THE MECHANICAL & DURABILITY PERFORMANCE OF CONCRETE CONTAINING WASTE CONCRETE ASH AS CEMENT REPLACEMENT MATERIALS

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By

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LIST OF ABBREVIATIONS

WCA	Waste Concrete Ash
OPC	Ordinary Portland Cement
HSC	High Strength Concrete
NSC	Normal Strength Concrete
NaOH	Sodium Hydroxide
SP	Superplasticizer
SEM	Scanning Electron Microscopy
UPV	Ultrasonic Pulse Velocity
LOI	Loss On Ignition
RHA	Rise Husk Ash
HRM	High Reactivity Metakolin
BS	British Standards
MS	Malaysian Standard

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PRESTASI MEKANIKAL & KETAHANAN KONKRIT MENGANDUNGI DEBUAN SISA KONKRIT SEBAGAI BAHAN PENGGANTI SIMEN

ABSTRAK

Penggunaan konkrit adalah penting dalam industri pembinaan dan ia menjadi bahan binaan yang paling penting dan utama digunakan di seluruh dunia. Kajian ini membentangkan kajian eksperimen mengenai pengaruh perbezaan peratusan debuan sisa konkrit sebagai bahan pengganti simen untuk membentuk konkrit baru. Keputusan eksperimen akan dinilai berdasarkan prestasi mekanikal dan ketahanan konkrit. Untuk meningkatkan kualiti konkrit penggantian simen, bahan tambah konkrit ditambah ke dalam konkrit sisa debuan. Kadar penggunaan campuran sisa debuan konkrit adalah antara 5% hingga 40% dan peratusan optimum bahan "Silica Fume" sebagai bahan tambahan konkrit. Semua spesimen melalui proses pengawetan air dan diuji pada umur 7, 14, 28, 90 dan 180 hari. Berdasarkan kajian ini, ia mendedahkan bahawa peningkatan peratusan sisa konkrit abu akan mengurangkan kualiti konkrit. Berdasarkan penemuan yang diperolehi, peratusan optimum sisa debuan konkrit yang digunakan adalah 10%. Walaubagaimana pun, kekuatan mampatan diperolehi adalah rendah apabila penambahan peratusan WCA ke dalam konkrit. Kehadiran bahan tambah konkrit akan membantu mengembalikan kekuatan dan ketahanan konkrit

THE MECHANICAL & DURABILITY PERFORMANCE OF CONCRETE CONTAINING WASTE CONCRETE ASH AS CEMENT REPLACEMENT MATERIALS

ABSTRACT

The use of concrete is important in the construction industry and it became the most important and major construction materials use all over the world. This research presents an experimental study of the influences of different percentage waste concrete ash used as cement replacement materials to form a new concrete. The results of the experiment were evaluated based on mechanical and durability performance of concrete. To improve the quality of cement replacement concrete, concrete admixture was added to work with waste concrete ash. The mix proportioning of waste concrete ash uses were between 5% to 40% and Silica Fume was used as an admixture. All specimens were cured by water curing process and it was tested at the age of 7, 14, 28, 90 and 180 days. Based on this study, it revealed that increasing a percentage of waste concrete ash reduces the quality of concrete. It was found that, the optimum percentage of waste concrete ash used in cement replacement is 10%. However, the compressive strength will be reduced when more percentage of WCA were added. The presence of concrete admixture helps to restore the strength and durability of concrete

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The increasing rate of development and construction industry does not only boost demand on concrete but it also makes concrete one of the major contributors to construction waste. Every development project which involves construction and demolition inevitably increases the construction waste which needs a place to be disposed of. RILEM Committee (2004) reported that waste concrete at the United Kingdom is estimated at 30 million tonnes/year, which is of 500kg/person/year. Meanwhile, the construction waste in Malaysia at years 2013 is 22 million tons. The construction waste has obviously become a major cause for concern among communities of developed countries. In developing countries like Malaysia, waste products from construction industry are not being taken seriously because almost all construction activities in Malaysia are based on build concept. However, concerns about construction waste among Malaysians have grown in recent years. Thus, the Malaysian government has started to promote a new concept of construction i.e., green building campaign to reduce construction waste nationwide.

