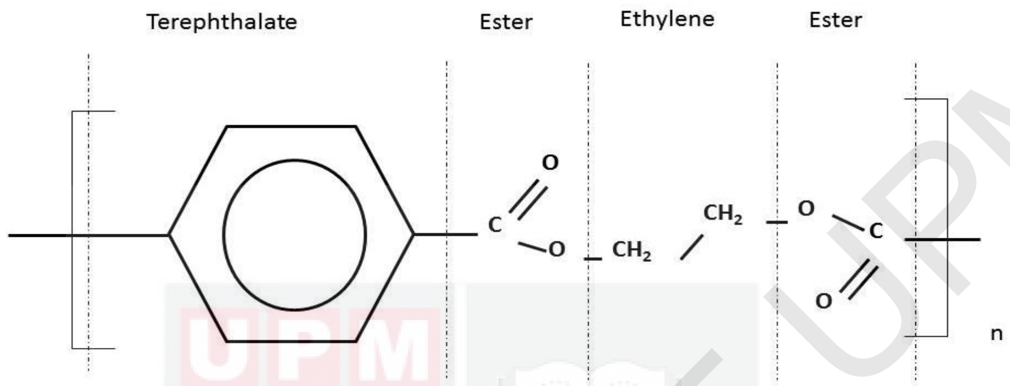

Figure 2.2: Chemical Structure of Polyethylene Terephthalate

Table 2.2 Physical properties of PET

Coefficient of Thermal Expansion	7×10^{-3} / °C
Long Term Service Temperature	115 -170 °C
Melting point	260 °C
Specific Gravity	1.3 – 1.4
Water Absorption	0.07 – 0.10%

2.3 Recycling of plastic waste

Recycling is where waste materials are collected and processed to become useful things or product (US EPA, 2020). Plastics waste are also recycled to products that are completely different from their original state (Merrington, 2007). Plastic wastes can be recycled in multiples of ways depending on the types of plastics (Hopewell et al., 2009). There are many products that are made from recycled plastics such as shopping bag, t-shirts, sleeping bags, sweaters and carpet (Geyer et al., 2017).

Nowadays the uses of eco-friendly and low cost construction materials are became well known. It can be seen as many studies have been conducted to use various types of wastes as one of the component or material in building industry. The attempts to incorporate wastes in building materials are made to recycle the wastes that would end up in the environment. By recycling, the amount of plastic waste in the environment can be reduce and the plastic waste could be put in good use (Wahid et al., 2015).

2.4 Bricks

A brick is a material that is used in the construction of building and it is typically used to make pavements, walls and other element in masonry construction (Merriam-Webster, 2020). Brick is a masonry units can be either hollow or solid. This masonry unit are made of with multiple type of material. The examples of bricks that are used in constructions such as blocks of stone, pressed earth bricks, clay bricks, calcium silicate bricks, soft mud bricks and concrete blocks (Thaickavil & Thomas, 2018). Types of raw materials that are commonly used to produce bricks include sand, cement, granite, fly ash and clay. The usage of materials also depends on the type of construction that the bricks will be used (Naji, Mousa, & Alameedi, 2019). Different types of bricks are used in different type of construction and it also based on location whether exterior or interior.

2.4.1 Eco-friendly bricks

Brick is an important material in construction because of its strong and durable characteristics. There are multiple attempts by researchers to make bricks as sustainable construction materials for example by incorporating waste as one of the component in the bricks (Wahid et al., 2015). Plastic waste, cigarette butts, coal combustion residues, wood sawdust and limestone powder, industrial wastewater treatment plant, rice husk ash were wastes that have been used as one of the component in eco-friendly construction bricks (Zhang, 2013). A study conducted by Arora & V. Dave (2013) have attempted to produce eco-friendly and cheap bricks production by grinding plastic and e waste and mixed them with the concrete mixture.

2.4.2 Bricks ratio

Three main materials of brick including cement, aggregates either course or fine and sand. A study conducted by Wahid, Rawi & Desa (2015) stated that the addition of plastic fibre into the raw material in the production of bricks should be

0% to 15%. As the result of the research showed that the compressive strength of the bricks will decrease when the composition of plastic fibre increased. There are various ratios and types of materials can be used to make bricks. It is depending on the usage and the purpose of the bricks. There are many types of fine and course aggregates can be used to make bricks. Materials that are commonly used for bricks are cement, sand, gravel and water (Machado, Lima, & Roberto, 2012) . Table 2.4.2 shows the material that used for the bricks and the percentage of plastic by other researcher.

Table 2.4.2: Bricks material and plastic percentage

No.	Author	Plastic Ratio	Result summary
1.	Wahid, Rawi, & Desa	• Sand: 9% • sand dust: 9% • cement: 4% (9:9:4) • plastic waste: 0%, 5%, 10%, 15%	• In term of strength the strength of the bricks decreases as the number of plastic waste increase. • For water absorption, the addition of plastic waste seems possible because water absorption is lower than 15% for all ratios. • The usage of brick is only suitable for low degree workability such as canal lining and so forth.

2.	Azmi et al. (2018)	• Sand: 1% • cement: 4% (1:4) • Plastic waste: 1%, 1.5%, 2% and 2.5 %	• The compressive strength of the bricks increases when 1% of plastic waste added. However, the compressive strength decreases when plastic waste are added more than 1%. • Water absorption of the bricks increase as the amount of plastic waste increase.
3.	Maneeth et al. (2014)	• Soil laterite • plastic • bitumen (This paper does not show the exact ratio of other materials) • Plastic waste: 65%, 70%, 75% and 80%	• In this study, it stated that the strength of bricks was depending on how much plastic waste added to mix. From this study, it also has shown that the compressive strength of the bricks decreases when the amount of plastic added more than 70%. • In water absorption test, the more plastic waste added, the lesser the amount of water absorbed • As a conclusion, the usage of plastic waste as one of the component of the bricks is

			effective.
4.	Foti (2013)	• Concrete Portland • Aggregate • superplasticizer, • water (This paper does not show the exact ratio of other materials) • PET plastic waste: 0.5%,	• The results shows the addition of plastics aggregate reduced the compressive strength of the bricks.
5.	Mathew et al., (2013)	20% Plastic course aggregate	• Plastic course aggregate was compared with natural course aggregate. It was shown that concrete that has 20% of plastic course aggregate has higher compressive strength.
6.	Zega, Antonio, & Maio (2011)	• Water • Cement • River siliceous sand	• As a general conclusion of these studies, it is possible to indicate that concretes made with up to 30% of recycled fine aggregate present an

