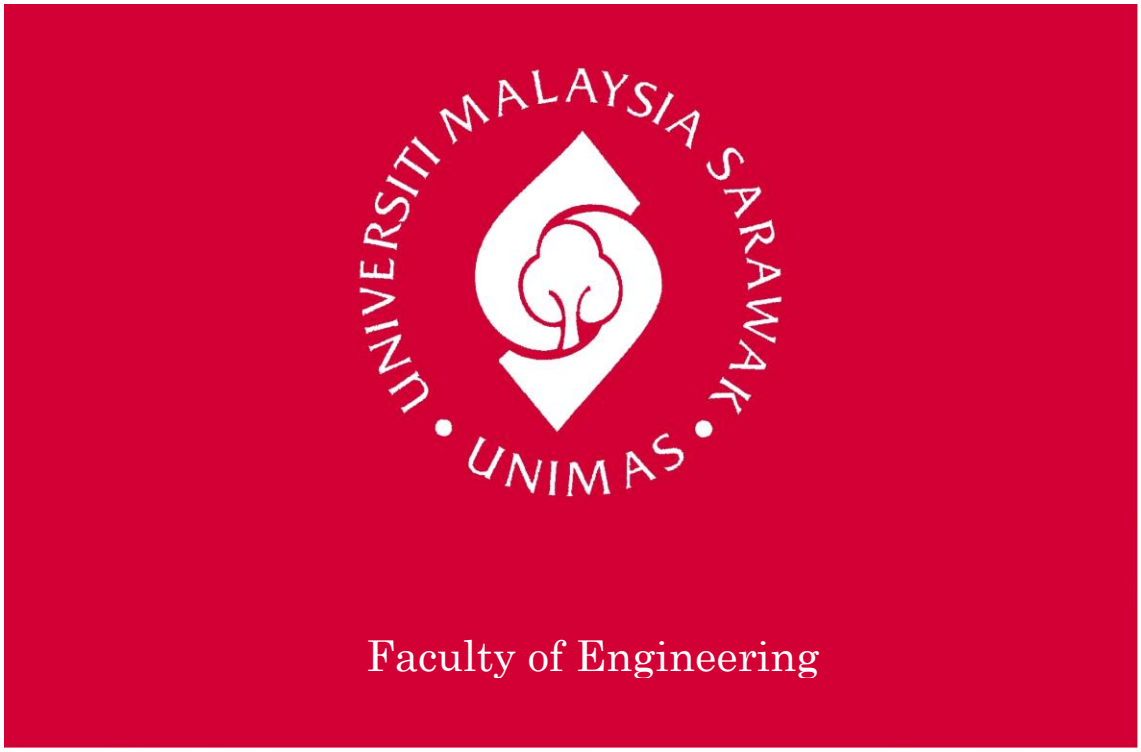

THE USE OF RECYCLED AGGREGATE AND FLY ASH FOR THE PRODUCTION OF PERVIOUS CONCRETE

PUA JIA YUNN

Bachelor of Engineering with Honours
(Civil Engineering)
2017

UNIVERSITI MALAYSIA SARAWAK

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THE USE OF RECYCLED AGGREGATE AND FLY ASH FOR THE PRODUCTION OF PERVIOUS CONRETE

PUA JIA YUNN

This project is submitted in partial fulfilment of

The requirement for the degree of

Bachelor of Engineering with Honours

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Faculty of Engineering

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To my beloved family, friends and lecturers.

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ABSTRACT

Nowadays, due to depleting of natural resource and increased environment pollution, recycling of waste material is promoted as a replacement to conventional material in the civil engineering field. The recycled concrete aggregate is used in the production of pervious concrete. Besides, another by-product, fly ash has been utilized in this research due to its pozzolanic and cementitious properties in the production of pervious concrete. The compressive strength, permeability, void content and density properties of pervious concrete produced from recycled concrete aggregate and fly ash as partial cement replacement are the major concerns in this research. There are four types of mix proportion of pervious concrete samples used in this research which includes pervious concrete produced from conventional aggregate (NA100), pervious concrete produced from natural aggregate and fly ash as a 20 % substitution of cement (NA100FA20), pervious concrete produced from recycled concrete aggregate (RCA100), and pervious concrete produced from recycled concrete aggregate and fly ash as a 20% substitution of cement (RCA100FA20). The w/c ratio used and design void content are 0.34 and 20% respectively. The RCA100 and RCA100FA20 samples can be applied on the construction of pedestrian pathway as the strength of samples were higher than the normal loading (5MPa). The RCA100 sample achieved the highest permeability coefficient among the samples.