Concrete is the most important and major construction material which is used universally. It is widely used in almost every type of construction among others, building, infrastructure and structures which are used to protect from rough environment and other developments. It became an important material in construction industry based on its strength of being able to support higher load and its durability against the environment compared to the other material. On the other hand, the usage of concrete for developmental purposes is double the usage of other material such as wood, glass and steel. Concrete is a manufactured product which consists of raw material such as cement, sand, aggregate and some admixture to improve the characteristic of concrete. High demand for concrete increases the use of raw materials in the mixture of concrete.

Cement is one of the raw materials that is used in concrete mix and acts as a binder between sand and aggregate. However, it has been criticized by some researchers on green environment grounds. This criticism was levelled based on the production of Portland cement which caused greenhouse emission: a phenomenon which contributes to global warming. According to some researchers, the production of a tonne of Portland cement generates about one tonne of carbon dioxide (CO_2) to the atmosphere and it is of 5% of global CO_2 emission. (Nuruddin etc al, 2010). Annually, global production of Portland cement accounts for 1.35 billion tonnes of greenhouse emission. (Malhotra, 2002; Hardjito, 2004).

Various studies have been carried out to minimize the dependence on cement by replacing or adding an admixture into concrete which is called as pozolanic material and geopolymer. There are a few materials which are used to reduce the dependency on cement such as silica fume, fly ash, rice-husk, slag, clay, etc. By using these alternative materials to replace cement, it will affect the durability and strength of concrete. Besides, another factor in choosing the material to replace cement is availability, the application to the end user and cost. These materials also have a binder characteristic compared to concrete but in low CO_2 emissions and they are environmental-friendly.

The reduction of cement in the concrete-mix will help to reduce the dependency on cement, which contributes to the global warming. However, the waste concrete is another problem that is being faced by the environment because waste concrete requires a suitable landfill for it to be disposed of. To date, the only available solutions to minimize the construction waste are by recycling and reusing. Conventionally, waste concrete from demolished buildings will be disposed of at designated landfill areas, however, it is not a good solution to dump the waste concrete though because it increases the number of landfill areas. In most developed countries, the waste concrete are being reused and recycled as an aggregate replacement to other construction projects such as highways and other structures. Many studies have been reported in the literature on recycled concrete aggregate being used in producing another new concrete. For instance, Myle Nguyen James, Wonchang Choi, et al (2011) studied about the "Use Recycled Concrete Aggregate (RCA)" and Fly Ash (FA) revealed that recycled RCA of up to 25% and FA of up to 15% do not create a significant effect on concrete and its strength is almost the same as concrete with natural aggregate. The report from The Cement Sustainability Initiative revealed that by using 40%-50% of waste concrete and other pozolanic material to replace cement can reach 20-40MPa strength of concrete. Concisely, the waste concrete can be recycled into another new concrete which helps minimizing the landfill areas. It provides an economical and environmental benefit by reducing the cost for new cement while reducing a CO_2 emission at the same time.

The waste concrete can be used in production of new concrete but the quality of it is less compared to conventional materials. This is because of the quality of waste concrete is relatively lower compared to conventional material. For example, in reusing waste concrete to replace cement, the silica element in waste concrete is less compared to the conventional cement. On the other hand, the characteristics of waste concrete are: higher water absorption, high rapid chloride ion permeability, and lower compression strength and it changes the strength and the durability of concrete. (Report Cement Concrete and Aggregate Australia, 2008). To improve a lack of recycled concrete, an admixture or geopolymer can be added to improve the concrete and produce a concrete that has the same strength and durability with normal concrete.

Generally, construction waste is one of problems that have been faced in the construction industries. The problem has always been of designating a suitable place to dispose of construction waste. The best solutions to handle the waste materials are by recycling and reusing them to produce another product. In the present study, the waste concrete is being recycled to be used as cement replacement materials. The waste concrete can help reduce the consumption of cement and contribute to reducing CO_2 emissions that disrupt the environment as well as reducing landfill waste.

1.2 Problem Statement

Acceleration of municipal, especially in both developing and developed countries produces a lot of construction waste and increases the demand for raw materials such as cement, sand and natural aggregate. The recycle and reuse construction waste can help to reduce the demand of the raw materials in construction industry. Almost all waste from construction and demolition of buildings can be reused and recycled to produce a new product. However, there is a lack of implementation in reusing and recycling the construction waste because it is difficult to produce reused product that comes from tonnes of construction waste. In order to maximise the reused material from construction waste, an effective plan should be drafted to identify how and what part or materials from construction waste and demolition project can be reused. By identifying which one of the construction waste are useful to be recycled and reused, the construction waste can be minimised and thus reduce the landfill areas.