		• Stone (This paper does not show the exact ratio of other materials) • Recycled fine aggregate: 20%, 30%	adequate mechanical and especially durable behav- iour, because they verify the requirements imposed by different codes for structural concretes.
7.	Youcef et al., (2009)	• Cement • Water • Sand • Gravel (This paper does not show the exact ratio of other materials) • Plastic bag waste: 10%, 20% , 20% and 40%)	• The mechanical resistance of the concrete reduced as the amount of PBW increased. However, PBW can still be used to replace conventional aggregate in concrete because it has acceptable strength properties.
8.	Shikhar, (2017)	• PET plastic waste: 5kg , 10kg, 15kg	• This study does not used other aggregate as its component. Only plastic waste used as whole bricks. More PET waste used the higher

			the compressive strength of the bricks. • It shows that the usage of plastic in this study helps people in rural and coastal region and it helps reducing the amount of plastic in environment.
9.	Tapkire, Patil, & Kumavat, (2014)	• Cement • Sand (This paper does not show the exact ratio of other materials) • PET plastic: 10% , 20% 30%	• Addition of plastic will reduced the weight of plastic up to 15% but addition of plastic will decrease the strength of concrete.
10.	Anumol & John (2015)	• Cement • Course aggregate • Fine aggregate (This paper does not show the exact ratio of other materials)	• The strength values of plastic concrete mixer tend to decrease with the addition of greater percentages of plastic aggregates.

		• Plastic waste: 10% 15% , 20%, 25%	
11.	Irwan et al., (2014)	• Cement • Fly ash • Fine aggregate • Course aggregate • Water • Super plasticizer (This paper does not show the exact ratio of other materials) • PET plastic waste: 25%, 50%, 75%	• The replacement of natural fine aggregate with PET aggregate reduces the mechanical properties that influence the performance of structural concrete in resisting shear stresses.
12.	Ge et al. (2013)	• Natural river sand • Limestone powder as mineral filler. (This paper does not show the exact ratio of other materials)	• The study showed encouraging results and established a new alternative for recycling waste PET bottles in a simple and effective way

		• sand-to-PET ratio used: in the mixture was : 1:1, 2:1, 3:1, and 4:1.	
13.	Bae et al. (2010)	• Cement • fly ash • gravel (This paper does not show the exact ratio of other materials) • PET plastic: 0.5%, 0.75% and 1.0% fiber volume fractions.	• From the material property tests, recycled PET fiber rein- forced concrete exhibited a slight decrease in compressive strength and elastic modulus as the fiber volume fraction increased. • The recycled PET and PP fiber-reinforced speci- mens showed compressive strength decreases of 1–9% and 1–10%, respectively, compared to specimens without fiber reinforcement.
14.	Bhushaiah, Mohammad, & Rao (2019)	• cement • fly ash • sand • water (This paper does not show the exact ratio of other	• The plastic bricks have a good performance in term of compressive strength and water absorption. Thus, plastic sand bricks can be useful in construction.

<table>
<tr><td></td><td></td><td>materials)
Plastic waste:
5%, 10%, 15% and 20 %</td><td></td></tr>
<tr><td>15.</td><td>Hiremath, G, & Prathima (2014)</td><td>Gravel-10%
Sand-83%
Silt & Clay - 7%
<table><tr><th>Bitumen</th><th>Plastic</th></tr><tr><td>0%</td><td>70%</td></tr><tr><td>2%</td><td>70%</td></tr><tr><td>5%</td><td>70%</td></tr><tr><td>10%</td><td>70%</td></tr></table></td><td>Bitumen was added to act as a binder of plastic component and other material.
It is showed that the higher percentage of binder (bitumen), the compressive test of bricks increases. However, further increase binder up to 10% the compressive test strength will reduced.</td></tr>
<tr><td>16.</td><td>Naji, Mousa, & Alameedi (2019)</td><td>Cement
Fine aggregate
Course aggregate
(This paper does not show the exact ratio of other materials)
Propylene 0%
2.5%</td><td>The addition of more plastic into the plastic bricks mix decrease the compressive strength of the bricks.</td></tr>
</table>

<table>
<tr><td></td><td></td><td>5.0%
7.5%</td><td></td></tr>
<tr><td>17.</td><td>Miruthula et al. (2016)</td><td>Soil
Cement
(This paper does not show the exact ratio of other materials)<table><tr><th>Plastic</th><th>Bitumen</th></tr><tr><td>50%</td><td rowspan="5">2%</td></tr><tr><td>60%</td></tr><tr><td>70%</td></tr><tr><td>75%</td></tr><tr><td>80%</td></tr></table></td><td>The result obtained shows that the brick that contain 2% bitumen and 60% plastic has the best outcome among all.</td></tr>
</table>

18.	Arora & V. Dave (2013)	• Sand • Cement (This paper does not show the exact ratio of other materials) • Plastic: 2% and 4%	• The addition of plastic waste causing the compressive strength of the brick to reduced
19.	Chauhan (2014)	• Cement • Course aggregate • Fine aggregate • Plastic fibre	• From the result, it can be observed that there was reduction in term of compressive strength when plastics waste was added. • It may be because of the presence of plastics in the mix that may interrupt the binding of cement and other aggregates
20.	Rahmani et al.(2013)	• Cement • Water • Gravel • Sand (This paper does not show	• Increasing the amount of PET waste up to 15% will decrease compressive strength of the bricks

		the exact ratio of other materials) • PET: 0%, 5%, 10% 15%	

2.4.3 Mechanical strength of bricks

2.4.4 Tests for bricks

There are few tests that are commonly done by most researchers to evaluate the properties of the bricks which are compressive strength test and water absorption (Zhang, 2013). To know how the condition of the bricks being compressed, Compressive strength test is being done. The response or behaviour of the bricks under crushing loads was able to identify by doing this test (Chee, Chee and Wai, 2017).

The durability of the bricks can also be determined by water absorption test. The purpose of the test is to identify the percentage of water absorption of the bricks. The percentage of the bricks should not exceed 20% of its total weight. The higher the percentage of water absorption, the greater the amount of water that the bricks absorbed. It shows that if the bricks absorbed more water, that means it has high number of pores in the bricks (Thaickavil & Thomas, 2018). High number of pores will decrease the bricks durability. This test also determines the compactness of the bricks (Mishra, 2009).