ABSTRAK

Pada masa kini, kitar semula bahan buangan digalakkan sebagai gantian kepada bahan konvensional dalam bidang kejuruteraan awam kerana semakin berkurangan sumber semula jadi dan peningkatan pencemaran alam sekitar. Agregat konkrit kitar semula yang digunakan dalam pengeluaran konkrit yg dpt tembus. Di samping itu, satu lagi oleh-produk, abu terbang telah digunakan dalam kajian ini kerana sifat pozzolanic dan bersimen dalam pengeluaran konkrit yg dpt tembus. Kekuatan, kebolehtelapan, kandungan tidak sah dan ketumpatan sifat mampatan konkrit tidak kedap dihasilkan daripada agregat konkrit kitar semula dan abu terbang sebagai pengganti simen separa adalah kebimbangan utama dalam kajian ini. Terdapat empat jenis campuran perkadaran sampel konkrit tidak kedap yang digunakan dalam penyelidikan ini, termasuk konkrit tidak kedap dihasilkan daripadal agregat semulajadi (NA100), konkrit tidak kedap dihasilkan daripada agregat semulajadi dan abu terbang sebagai penggantian 20% daripada simen (NA100FA20), konkrit tidak kedap dihasilkan daripada kitar semula sampel agregat konkrit (RCA100), dan konkrit tidak kedap dihasilkan daripada agregat konkrit kitar semula dan abu terbang sebagai penggantian 20% simen (RCA100FA20). W / c nisbah digunakan dan reka bentuk kandungan tidak sah adalah 0.34 dan 20%.. The RCA100 dan RCA100FA20 sampel boleh digunakan pada pembinaan pejalan kaki laluan sebagai kekuatan sampel adalah lebih tinggi daripada loading yang normal (5MPa). Sampel RCA100 mencapai pekali kebolehtelapan yang tertinggi di kalangan sampel.

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LIST OF ABBREVIATION

ACI	-	American Concrete Institute
Al_2O_3	-	Aluminum Oxide
ASTM	-	American Society for Testing and Material
BS	-	British Standard
CaO	-	Calcium Oxide
FA	-	Fly Ash
Fe_2O_3	-	Ferric Oxide
K_2O	-	Potassium oxide
LOI	-	Loss on Ignition
MgO	-	Magnesium oxide
NA	-	Natural Aggregate
Na_2O	-	Sodium Oxide
RCA	-	Recycled Concrete Aggregate
SiO_2	-	Silicon Dioxide
SO_3	-	Sulphur Trioxide
SSD	-	Saturated Surface Dry
w/cm	-	Water to Cement Ratio

CHAPTER 1

INTRODUCTION

1.1 General

Pervious concrete is considered as a special type of concrete which consists of Ordinary Portland cement (OPC), water, and coarse aggregate only (Cosic et al., 2015). A little of fine aggregate may be added into the mixture of pervious concrete. It is a zero slump pervious concrete that allow water to flow through the sample of pervious concrete freely and be recharged as groundwater (Joshaghani et al., 2015). ACI Committee 522 (2010) stated that a typical pervious concrete has connected pores that is the range of 2 to 8 mm in size and void content of a pervious concrete is from 15 to 25%. Typically, the compressive strength of the pervious concrete is in between 2.8MPa and 28 MPa (ACI Committee 522, 2010). Thus, the compressive strength of pervious concrete is low due to the high percentage of void content of pervious concrete. The strength of cement paste, binding the aggregate together is weak due to cement paste binder layer of the pervious concrete is very thin (Yang & Jiang, 2003). Therefore, the thin cement paste binder layer of the pervious concrete affects strength of the pervious concrete (Yang, & Jiang, 2003).