Another major challenge in reusing the construction waste is the environment. In the present study, a waste concrete from new projects or demolition projects were used as replacement cement base to produce a new and fresh concrete. Based on previous research and report reviewed, recycled concrete has higher water absorption, higher rapid chloride ion permeability, and lower compression strength compared to normal concrete without recycled concrete. (J.M. Khatib, 2004; Report Cement Concrete and Aggregate Australia, 2008). From the aforementioned report, it was found that by using recycled concrete in new concrete reduced the strength and durability compared to the concrete using a conventional material (natural material). With the surrounding environment, the concrete that is produced using waste concrete will fail unless the quality of it is of the same with the natural concrete that is made from the conventional material. The new design mix should be produced to optimize the usage of recycled concrete without compromising the strength and durability of concrete that is being exposed to the environment.

The production of concrete using waste concrete materials to achieve same quality with conventional concrete is possible. Concrete admixture used in fresh concrete can increase the durability and strength. However, not all admixtures are suitable to be used and affected to increase durability and strength of concrete especially concrete that containing waste concrete. Different characteristics between waste concrete and conventional material are the major problem to identify a suitable admixture. It requires further research to identify a suitable admixture that can increase the durability and strength of concrete from the recycled concrete.

1.3 Aims and Objectives

The aim of this study was to recycle the waste concrete by replacing a cement base on a new concrete. The fresh concrete produced were using less quantity of cement content by replacement cement to waste concrete ash (WCA). Therefore, the objectives of this study are to:

a) Determine the optimum percentage of waste concrete ash to replace cement content.
b) Explore the strength of concrete with cement replacement from waste concrete ash.
c) Identify the suitable admixture that can be used with cement replacement to gain the strength and durability of concrete.

1.4 Scope And Limitation Of Study

The scope of the project study is to produce the design mix for concrete using the waste concrete ash as cement replacement. In order to ensure the quality of concrete, the concrete was tested based on its strength and durability factors. Few concrete admixtures were used in trial mix design to determine the best admixture and they were selected. The design was divided into two types of concrete namely low strength concrete (normal concrete) and high strength concrete (HSC). The purpose was to ensure that a recycled concrete was capable of being used in construction projects in Malaysia. The percentages of waste concrete ash as cement replacement were conducted within the range of 5% - 40% from the quantity of cement content. These concrete were tested by mechanical and durability properties after it been cure in water tanks.

1.5 Significant Of Research Study

Production of construction waste can be a major concern to environment because it needs a place to be disposed of. In Malaysia, the construction waste is not a major concern of its society yet but, it will be in years to come. The proper planning and solutions should be thought about to ensure this problem is resolved before it becomes worse for the country in the future. The purpose of this study was to produce an alternative solution to reduce the construction waste while reducing dependence on a raw material such as cement. Cement is the most important material in construction industry and the demand for this material has always been increasing. Meanwhile, the source for the production of cement comes from the lime stone and with a rising demand for cement will contribute to a large volume of lime stone consumption.

This study was conducted by recycling waste concrete to replace the cement content without reducing the strength and quality of concrete. The optimum design on quantity of waste concrete needs to be defined to ensure the recycled concrete as replacement cement can be used in construction industry. Hence, proper plans should be made to reduce the construction waste.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the topic that should first be highlighted is waste concrete being reused and recycled to form a new-end product. Concrete is the most common material which is used in construction industry because it has characteristics such as better strength and durability. The production of concrete is estimated that roughly 25 billion tonnes of concrete are manufactured globally each year and twice as much concrete is used in construction around the world compared to other materials like steel and timber. What follows next is, the criteria of recycling a vast concrete is further discussed to identify the characteristics of waste concrete.