Other test that is conducted to determine the quality of bricks is Efflorescence test. This test is where the bricks are immersed in distilled water for 24 hours to find out the presence of soluble salt. It detects the presence of soluble salts when there are presence of white or grey deposit on the bricks when there is presence of efflorescence on the bricks it would leads to serious problem because it can cause various problem such as dry rot of woodwork, unhygienic conditions, , disintegration of masonry, decay and crumbling of plaster (Kumar & Hooda, 2018).

Table 2.4.2: Laboratory Testing for Bricks Performance

Tests	Objective	How it being tested	References
Compressive test	To measure the maximum compressive load that a bricks can bear before fracturing.	The bricks are placed between the platens of compressive test machine and load is gradually applied until it breaks.	• Wahid et al., 2015 • Zhang, 2013 • Maneeth et al., 2014 • Bhushaiah et al., 2019 • Ge et al., 2013 • Chauhan, 2014 • Irwan et al., 2014 • Taaffe, Sullivan, Ekhlasur, & Pakrashi, 2014 • Atis, 2010 • Rahmani, Dehestani, Beygi, Allahyari, &

			Nikbin, 2013 • Carlos, Galvão, Franke, Joukoski, & Mendes, 2011 • Frigione, 2010 • Khalid et al., 2018
Water absorption test	To identify the amount of water absorbed by the bricks,	Bricks are immersed in water completely for 24 hours. The weight before and water immersion are recorded.	• Wahid et al., 2015 • Zhang, 2013 • Maneeth et al., 2014 • Bhushaiah et al., 2019 • Atis, 2010 • Khalid et al., 2018
Efflorescence test	It detects the presence of soluble salts when there are presence of white or grey deposit on	Bricks are placed in water bath for 24 hours and then dry it in shade. The surface of the	• Wahid et al., 2015 • Bhushaiah et al., 2019

	the bricks when there is presence of efflorescence	bricks is observed to detect the presence of white precipitation.	

2.5 Advantages of eco-friendly bricks

There are multiple advantages of eco-friendly bricks. First of all, the production of the eco-friendly plastic bricks could help in reducing the amount of plastic waste in the environment and also prevents the contamination of the environment (Mwanza et al., 2018). Other than that, according to Antico (2017) the production of the bricks using waste material is cost effective because basically wastes are used as one of the component in the bricks. Eco-bricks are lighter than conventional bricks up to 40% due to the properties of plastics that is lightweight (Bhushaiah et al., 2019). The advantages of lightweight bricks are the bricks will not overload the structure of the buildings because heavy bricks will make it harder to stack the bricks, adding the floor and improve the building. This is due to the addition of more bricks that are heavy will increase the possibilities of the structure to break. In term of the benefit to the environment, the production of eco-bricks can make the air quality become better; this is due to less of plastics being burnt in incinerator. Carbon footprint also reduced, because of the used of plastic waste in bricks replacing metal. This is due to 5% of greenhouse gases comes from the production of conventional bricks (Kognole et al., 2019).

2.6 Sustainable Development Goals

On the other hand, according to World Health Organization (WHO) (2019), the sustainable development goal 14 (SDG 14), Live below Water was established to sustainably manage and protect marine and coastal ecosystems from pollution**.** The goals have been introduced to be implemented by several countries. There is one goal in this SDG that relates to plastic pollution which is goal 1. This goals aim to reduce and prevent all kind of marine pollution and this includes plastic pollution. This goal is plan to achieve by 2025. In this study, plastic bottle wastes are used as one of the component in the bricks. Therefore, the use of waste plastic bottles for the production of bricks can become optimal method to solve the environmental problem related to plastic. By including plastic waste into the bricks by adding or replacing the bricks ingredient could became appropriate way to dispose it (Chauhan, 2014).

2.6 Carbon footprint

Zhang (2013) states that bricks that are produced from cement or clay are burnt in high temperature, therefore, it contain high carbon footprint. Carbon footprint is defined as greenhouse gases or specifically carbon dioxide that is produced by manufacturing of a product, vehicles and human activities. Carbon dioxide is one of the greenhouse gases and it is the major contributor of the emission. It is stated that carbon dioxide emits three-quarters of greenhouse gas (National Geographic, 2019). Carbon dioxide can accumulate a lot faster in the environment and this this accumulation happens quickly before the natural phenomena can take them away. Various environmental issues can arise due to overabundance of carbon dioxide trapped in the atmosphere. The increase of carbon dioxide concentration causes temperature rise. This temperature rise causes the ice melts into the ocean quickly and this can lead to rising of sea levels. Because of that, some island could be submerged and there are possibilities large coastal cities around the world be submerged (Ekwurzel, Boneham, & Dalton, 2017). That is why is important to quantify carbon footprint of the bricks so that the potential impact to the environment can be assessed (Kumbhar et al., 2014). To assess the effects of production and the uses of concrete, carbon footprint are commonly used to represent the amount of carbon dioxide that are released or associated with the concrete (Jiménez et al., 2018).

CHAPTER 3

METHODOLOGY

3.1 Study Design

This study is an experimental study. Plastic bottles wastes are collected from Kolej 17, Universiti Putra Malaysia students. Types of plastic bottles are PET, 1.5 litre bottles.

Figure 3.1 PET plastic bottle wastes

3.2 Plastic bottles waste preparation

Plastic bottles (1.5 litre) wastes were collected from College 17, Universiti Putra Malaysia students. The cap of the bottles and plastics sleeves was removed because the cap and the sleeves were made of different type of plastics (figure 3.2.1). After that, plastic bottles waste was then cut into smaller pieces using scissors. The steps are shown in figure 3.2.2.

Figure 3.2.1: Caps and sleeves were removed

Figure 3.2.2: Plastics bottles were cut into smaller pieces

3.3 Eco friendly bricks preparation

For the brick preparation, the ratio that was used for this eco-friendly construction bricks was 1:6, whereby 1 part of cement (Ordinary Portland Cement) (figure 3.3.2) and 6 part of sand. The sand that was used is fine sand (river sand) (figure 3.3.1) Water (tap water) cement ratio that was used is 0.55.

Figure 3.3.1: River sand

Figure 3.3.2: YTL cement

After that, the raw material which is cement and sand was weighed using electronic weighing scale. Next, 200g of cement and 1200g of sand were mixed using spatula. The plastics materials (4%, 8% and 12%) then were weighed and were mixed together with the raw materials. According to Wahid, Rawi & Desa (2015), the amount of plastic waste added should not exceed 15% because the addition of plastics more that 15% can reduced the compressive strength of the bricks. After that, 165 ml of water was added into the mixture. The mixtures are mixed for about 5 to 10 minutes. Finally, the mixture was put into the mould to form bricks. The process of mixing was not exceeding 1 hour because the longer time will cause the mixture to harden.