Recently, large amount of construction wastes are composed. These waste materials without any processing are normally used for embankments and road construction (Bhutta et al., 2013). Nowadays, the reuse of construction and demolition waste is getting more popular in order to promote the green concept. This is because the problems of pollution of construction waste are getting severe than unexpected. Thus, the recycling the construction waste material is promoted to conventional material in civil engineering field. Recycled aggregate is derived from recycling the construction wastes. Recycling the construction wastes is a process that involves breaking, removing, and crushing these wastes into a material with a specified size and quality (Bhutta et al., 2013). The problem of environmental such as pollution and waste storage can be

reduced by recycling the wastes. In addition, it also helps to preserve the natural resources (Zaetang et al., 2016). Researches on recycled aggregate have been carried out around the world to prove feasibility, economic viability and cost effectiveness of recycled aggregates (Bhutta et al., 2013). Low in density and abrasion resistance, high in water absorption and porosity are the properties of recycled aggregate (Zaetang, 2016). Due to its properties, the compressive strength of recycled aggregate in concrete is relatively low. In recent, combinations of recycled aggregates and fly ash in concrete of studies have been done in order to investigate the effects on the physical and mechanical properties of the pervious concrete (Kim et al., 2013).

Not only construction and demolition waste, fly ash produced by burning pulverized coal in power station has been widely used as finely divided mineral admixtures for producing high strength and high performance concrete. The fly ash acts as a pozzolanic material in low volume fly ash concrete. According to Poon, Lam and Wong (2000), fly ash contributed slight to compressive strength of the concrete at early ages. In addition, fly ash contributed much larger to compressive strength of the concrete at the later ages. Hydration of cement is accelerated due to cement dilution effect in the fly ash concrete (Wang, & Park, 2015). Therefore, cement dilution effect and fly ash pozzolanic reaction should be considered to evaluate the compressive strength of fly ash concrete (Wang, & Park, 2015). The use of fly ash also improved the workability and flowability of recycled aggregate concrete due to spherical particle of fly ash (Kim et al., 2013).

1.2 Problem statement

The combination of increased rainfall and impermeable surface areas leads to frequent flooding occurs in the cities (Sriravindrarajah, Wang, & Ervin, 2012). Besides that, the storm water runoff is increased rapidly by increasing impermeable open areas and amount of infrastructures such as residential houses, commercial buildings, and factories (Sriravindrarajah et al., 2012). Thus, the drainage system gets overloaded in the cities. However, there is no technical data and information on application of pervious concrete which are parking lots, driveways, walkways and light-traffic roads in Malaysia (Bhutta et al., 2013). Hence, pervious concrete is used in application of pavement in order to reduce the amount of storm run-off.

Recently, huge quantities of construction wastes materials were produced in Malaysia such as construction waste material, concrete block waste, brick waste and timber waste. This was due to the rapid growth of construction industry. The increasing of demand of houses and major infrastructure projects led to the increasing of the amount of construction waste (Nasaruddin et al., 2008). Normally, the construction wastes generated are disposed illegally into landfills. Among of the 46 illegal dumping sites, 42 % wastes were the construction waste in Johor (Rahmat and Ibrahim, 2007). The illegal dumping problems caused risks to human health and environment. Instead of disposed these construction materials illegally, part of society are more concern about the way to reuse and recycle these construction waste product in a proper way.

In addition, fly ash also is considered as a waste material and a by-product from coal fired power plants. Normally, the fly ash is disposed into landfills. This may endanger the health of the surrounding environment and population. Heavy metals may leach from fly ash into groundwater (Rahmat & Ibrahim, 2007). Therefore, the groundwater will be contaminated. Hence, it is possible to utilize the fly ash in construction field in order to reduce the environmental problem.

1.3 Research Significance

In Peninsular Malaysia, average total of construction and demolition waste generated was 28.6 tons per day in 2015 based on the data given by SW Corp Malaysia (Rahim & Kasim, 2017). The number of construction waste was increased critically from year 2014 to 2015, which increased from 7.2 to 28.6 tons per day (Rahim & Kasim, 2017). Construction and demolition waste generation has the highest percentage (41%) among the solid wastes due to rapid development in Peninsular Malaysia (Eusuf et al., 2012). Problems of the ways of disposal concrete and fly ash are not solved yet. Improper ways of disposal of concrete and fly ash will cause pollution to the environment and affect the human health.