The following discussion in this chapter is to determine the important factors needed to be considered to use the cement replacement materials. In designing a concrete mix, the change of any materials causes a change of the mix's characteristics. For instance, the change may affect the characteristics of concrete in terms of mechanical performances and durability. Thus, it is important to identify the effect of cement replacement to ensure the end product will have same quality to conventional concrete. In this chapter, a few roles of cement replacement in other contexts will be reviewed to ensure to produce a perfect design mix in containing waste concrete ash as cement replacement materials. The last part of this chapter is the summary of a thorough review of literature and it highlights the gap identified in relation to the application of recycled vast waste concrete as cement replacement. Also, through this gap, a conceptual framework for the study has been developed.

2.2 Definitions of waste concrete

Concrete is the most common material which is widely used in construction industries. In fact, concrete is the mostly produced waste material in the industry compared to other materials like timber, steel, plastic and aluminium. Based on a report by The World Business Council for Sustainable Development (WBCSD) entitled “Report The Cement Sustainability Initiative (Recycling Concrete)”, it is about 1,300 million tonnes of waste are generated in Europe each year, of which about 40% or 510 million tonnes are construction and demolition waste. However, the impact of concrete is bigger in developing countries such as China and India: they are now producing and using 50% of the world concrete, their waste generation is also significant for development. The increase of waste concrete becomes a global issue and because of that, many countries have recycling schemes for Construction and Demolition Waste (C&DW) concrete such as the Netherlands, Japan, Belgium, Germany and other developed countries. For developing countries like Malaysia, waste concrete are put in landfill sites.

There are interesting facts about waste concrete, which are recycling concrete is not a new and has always been an element in construction. Based on the report of The Cement Sustainability Initiative (Recycling Concrete), since early Roman time, construction material have been recycled and reused. Research on the properties of recycled concrete began in the 1940s. However, it is hard to find any data because the collection is not systematic and there is no specific data on waste concrete produced by most countries. In general, most developing countries use the data about waste that are disposed of in designated landfill areas and it is different from developed countries which use a vast concrete to produce a reusable aggregate from crushing concrete. As technology has crept into the ways of crushing concrete and considering the fact that it is relatively inexpensive these days, it is therefore possible for any country to recycle waste concrete. With the wealth of research findings, both developed and developing countries can enlarge their scope in recycling waste concrete.

Concrete is an excellent material in construction because it is durable and energy efficient. Even though it is a perfect material, waste is always generated due to human beings always wanting changes. Waste concrete is able to be reused in its original form and it also can be recycled by means of a process of crushing and sieving to turn it into smaller blocks or aggregate for use as new product. Concrete is made from coarse aggregate, fine aggregate, cement and other added mixture if necessary. It binds with water as an activation agent to cement. It can be recycled in 3 stages which are: a returned concrete (fresh and wet concrete) that mostly comes in excess in concrete truck, waste produced at a pre-cast production facility and lastly waste from construction and demolition (in the form of hardened concrete). The options for managing waste concrete can be considered diagrammatically:

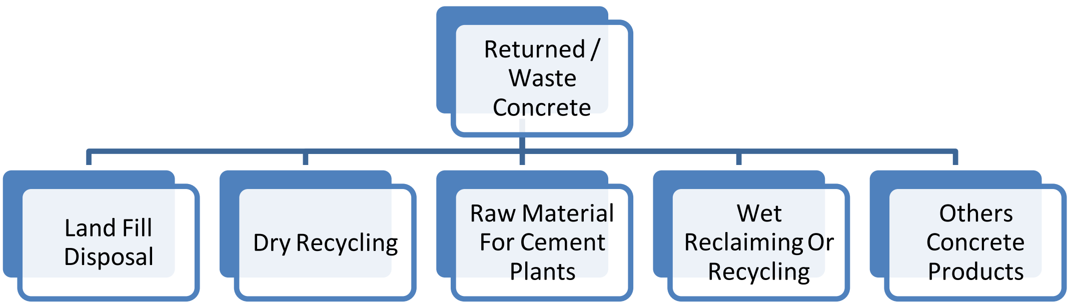

Figure 2.1: The Solution To Disposal Waste Concrete

Based on the diagram above, most of waste concrete are being disposed of at landfill areas because it is the easiest solution for managing waste concrete to date. For dry recycling and raw material for cement plants, it involved another process before it can be used to new product and it is basically a process that crushes a vast concrete to be used as recycled aggregate. Wet reclaiming or recycling is a process that involves a wet concrete by washing it before concrete becomes dry and hardened. This procedure is normally used when there are excessive concrete left in the truck and sometimes, wasted concrete are used to make pre-cast concrete blocks that can be used on site or sold. Finally, waste concrete can be reused from another concrete product such as a block by cutting into smaller sizes and it produces less environmental impact compared to other processes. The limited market available is the biggest problem in this process.