3.4 Compressive test

This test was done to identify the compressive stregth of the bricks. This method was adapted from British Standard 5628: Part 1: 1992.Three bricks of each composition of plastics (4%, 8%, 12%) and concrete bricks are taken to the to be tested. Each of the bricks were tested one by one. Basically, the crushing machine applied pressure to the bricks until it breaks and the highest pressure where the bricks is crushed were recorded. Three bricks of each plastic composition were tested one by one and the average result were taken as the bricks compressive strength. Figure 3.4 shows on how te bricks is tested.

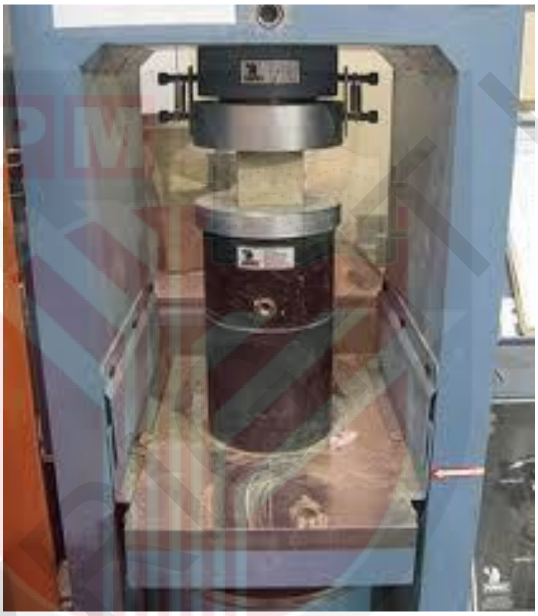

Figure 3.4 [Compressive strenght test](2019). Retrieved from

http://www.civilengineeringforum.me/compressive-strength-test-of-concrete/

3.5 Water Absorption test

This tests are conducted to know the compactness of the bricks as well as the durability of the bricks. Generally, the bricks are immersed in water for 24 hours. The bricks are weighed before and after the immersion. The difference of weight before and after the immersion is the calculated. The weight recorded was then put into a formula to calculate the percentange of water absorption. The bricks is consider good quality when there are less water absorbed by it. Bricks that have good quality only absorbed less than 20% of its total weight and if its absorbed more than that the quality will deterioerate The less water absorbed by brick the greater its quality. The procedure of this test is shown in Figure 4. This method was adapted from British Standard Testing concrete Part 122 (1983) (Wahid et al., 2015)

Figure 3.5.1: [Bricks was immersed in water] (Wahid et al., 2015)

Figure 3.5.1: [Bricks was weighed after 24 hours of immersion in water] (Wahid et al., 2015)

All the bricks that will be tested were dried out in ventilated oven (105^{o}C to 115^{o}C) to attained its contant mass. After the bricks were taken out from the oven, it was allowed to cool at room temperature to obtained its weight (M1). Next, the dried bricks was fully immersed in water (tap water) for 24 hours. Then it was removed from the water and any excess of water are wiped out. The weigh of the bricks is recorded (M2). The percentage of water absorption is calculated using equation below:

$$W = \frac{M2 - M1}{100}$$

3.6 Efflorescence test (white precipitation)

This test was carried out to identify the presence of alkali in the bricks. For this test, bricks were immersed in distilled water for 24 hours. After 24 hours, the bricks were taken out to dry. If there is presence of white precipitation on the surface of the bricks, it shows the presence of alkali the bricks. The white precipitation on the surface of the bricks should be about 10% to be acceptable. If more than that, the bricks are affevted by the presence of alkali and it is not good to use for construction. This method was adapted from ASTM C67 / C67M-20, Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile. The detail of the procedure is shown with the figure below.

Figure 1.6.1: The brick was marked to 2.5 cm

Figure 3.6.2: Distilled water was put until it reached the mark

Firstly, all the bricks that need to be tested was measured for 25 mm which is half of the size of the bricks, because on partial of the bricks are immersed. Second step was, the bricks was put in a basin (porcelain) individually and the depth of immersion in water was 25 mm. Thirdly, the basin are placed in well ventilated room until all the water is absorbed by the bricks.The basin are covered using suitable cover to prevent excessive evaporation. After all the water in the basin are fully absorbed by the bricks and bricks appear to be dry, first until third step are repeated. The bricks are all observed to examine the efflorescene after two times of evaporation.The results are reported as below:

Table 3.6: Efflorescence test label

NIL	When there is not perceptible deposit of efflorescence
SLIGHT	Not more than 10% area of the brick covered with a thin deposit of salt.
MODERATE	Covering up to 50% area of the brick. -HEAVY-Covering 50% or more but unaccompanied by powdering or flacking of the brick surface.
SERIOUS	When there is a heavy deposit of salts accompanied by powdering and/or flacking of the exposed

3.7 Statistical Analysis

The software used in this study is from Statistical Package for Social Science (SPSS). All the obtained data from the samplings are analyse with SPSS. The statistical test that were used for this study Kruskall-Wallis for comparison of Different Ratio of Plastic Waste and Conventional bricks on Water Absorption Test and Spearman's Correlation for The relationship between water absorption and bricks with proportion (0%, 4%, 8% and 12%) of PET plastic.

3.8 Carbon footprint of the bricks

Embodied carbon are calculated for bricks with proportion of plastics (4%, 8%, 12%). This equation and method are adapted from Royal Institution of Chartered Surveyors (RICS), Methodology to calculate embodied carbon. The bricks are being weighed individually in kg (M) (Lockie & Berebecki, 2014). Firstly, all the bricks were weighed using electronic scale. Next, the weight of the bricks in kg was inseted into the equation to calculate the weight of constituent material. Equation used as below:

Equation 3.8.1: Constituent material Calculation

Bricks: Quantity of bricks (nr) × M (kg) = Mass per m^2

After that, the embodied carbon factor are applied into the equation.

Equation 3.8.2: Embodied Carbon Calculation

Bricks: Mass (kg) × Embodied carbon factor (CO_2/kg) = Embodied carbon (kgCO_2)

*Embodied carbon factor (CO_2/kg) = 0.5512 CO_2/kg

All the steps above are repeated for all the bricks that have different proportion of plastics. Lastly, the amount of carbon footprint is then compared between the bricks.