Concrete has been recycled into recycled concrete aggregate based on previous studies. Recycled concrete aggregate from demolition waste could be used as production of pervious concrete (Zaetang, et al., 2016). Recycled concrete aggregate and fly ash are the waste materials that have potential to become material for production of pervious concrete. Recycled concrete aggregate can be used to replace natural aggregate in pervious concrete in order to enhance the mechanical and physical properties of pervious concrete.

Fly ash has the potential to become cement replacement for concrete due to its properties. Fly ash can enhance the workability and compressive strength of concrete. However, applications of fly ash in pervious concrete are very limited. Hence, in this study, the properties of this pervious concrete will be compared with the recycled concrete aggregate pervious concrete with replacement of fly ash. Besides, it is used to investigate the properties of the pervious concrete by using the locality material in order to promote sustainability concept.

1.4 Objectives

The main aim of the this research is to determine the properties of pervious concrete produced from recycled concrete aggregate and fly ash as partial cement replacement. The objectives of this study are listed as below:

I. To determine the optimum mix proportion of pervious concrete produced from recycled concrete aggregate and fly ash as partial cement replacement.
II. To determine the compressive strength and density of hardened pervious concrete produced from recycled concrete aggregate and fly ash as partial cement replacement.
III. To determine the permeability and void content of hardened pervious concrete produced from recycled concrete aggregate and fly ash as partial cement replacement.

1.5 Scope of work

This research is carried out by conducting laboratory work on mix design, concrete mixing, cuing and casting. The experimental works are carried out to obtain the data required for the study. The data collected is used to determine the strength and permeability of the pervious concrete. The general scope of this study is to determine the mix proportion of the pervious concrete by using ACI 522R-10.

In the laboratory work, there are a number of laboratory tests conducted to study the properties of the pervious concrete. The specimens are put in the curing tank filled with water at room temperature after the specimens are taken out from moulds. The compressive test is carried out to study hardened concrete's properties at 3 days, 7 days, 28 days and 56 days. The void content, density and permeability tests are carried out at 28 days only.

Finally, the results from the laboratory tests are analyzed. The conclusion and recommendations are made to complete the study.

1.6 Thesis organization

The research is divided in to five chapters. Chapter one is the general introduction of pervious concrete, objectives of the research, problem statement, and scope of work. After that, chapter two of the research is about the literature review of the development of the recycled aggregate previous concrete with replacement of fly ash. Chapter three of the research involves the methodology of the laboratory work such as material tests, producing of pervious concrete, fresh pervious concrete tests and hardened previous concrete test. Chapter four includes the results and data analysis of the laboratory pervious concrete test. Discussion is also involved in the chapter four. Lastly, chapter five concludes the development of pervious concrete with replacement of recycled aggregate and fly ash. Recommendations are included for further study.

CHAPTER 2

LITERATURE REVIEW

2.1 General

According to ACI Committee 522 (2010), pervious concrete had been used in Europe and Australia for the past 60 years. Production of pervious concrete was confined to two-story homes before World War 2 (ACI Committee 522, 2010). After the war was over, there were large quantities of brick rubble disposed and then led to research into the properties of pervious concrete in order to find out that the disposed brick could be used as building material (ACI Committee 522, 2010).

Pervious concrete typically consists of Portland cement, single-sized coarse aggregate, and water. This type of concrete is used for low volume traffic area, driveways and parking lots. The concrete has interconnected voids that allow water to flow through it. Pervious concrete technology has been used as a storm water management system. Pervious concrete shows a number of advantages on traffic. Reducing the noise between tire and pavement is one of the advantages on traffic. Due the voids present in the pervious concrete, it absorbs the tire noise and reduces sound wave reflection (ACI Committee 522, 2010). However, the disadvantages of pervious concrete are its strength including compressive and flexural, clogging by fine materials and cost of maintenance for the pervious concrete (Joshagani et al., 2015). By applying pressure washing and power vacuum, debris will be removed (ACI Committee 522, 2010). This will improve the infiltration rate of pervious concrete.