A few initiatives are taken to recycle and reuse waste concrete. Waste concrete can be used as coarse aggregate, fine aggregate or as blocks (cut-down form). Coarse and fine aggregate that come from waste concrete (old concrete) are called as recycled aggregate. Consumption of concrete in construction industries is larger and it is included with raw material which is used in making concrete. Mostly, the concrete mix involves a ratio of raw material in the order of 1:2:4 (cement: fine aggregated: coarse aggregate). So, it shows that fine and coarse aggregate are the largest raw materials needed in making concrete and because of that, recycled fine and coarse aggregate is commonly used for recycling waste concrete. The criteria to recycle and reuse of waste concrete are based on the quality of the end product of waste concrete such as the use of recycled aggregate from waste concrete. Generally, there are two types of quality for recycled aggregate which are low and higher quality. The lowest quality of recycled aggregate is used in structure with low load impact and road construction as road base. However, higher quality recycled aggregate is used as replacement aggregate in normal concrete. There are few qualities of recycled aggregate: it is based on the quality of the original product and the degree of processing and sorting of waste concrete. The quality of recycled aggregate is based on its characteristics and strength. Any contamination with other material affects the quality of recycled aggregate.

Most countries in managing to recycle and reuse waste concrete, use it in three types of form namely coarse aggregate, fine aggregate and reused in original form. In form as coarse aggregate, generally waste concrete is used for road sub-base application and concrete. A research has been carried out by the Federal Highway Administration of United States about application of coarse aggregate and found that the recycled concrete specified to an agreed quality and composition in the sub-base and base layers can allow the thickness of these layers to be reduced due to the good bearing properties of the materials. (Lohja Rudus, 2000). This theory supported the use of waste concrete as a base and sub-base the unbound cementation material in recycled aggregate was found to have a bonding that was superior to that were from fines in virgin aggregate such as the strength and a very good construction base for new pavement.

However, there are common misperceptions about the use of recycled coarse aggregate from waste concrete should not be used in structural concrete. This misperception can be changed by promoting the use of recycled aggregate with proper guidelines and effective regulations. In a developed country, a research has been carried out recently to promote the use of recycled aggregate and a few guidelines were provided with. A study by the National Ready Mixed Concrete Association (NRMCA) in the U.S.A has concluded that up to 10% of recycled concrete aggregate is suitable as a replacement for virgin aggregate for most applications including structural concrete. (Obla, et al, 2007). It is different from another study that which was carried out in the United Kingdom, in which the recycled concrete aggregate can be used up to 20% including structural concrete (Dhir and Paine, 2007) and in Australia, guidelines stated up to 30% without any noticeable difference in workability and strength compared with natural aggregate. (Clarks, Australia's Guide to Environmentally Sustainable Homes). Based on study in Australia, a well graded, good quality of recycled concrete aggregate with no greater than 0.5% brick content had the potential for use in a wide range of applications. (CISRO, 2007). From another study, a recycled concrete aggregate could be incorporated into 30-40 MPa concrete exposed to normal environment, but with some penalties in mix adjustment, permeability and shrinkage properties. (Dumitru, et al, 1999).

Besides, the waste concrete can also be used as recycled fine aggregate that will replace the natural sand. However, this may affect the mix in terms of its workability, strength and shrinkage. These problems occur because recycled fine aggregate has higher water absorption that could increase the risk of settlement and dry shrinkage cracking. Based on the study from the U.S.A, recycled fine aggregate are as good as fill for sub-grade corrections as they can act as a drying agent when mixed with sub-grade soil. (FHWA, 2004). Recycled fine aggregate can be used in sub-base or any other applications in aggregate use. It gives alternative resources in sand washes that are extracted from river or sea.

Reuse waste concrete in original form, or cutting into smaller blocks are the most effective solutions in recycling because there are less processes involved and less environmental impact generated. However, the markets of this product are limited and only a few countries use this method in recycling waste concrete. Few parts of demolishing buildings like slab or beam can be reused by dismantling and reusing it in another building.