CHAPTER 4

RESULT

4.1 To develop eco-friendly construction bricks by using different proportion of plastic bottles waste as one of its component

Table 4.1 shows the bricks by percentage of plactic. all the bricks able to maintained the shape from the mold event though at various percentage of plastic. Based on the result in figure 4.1, there was 4 bricks that have different percentage of plastic incorporated which are 0%, 4%, 8% and 12%. All the bricks are successfully developed and all the bricks are able to maintained its shape after removed from the mold. The mold that have been used to shaped the bricks have 5 cm x 5 cm x 5 cm dimension. There are three different dimension of mould available which are 5cm x 5cm x 5xm, 10 cm x 10 cm x 10 cm and 15 cm x 15 cm x 15 cm. The reason why 5cm x 5cm x 5cm mold are used is because to reduce the amount of mixture needed as well as to reduce the cost of the research. However, there are few problem arise during the process of developing of the bricks. First of all, the process of developing the bricks takes a lot of time. This is due to the plastic flakes unable to bind well to the cement. It is shown at table 4.1 that bricks that have 0% of plastics waste has sharper edges compared to other bricks. Bricks that have 0% of plastics also have smoother surface. The more plastic added into the bricks mixture, the rougher the surface of the bricks.

Table 4.1: Bricks that have different percentage of plastic

Percentage of Plastic	**Bricks**
0%	
4%	
8%	

12%	

4.2 To compare the compressive strength, water absorption, and soluble salt content of eco- friendly construction bricks with different proportion (4%, 8% and 12%) of PET plastic. and conventional bricks

4.2.1 Comparison of bricks with different percentage of plastic waste on compressive test

Table 4.2 shows the result of bricks that have different percentage of plastics and conventional bricks which is bricks that have 0% of plastic waste compressive test from other study that are similar to this research. The result in 4.2 shows the compilation of other paper result that has similar study to this research. This test is unable to conduct due to certain situation which is COVID-19. During this outbreak there is Movement Control Order (MCO) by government that causes the entire lab at to be closed including the lab where the test is supposed to conduct.

Table 4.2.1: Result of compressive strength

Bricks	Percentage of plastic	Compressive test result (N/mm2)
Wahid, Rawi, & Desa (2015)	0%	12.4
	5%	11.617
	10%	5.956
	15%	2.978
Azmi et al. (2018)	0%	29.900
	1%	27
	1.5%	28.1
	2%	33.3
	2.5%	25
Maneeth et al., (2014)	0%	2.16
	65%	8.16
	70%	8.16
	75%	6.63
	80%	3.15

Foti (2013)	0.5%	36.9
	0.75%	39.27
Mathew et al. (2013)	0%	24.2
	20%	30.83
Zega, Antonio, & Maio (2011)	0%	4.36
	20%	42.7
	30%	41.4
Youcef et al., (2009)	0%	27
	10%	24
	20%	20
	30%	18
	40%	13
Shikhar, (2017)	5kg	0.09
	10kg	0.129
	15kg	0.198
Tapkire, Patil, & Kumavat, (2014)	0%	41.1
	10%	40.7

	20%	38.97
	30%	37.77
Anumol & John (2015)	0%	17.2
	10%	15.12
	15%	14.06
	20%	10.26
	25%	8.7
Irwan et al., (2014)	0%	4
	25%	3
	50%	2
	75%	2
Ge et al. (2013)	1:1	19.6
	2:1	30.7
	3:1	32.7
	4:1	35.7
Bae et al. (2010)	0%	26.5
	0.5%	26

	0.75%	25
	1.0%	24
Bhushaiah et al., (2019)	0%	18
	5%	18.65
	10%	19.2
	15%	19.4
	20%	19.8
	25%	19
Hiremath, G, & Prathima (2014)	0%	2.16
	65%	8.16
	70%	8.16
	75%	6.63
	80%	3.15
Naji, Mousa, & Alameedi (2019)	0%	34.454
	2.5%	27
	5.0%	25.373
	7.5%	24

Miruthula et al. (2016)	10%	24
	20%	20
	30%	18
	40%	13
Arora & V. Dave (2013)	0%	22.33
	2%	20.02
	4%	18.26
Chauhan (2014)	10%	24
	20%	20
	30%	18
	40%	13
Rahmani et al., (2013)	0%	55.4
	5%	59.51
	10%	55.5
	15%	52.07