Due to increasing of the construction wastes and inappropriate managing the disposal of construction waste, severe environmental pollution problems occur in US (Kim et al., 2013). Recycling of concrete and use of supplementary cementitious materials such as fly ash, have been used as material of pervious concrete production in order to meet the global consensus of sustainable development.

2.2 Pervious Concrete

Pervious concrete typically consists of coarse aggregate, cement and water. A little amount of fine aggregate is suggested to be added into the mix of pervious concrete in order to improve the mechanical properties of the pervious concrete. This type of concrete is used for low volume traffic area, driveways and parking lots. The concrete has interconnected voids that allow water to flow through it. The normal loading of pedestrian walkway is typically 5 MPa (Concrete Bridge Development Group, n.d.).

Portland cement is the main component of a pervious concrete. It is used as main binder in a pervious concrete. Normally, the typical range of cement content used in pervious concrete is between 450 and 700 kg /m^3. The content of cement is dependent on the amount and size of coarse aggregate and the water content.

Zhuge and Lian discussed the importance of adding the proper amount of water content in a pervious concrete. When the amount of water is added properly, the cement hydration can be developed thoroughly. However, the mixture was considered as too wet if the aggregate was running off and sticking on the mixer or glove (ACI Committee 522, 2010). Too much water in the mixture may result in clogging the pores in the mixture of pervious concrete (Manju et al., 2015). The optimum water content must be determined by doing several trial batches in order to ensure that the high compressive strength and permeability of pervious concrete can be achieved (Zhuge and Lian, 2010).

The properties of coarse aggregate including sizes, type of aggregates, and aggregate gradations have been found to affect the properties of pervious concrete (Cosic et al., 2015). In reality, aggregate that have the range of 4.75 – 9.75mm are widely in construction. Other size of aggregate and type of aggregate have been used in laboratory test in order to study the effect of coarse aggregate (Zhuge and Lian, 2010). The size of coarse aggregate used in pervious concrete are normally either single-sized coarse aggregate or sizes in between 9.5mm and 19mm (ACI Committee 522, 2010). The shapes of coarse aggregate normally used in pervious concrete are round and crushed (ACI Committee 522, 2010).

Normally, a little amount of fine aggregate is added into the mixture of pervious concrete in order to enhance the mechanical properties of the pervious concrete. When the fine aggregate is used, it will fill the pores between aggregate and cement paste. Therefore, the compressive strength of the pervious concrete can be improved significantly (Zhuge and Lian, 2010). Zhuge and Lian (2010) studied that pervious concrete with 18% of fine aggregate of total weight of aggregate is the optimum percentage for pervious concrete. The fine aggregate content should be limited in pervious concrete mixtures because it tends to compromise the connectedness of the pore system (ACI Committee 522, 2010). The increasing of permeability of pervious concrete may results in reduction of compressive strength of a pervious concrete.

Admixtures are normally added into pervious concrete in order to improve the properties of the pervious concrete. Normally, water reducing admixtures such as high range and medium range water-reducing are added to decrease the water content in a mix (ACI Committee 522, 2010). If too much water presents in the mix, clogging may occur due to the settlement of cement (Mujan et al., 2015).

2.3 Recycled Coarse Aggregate

Recycled aggregate, produced by recycling the waste from demolition buildings can be used in production of pervious concrete (Kim et al., 2013). In Malaysia, most of the construction wastes are deposited into landfill that may lead to occurring of environmental pollution problem (Eusuf, Ibrahim, and Islam, 2012). Using recycled coarse aggregate as a concrete material is one of the ways to achieve a goal that is to produce environmentally products. In recent, recycled concrete aggregate could be feasible for construction replace natural aggregate to reduce the impact of the construction wastes (Kim et al., 2013). Besides that, Sriravindrarajah et al. (2012) also mentioned that demolished concrete can be used as recycled concrete coarse aggregate in pervious concrete production. The recycled aggregate in pervious concrete has the potential to be used as materials for mixture of pervious concrete. Thus, the environmental benefits of a pervious concrete is also improved.