2.3 Type of Cement Replacement.

The rapid increase in development has resulted in the need for building materials and because of that, proper studies with reliable findings are required to reduce dependence on natural resources. That is why there is a replacement of cement work to replace part or the entire cement in concrete. There are a variety of materials used to replace cement in concrete and they come from special materials which are natural, industrial waste or recycled materials. Each uses a replacement material and has different properties from each other, but the nature of the characteristics that must replace cement is pozzolans reaction. Pozzolanic materials do not harden in themselves when mixed with water but, when finely ground and in the presence of water, they react at normal ambient temperature with dissolved calcium hydroxide ($Ca(OH)_2$) to form strength-developing calcium silicate and calcium aluminates compounds. (BS EN 97-7:2000,)

It is these properties which are required to function as a binder in concrete and can increase the strength of concrete. A definition taken from "Pozzolanic and Cementitious Materials" by Malhotra and Mehta (1996) showed that, a "pozzolan" is defined as "a siliceous or siliceous and aluminous material, which in itself possesses little or no cementing property, but will in a finely divided form and in the presence of moisture - chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.". Because of that, most of the reaction in replacement of cement with pozzolans reactions to improve in terms of compressive strength of concrete and its durability. There are few cement replacements that are used in concrete which are:

2.3.1 Fly ash

Fly ash is an artificial pozzolan mostly known and results from the combustion of pulverized coal in electric power plants. Glassy amorphous spherical particles are the active pozzolanic fly ash. It is important that the coal burned at a relatively low temperature. At higher temperatures, it turns into crystal glass particles, rendering them useless as pozzolans. Fly ash is 66-68% glass, on average. There are two types of fly ash in the industry: Class F fly ash readily reacts with lime (produced when Portland cement hydrates) and alkali to form cementation compounds. In addition, for another type of fly ash is Class C, it may also exhibit a hydraulic drive (cementing) properties. The differences between this fly ash are a concrete made with Type C fly ash (opposite to Type F) has higher early strengths because it contains its own lime. Therefore, this allows pozzolanic activity to begin earlier. At later ages, Type C behaves very much like Type F - yielding higher strengths than conventional concrete at 56 and 90 days.

Standard percent fly ash utilization in cement replacement varies with the type of fly ash and based on the standard (ACI Committee 211 2008), fly ash replacement level of 15-25% is recommended for high-strength concrete. From numerous reports showed, the substitution of 50% of cement in the binder system with unprocessed High Calcium Fly Ash resulted in lower early compressive strength (25% and 7.5% lower when comparing to control at 7 and 28 days, respectively), but final strength was increased 12% at ages of 365 days. (Anastasiou, et al, 2014). However, a study by Fereshteh Alsadat Sabet (2013) found replacing cement with 10% and 20% fly ash also raised the 28-day compressive strength from 62 for control mix to 67 and 80.5 MPa, respectively. Enhancement of compressive strength of the mixes containing fly ash could be due to filling of the voids between cement grains by smaller particles of fly ash and also to pozzolanic reactivity of it.. Based on their studies, by replacing cement with fly ash, either type of fly ash that is used it may increase and improve the durability and the strength of concrete.

2.3.2 Metakaolin

Another material that is used for replacement cement is metakaolin which is manufactured pozzolan materials and produced by thermal processing of purified kaolinitic clay. Metakaolin is one of pozzolanic materials which have a size of average particle less than 2μm and a specific gravity of about 2.5. Metakaolin admixtures enhance microstructure mainly results from micro aggregate filling and the pozzolanic effect, fine particles bridge the gaps between cement particles, hydration products, matrix and aggregates, so pore structure becomes denser as well as ITZ. (Ping Duan, et al, 2013). The process to make metakaolin by high purity kaolin clay is heated using thermal activation control to dehydroxylate hydrous kaolin particles without causing recrystallization structure. The end result is almost 100% reactive pozzolan, which may chemically combine with calcium hydroxide to form additional cementation products. However, its reaction depends on the purity metakaolin and kaolin thermal processing conditions. Reactivity metakaolin has been associated with the content penta-coordinated aluminium ions which are formed during the dehydroxylation process.