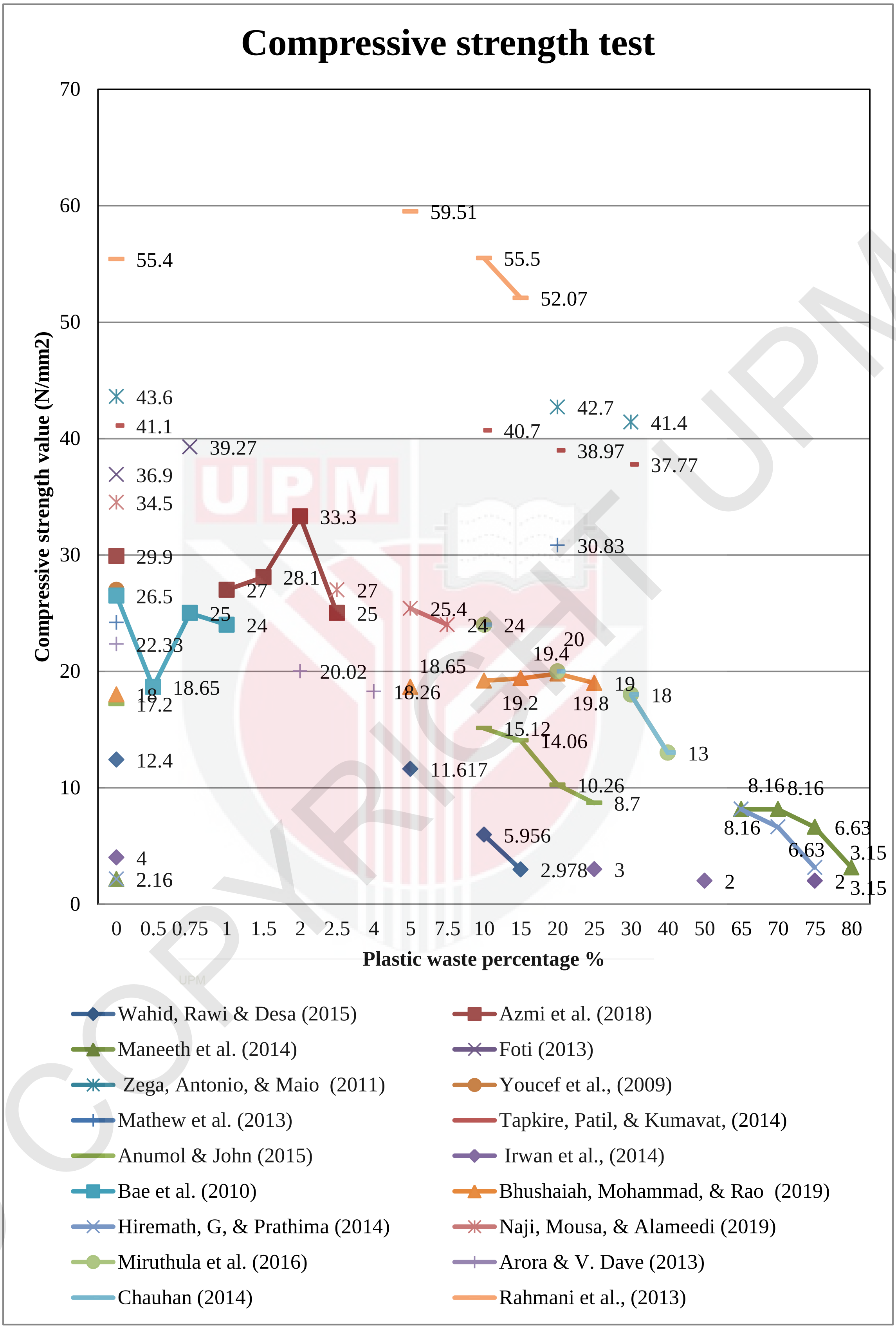

Figure 4.2.1: Graph for Compressive test results

4.2.2 Comparison of bricks with Different percentage of Plastic Waste and conventional bricks on Water Absorption Test

Water absorption test was done to determine the percentage of water absorption of each bricks. Water absoprtion determine the compactness of the bricks as well as the durability of the bricks. Water absorption percentage of the bricks are represented in figure 4.3.2. Based on result illustrated, there are difference of weight before and after immersion. More water are absorbed as the percentage of plastic increasing. Bricks that has the lowest percentage of water absorption is 4% of plastic waste which is 21.88% while water absorption for 8% and 12% plastic waste are 25.14% and 29.82% respectively.

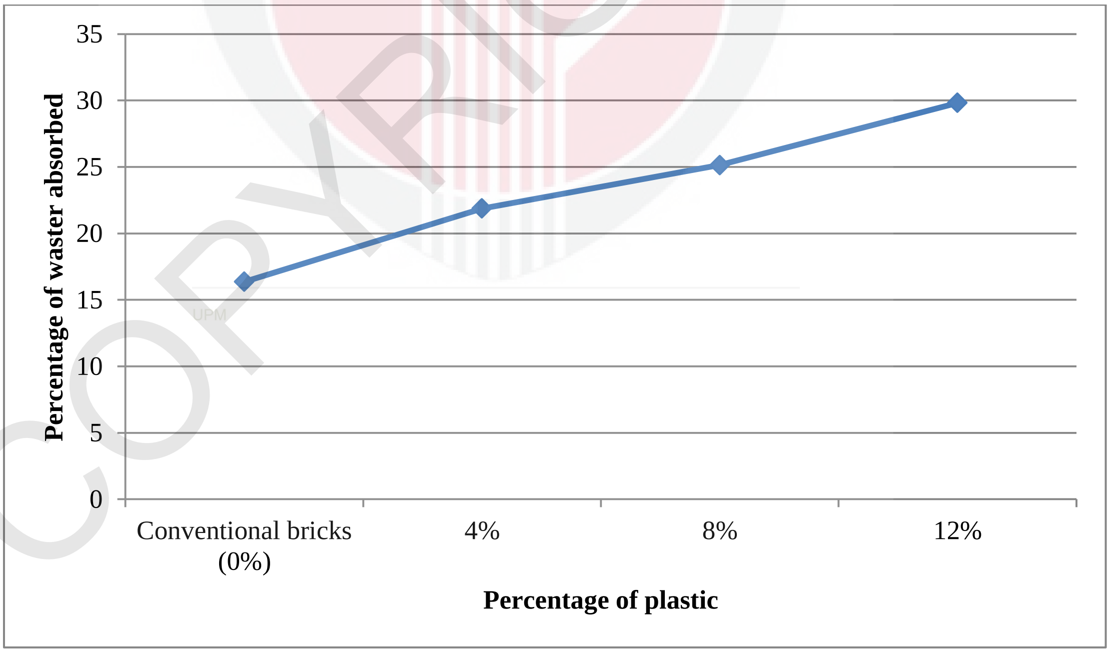

Figure 4.2.2: Graph percentage of water absorbed versus plastic waste ratio

Table 4.2.2 Result summary of water absorption test

Bricks	Weight before (g)	Weight after (g)	Difference (g)	Mean ± SD	Percentage
0%	209	247	38	0.035± 0.006	16.64%
	217	255	38		
	216	246	30		
4%	190	236	46	0.043± 0.003	21.88%
	193	233	41		
	195	236	41		
8%	178	222	44	0.045± 0.002	25.14%
	177	224	47		
	183	226	43		
12%	173	216	43	0.051± 0.007	29.82%
	168	220	52		
	172	223	57		

4.2.3 Comparison of bricks with different percentage of plastic waste on white precipitation

The efflorescene test was done to determine the presence of alkali in the bricks. Based on observation, there is no present of grey or white precipitate was shown on the bricks surface for all bricks that have different proportion of plastics.

Table 4.2.3: White precipitation on the surface of bricks

Bricks	NIL	SLIGHT	MODERATE	HEAVY	SERIOUS
Concrete (0%)	X				
4%	X				
8%	X				
12%	X				

4.3 To identify the relationship between the water absorption with proportion (4%, 8% and 12%) of PET plastic in the eco- friendly construction bricks

The relationship between water absorption with different proportion of PET plastic in the eco-friendly construction bricks is able to explore using IBM SPSS. Due to the sample was less than 30, Spearman;s Correlation was conducted. Because of the amount of the samples is below 30; thus, non-parametric test is being done. This test was done to determine the statically significant relationship between the percentage of plastic and water absorption between 4 different bricks.