There are few studies that have been conducted regarding the use of this material to replace the cement content and the results of the study showed that with suitable replacement level, metakaolin inclusion significantly enhanced the compressive strength within the first 14 days up to 27%. It seems that 10% metakaolin can be considered as a suitable replacement regarding to the economic efficiency, fresh and hardened properties of metakaolin concrete. (Rahmat Madandoust, & S. Yasin Mousavi, 2012). Among other properties available on metakaolin is because of the white colour, it does not darken the concrete. Because of that, it can be used for colour matching and design applications on buildings or other structures to show artistic value.

2.3.3 Ground Granulated Blast-Furnace Slag (GGBF)

Ground granulated blast-furnace slag is an industrial waste material resulting from the molten iron furnace slag that was cool using a water-quenching process. In concrete mixtures, GGBF slag exhibits both characteristics needed in concrete which is pozzolanic and cementation properties. It contains the same chemical components as Portland cement, but the amount in each may however differ. As the features of this material are finely granular, crystal formation by these materials is limited and it is very cementitious in nature causing mix of cement and GGBF slag, this also causes it to hydrate like ordinary cement. However, concrete made by GGBF slag are slow sets compared to the normal concrete made from ordinary cement and it sets time to these concrete depending on the percentage of GGBF slag in mix. two major uses of GGBS are in the production of quality-improved slag cement, namely

Portland Blastfurnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content typically in range of 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

There are publications by Susanto Teng, et al (2013), about the properties of high strength concrete incorporating ultra fine Ground Granulated Blast-furnace Slag. The result showed that the Ultra fine Ground Granulated Blast-furnace Slag (UFGGBS) used in this study has a large surface area, and thus, more of it is available for hydration and pozzolanic reactions. With the inclusion of UFGGBS into the concrete, it is possible to obtain a consistent mix, as the UFGGBS improves the workability and consistency of fresh concrete.

2.3.4 Limestone

Materials that are often used in replacement of cement in concrete production are limestone. The chemical properties for limestone mainly consist of calcium carbonate ($CaCO_3$), which reacts with the tricalcium aluminate (C_3A) Portland cement to form calcium carboaluminate (CCA). The use of limestone in the mix concrete has been investigated for many years and because of that, there are standards for the use of this material. According to BS EN 197-1:2000, type II cements (CEMII/A-LL 32,5/42,5) may contain various materials as their main constituents in percentages ranging from 6% to 35%. However, the use of limestone in mix concrete may affect the mechanical and durability performance of concrete. There is a recommendation based on Lafarge product i.e., an established cement supplier in the market that replacement amount ranges between 6% and 20%.

Another study was conducted to focus on binary and composite of limestone in concrete. The findings revealed that the compressive strength of the binary Portland cement and limestone concrete decreased when increasing the Portland cement replacement level. Based on these results, strength loss was more pronounced when the replacement level of Portland cement by limestone was higher than 15% replacement. In environmental concept, the binary and composite cements significantly contributes to reducing the embodied CO_2 emissions compared with Portland cement. (Mohammed Seddik Meddah, et al, 2013). Through various studies conducted, it showed that limestone earn significant potential to replace the use of cement in concrete

2.3.5 Rice Husk

Rice husk ash is a waste product resulting from industrial and agricultural waste. This material is a product resulting from the manufacture husk rice. In milling, about 78% of rice production is heavy, broken rice and bran. But the remaining 22% is rice husk. The original use of this husk is used as fuel for the rice mills to generate steam for the parboiling process. But the use of these fuels produces large amounts of ash that has no useful immediate applications and usually dumped into waterways causing pollution and water pollution. The properties of this husk contains about 75% organic volatile matter and the balance 25% of the weight of this husk is converted into ash during the firing process, known as rice husk ash (RHA). RHA in turn contains around 85% - 90% amorphous silica.

From other studies, the chemical composition of RHA depends on temperature and burning time, but the variations in the components are not significant. The ash from open-field burning (or from non-controlled combustion in industrial furnaces) usually contains a higher proportion of non-reactive silica minerals such as cristobalite and tridymite, and it should be ground into very fine particles to develop pozzolanic activity. (Gemma Rodríguez de Sensale, 2010).