Table 4.3: Spearman's Correlation test

Correlations				
			bricks	Difference
Spearman's rho	bricks	Correlation Coefficient	1.000	.836**
		Sig. (2-tailed)	.	.001
		N	12	12
	Difference	Correlation Coefficient	.836**	1.000
		Sig. (2-tailed)	.001	.
		N	12	12
**. Correlation is significant at the 0.01 level (2-tailed).				

4.5 Carbon footprint of bricks with different percentage of plastic and conventional bricks

Formula that has been adapted from Royal Institution of Chartered Surveyors (RICS), Methodology to calculate embodied carbon was used to calculate the total embodied carbon factor of the bricks. From table 4.5, concrete bricks that has 0% of plastic waste has the highest amount of total embodied carbon factor which is 0.1174 $kgCO_2$. Total emobodied carbon factor for bricks that has 4% of plastic waste was 0.1058 $kgCO_2$ while 8% of and 12% were 0.0987 $kgCO_2$ and 0.0943 respectively

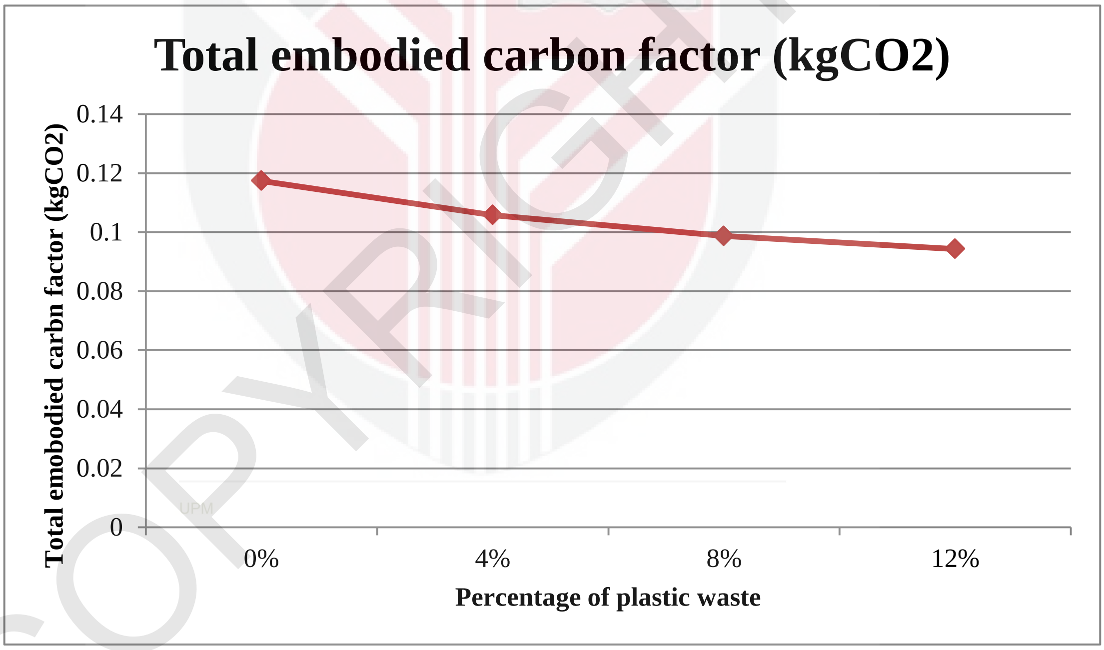

Figure 4.5: Graph of total embodied carbon factor of bricks (kgCO2)

CHAPTER 5

DISCUSSION

5.1 Development of eco-friendly construction bricks by using different percentage of plastic bottle waste as one of it component

The bricks that have the best shape, sharper edges and smoother surface is the bricks that have 0% of plastics waste. While other bricks that have plastic waste incoporate with it have rougher surface and it does not have sharper edges. The main reason was probably due to the plastic waste does not bind well with other mixture of the bricks. The size of plastic waste prepared was randomly and its not uniform. Moreover, the size of plastic waste incorporated was quite big. According to Wahid, Rawi & Desa (2015), their study recommend to grind the plastic flakes into smaller diameter or fine powder to make it easier to bind to the concrete mix. Other than that, they also suggest to add plasticizer as binder to bind plastic waste and concrete particles. Most of the previous study that use PET plastic waste as one of its component does not exceed 15% of its own weight. It is stated by Wahid et al. (2015) the amount of plastic waste added into the mix should not exceed 15% of its weight. If more plastic are added the quality of the bricks will decrease. There are also study conducted with more than 15% of plastic waste, however those studies added plasticizer or binder to make the plastic waste bind well to other mixture. For example, study conducted by Irwan et al., (2014), Tapkire, Patil and Kumavat (2014) and Anumol and John (2015) added super plasticizer into the mix to increase the cohesion between PET plastic waste and other mixture. Other than that, study conducted by Hiremath et al., (2014) added bitumen to the brick mixture as a binder between plastic waste and other mixture. In term material that used to make bricks, this study used fine sand, cement and water as its main ingredient. This is most common material that used to make bricks. Previous studies also uses cement, sand and water. Other material that are also commonly used gravel and stones.

5.2 To compare the compressive strength, water absorption, and soluble salt content of eco- friendly construction bricks with different proportion (4%, 8% and 12%) of PET plastic and conventional bricks

5.2.1 Comparison of compressive strength of eco- friendly construction bricks with different proportion (4%, 8% and 12%) of PET plastic and conventional bricks

It is clearly showed all the trend of compressive strength test result for all the study was decreased. It can be seen that there are reduction of compressive test strength of the bricks as the amount of percentage of plastic waste increase. According to Rahmani et al. (2013), when more PET plastic waste are added into the brick mix, it will decrease compressive strength of the bricks because more plastic waste added will reduced the cohesion between the bricks mixture and plastic wastes. The plastic waste will be the barrier and prevent the bricks to bond with the natural aggregate. One of the reasons why the plastic waste does not bind well to the other mixture is because the size of plastic waste particle that incorporate in the bricks was not uniform and big. This is due to the unavailability of crusher machine to grind the plastic waste into smaller particle. Plastic waste was only cut using a pair of scissor. When the size of plastic waste particles is big, during the development of the bricks the mixture wasn't able to compress well. According to Wahid et al. (2015), they recommended to grind the plastic waste until it become fine powder because by doing that it will increased the maximum packing density; therefore it will increase the compressive strength. Plastic waste should be grind and then sieve through 5mm sieve so that plastic waste particle that greater that 5mm will be removed (Irwan et al., 2014). Other than that, there are other studies suggested that addition of binder or super plasticizer will increased the compressive strength of bricks. A study conducted by Rai et al. (2012), showed that addition super plasticizer into the mixture of bricks will increase the compressive strength by 5%. Therefore it can be observed that addition of super plasticizer will increase the adhesive strength between plastic waste and other mixture of the bricks. It was also proved by study conducted by Foti (2013) and Irwan et al. (2014) as these studies shows that addition of super plasticizer increased the compressive strength of the bricks. Type of super plasticizer that is usually used in the production of bricks was MasterGlenium sky 8233. Besides that, from the result in figure 2 we can see that the compressive test result for all the studies varies between each other. This is because all of the bricks are not being tested in same shape and size. The shape that commonly used by researchers include rectangle, cube and cylinder. The shapes and diameter of the bricks affecting the result of compressive strength test.