2.3.6 Condensed silica fume

Most material which is used to replace cement content is based on pozzolon material. An alternative material which is a highly pozzolon is condensed silica fume. Condensed Silica Fume is also known as micro silica, and it is the product of surplus high-purity quartz with coal in electric furnaces in the production of silicon, SiO and ferrosilicon alloys. Besides, it also arises from the production side other silicon alloys such as ferrochromium, Ferromanganese, ferromagnesium, and calcium silicon. Combination use of silica fume with others cementations materials results in reduced water demand compared to mixes containing silica fume. Using ternary mixes it is also possible to reduce water demand compared to the control concrete. (Ali Reza Bagheri, et al, 2012). The typical particle size of silica fume is around 0.1 –0.5 mm and the nitrogen BET surface is 20,000 m^2/kg. Once in the century before the mid-1970s, silica fume was released into the air and then concerned for the environment due to the accumulation and burial of silica fume, steps have been taken to use it economically desirable in many applications. In theory, using condensed silica fume into mix may increase compressive strength, bond strength, and abrasion resistance; reduce permeability; and therefore helps in protecting reinforcing steel from corrosion.

There were some studies about replacement cement using silica fume and the result was observed based on strength and durability performance of concrete containing silica fume. From this study, concrete with silica fume had consistently higher compressive strength than the normal concrete. There was a systematic increase in compressive strength with the increase in silica fume content in concrete at different water/ cement ratios. The utilizations of silica fume led to an improvement in early age mechanical properties (Erhan Güneyisi, et al, 2012). In other studies, it was reported that compressive strength of silica-fume concrete was significantly improved the concrete. The optimal replacement level is 7.5–10% for silica fume and utilizing pozzolans is more effective in enhancing the durability of concrete than lowering w/c ratio. (Mahdi Valipou, et al, 2013)

2.4 Impact of Recycled Concrete into New Concrete

Recycling a waste concrete into a new concrete will affect the concrete situation in terms of load capacity and durability. Many studies have been conducted especially in developed countries indicating that the use of waste concrete to new concrete will affect and alter the ability of the concrete. There are a few effects that mostly been highlighted in the use waste concrete into new concrete:

2.4.1 Compressive Strength

The compressive strength is the most significant factor used in testing the ability of concrete and it became a benchmark in design a concrete. Most studies revealed that the uses of waste concrete into new concrete are definitely changing the compressive strength of concrete. Research conducted in Malaysia revealed that an increase in a percentage of recycled aggregate of the normal aggregate will decrease the compressive strength. For this study, the researcher used recycled aggregate from waste concrete as replacement natural aggregate in different percentage of replacement from 0 % to 100 % and different water-cement (w/c) ratio from the range 0.4 to 0.6. The result shows that, increasing percentage of recycled aggregate will decrease the compressive strength up to 43%, however, the strength will increase due to lowering the water-cement (w/c) ratio. (Suraya Hani Adnan,et al; 2007)

Theory on recycling waste concrete is quite similar to other studies about the use of waste concrete as replacement raw materials in concrete mix. In other research, there are 3 different recycled aggregates being used which are RG I for recycled coarse aggregate having a specific gravity of 2.53 and a water absorption of 1.9%, RG III for recycled coarse aggregate having a specific gravity of 2.4 and a water absorption of 6.2%, and RS II for recycled fine aggregate having a specific gravity of 2.36 and a water absorption of 5.4%. The percentages of replacement are in the range 30 % to 100% or replacement natural aggregate. The result shows that, compressive strength of concrete using recycled coarse aggregate with lower absorption (RG I) was similar to that of the control specimen. However, compressive strength of concrete containing both higher absorption fine and coarse aggregates, RS II or RG III, was 60 to 80% of the control specimen at early ages of 1 and 3 days and slightly improved with the increase of age. It can be conclude that, the compressive strength of the recycled aggregate increased due to the age and the increase percentage of replacement recycled aggregate will affect the decrease of the compressive strength. (Keun-Hyeok Yang, et al; 2008).

There are studies about the influence in strength of waste concrete before it is recycled due to a percentage of replacement in new concrete. A study are conducted with three different concrete grades (40 MPa, 60 MPa and 100 MPa) where crushed concretes were used as coarse recycled aggregate concrete for high performance concrete production. According to these studies, recycled aggregate concrete which is made from waste concrete grade 40 can be used to produce high strength concrete