5.2.2 Comparison of water absorption of eco- friendly construction bricks with different proportion (4%, 8% and 12%) of PET plastic and conventional bricks

Concrete bricks have the lowest percentage of water absorption which is 16.36% while water absorption for 4%, 8% and 12% plastic waste are 21.88%, 25.14% and 29.82% respectively. Bricks contain pores; therefore it has a tendency to absorb water or any type of moisture. Water absorption percentage of bricks should be between 12% and 20%. More than 20% of water absorption of bricks will causes the bricks become weak and it will reduce the strength of the structure. However, if water absorption is lower than 12%, the bond between bricks and mortar is hard to achieve (Parikh, 2019). The addition of plastic waste into the bricks causes more water to absorb because the plastic waste does not intact well with the cement and natural aggregate which is sand (Azmi et al., 2018). When the plastic waste does not bind well, more pores will be created and more water is absorbed in the bricks. The mixture was unable to tightly pack due to the characteristic of plastic waste particles. More water will quickly absorb if the bricks is highly porous (Kamble & Karad, 2017). Bricks could have lower water absorption if its impermeable to water even it contained high number of pores. If the bricks that have high percentage of water absorption use in construction, it will absorb water from environment and rainwater, and it will cause the dampness in the wall increase, thereby will contribute to weak structure of building. From previous study conducted by Wahid et al. (2015), water absorption decrease as more plastic waste added to the bricks. Plastic waste particle was grind finely and causes the plastic waste and other mixture is able to bind properly. This positive result was achieved probably due to the properties of plastic waste that impermeable to water. Kruskall-Wallis test also showed that there is significant different between different ratio of plastic waste and conventional bricks on water absorption test.

5.2.3 Comparison of white precipitation of eco- friendly construction bricks with different proportion (4%, 8% and 12%) of PET plastic and conventional bricks

White precipitation on the surface of the bricks should not exceed 50% because if it is more than that the white precipitation will become powdery mass and it will destruct the structure of the bricks. When there is present of water on or in the bricks, the efflorescence effect will happened on the surface of bricks. It was mainly caused by the presence of the salt in the bricks. As in the result in table 3, none of the bricks has white precipitation; therefore soluble salts are not presence in the bricks. The mechanism that causes the presence of white precipitation is when the salt in or on the bricks react with water. Types of soluble salt that are present include carbonate or sulphate compounds of sodium, magnesium, calcium as well as magnesium. The presence of salt in the bricks is depending on type of material used to construct the bricks. The absent of efflorescence in bricks in Table 3 was probably due to the material used in this study does not contain soluble salt. However, the environment also plays role in the efflorescence effect.

5.3 The relationship between water absorption and bricks with percentage (0%, 4%, 8% and 12%) of PET plastic

In this study, the result revealed that the percentages of plastic waste were positively correlated with water absorption percentages. When the percentage of plastics in the bricks increased, the water absorption percentage significantly increases. This result consistent with the study conducted by Albano et al. (2009), the result indicates that the water absorption percentage increased when plastic waste increases. This study reported that, the mixture is not fully compacted. A study conducted by Azmi et al. (2018), sand cement bricks that incorporated PET increased the water absorption of the bricks.

5.4 Carbon footprint of different percentage of plastic and conventional bricks

This was probably due to the weight of the bricks reduced as more plastic waste added. The study that can be relate to this result was study conducted by International Transport Forum (ITF). Their study state that vehicle that has lighter weight produce lower carbon emision (Internal Transport Forum, 2017). Due to lack of standard and studies regarding embodied carbon factor of the bricks, it is hard to identify the benchmark values for this study. It has been acknowledge by Lockie and Berebecki (2014) that the calculation of total embodied carbon is a new area of study thus many research and assumption need to be done to have an accurate outcome. Other than that, life cycle data that are associated with the production of the bricks, for example energy used in the production of cement and plastic as well as end-of-life stage need to be provide, however it beyond the scope of this study and can only be done by the life cycle specialist. Therefore, calculation of carbon footprint will neglect many component. Unfortunately, there is still not standard or proper way on how total embodied carbon should be calculate or define. Thus, more research need to be done to developed the standard and method of assessment. Estimation of total embodied carbon is not simple and easy. It require standard method, rules, calculation and data structure to ensure reliable and consistent result.

CHAPTER 6

CONCLUSION

As the conclusion, eco-friendly bricks that incorporated plastic waste were able to develop. The data from previous studies have been analysed and discussed. Next, the compressive strength of the bricks decrease as more plastic waste particles added into the mixture due to the decreased of adhesive strength between plastic waste particles and other mixture. From the result of water absorption, bricks with different proportion PET significantly affected the increased water absorption characteristic of bricks. Furthermore, there is no presence of white precipitation on the surface of the bricks; therefore there is no soluble salt presence inside the bricks. Carbon footprint showed a positive result as addition of plastic waste reduced the carbon emission from the bricks. However, there are limitations in this study such as plastic wastes are not finely crushed due to the unavailability of crusher machine. Other than that, compressive strength test for the bricks unable to conduct because of COVID-19 outbreak and lastly carbon footprint only estimate the possible carbon emission using the weight. Recommendation for future study, plastic waste should be crushed and sieve to get fine particle and uniform size. Other than that, plasticizer and binder should be added to increase the bind between plastic waste and other mixture. Due to the compressive strength of the bricks of this study is low when plastic waste is added, I would suggest that this to use this bricks as decoration. Lastly, consider life cycle analysis framework in addition to carbon footprint.

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