CERAMIC TILES WASTE AS COARSE AGGREGATES PARTIAL REPLACEMENT FOR CONCRETE PRODUCTION

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ABSTRACT

In accordance with conservation efforts, this research focuses on ceramic tile waste as partial coarse aggregates replacement for concrete production, prevention of environmental pollution with considering the elements of sustainable and cost-saving construction projects, especially material usage. Moreover, many of the construction industry in Malaysia produce construction waste that contributes largely in solid waste. Utilising ceramic tile waste, this research will focus on ceramic wastes obtain from the construction industry in Malaysia. Presently, much of ceramic industries production goes to waste, which is not undergoing the recycle process yet. A total forty cubes with the same dimensions (100 mm x 100 mm x 100 mm) were cast with five different proportion. Eight cube as one type of control proportion that is 0 % percentage of ceramic waste as partial replacement of coarse aggregates and the remaining 32 cubes are 5% ,10 % ,15% and 20% of ceramic as partial replacement of coarse aggregates. Besides that, all other parameters are constant. The concrete cube were tested as destructive test at last which is compression test that to find out compressive strength of specimens of hardened concrete at 3 days, 7 days and 28 days .Before undergoing the destructive test, the performance of the concrete was determined by undergoing slump test, compressive strength test, Ultrasonic Pulse Velocity test, Rebound Hammer test and water absorption test. From the results of the study, samples of concrete with 15% ceramic coarse aggregate replacement (A4) has reached optimum strength. Findings showed that concrete containing Ceramic Tile 15% showed the highest amount of strength compared with other specimen. Addition of 15% ceramic material has led to compaction of concrete structures in ceramics and exhibit low water absorption rate.

ABSTRAK

Selaras dengan usaha-usaha pemuliharaan, kajian ini memberi tumpuan kepada sisa jubin seramik sebagai sebahagian pengganti kepada agregat kasar untuk pengeluaran konkrit, pencegahan pencemaran alam sekitar dan mempertimbangkan unsur-unsur projek-projek pembinaan yang berterusan dan penjimatan kos, terutamanya dari segi penggunaan bahan. Tambahan pula, kebanyakan industri pembinaan di Malaysia menghasilkan sisa pembinaan yang menyumbang sebahagian besar daripada sisa pepejal. Menggunakan sisa jubin seramik, kajian ini akan memberi tumpuan kepada sisa seramik yang diperolehi daripada industri di Malaysia. Pada masa kini, industri seramik menhasilkan sisa lebihan iaitu bahan buangan yang tidak menjalani proses kitar semula lagi. Empat puluh jumlah kiub dengan berdimensi yang sama iaitu (100 mm x 100 mm x 100 mm) dibancuh dengan lima perkadaran yang berbeza. Satu jenis kawalan perkadaran iaitu 0% sisa seramik sebagai penggantian sebahagian agregat kasar sebagai spesimen kawalan dan baki 32 kiub adalah untuk jenis perkadaran 5%, 10%, 15% dan 20% seramik sebagai sebahagian pengganti agregat kasar .Di samping itu, semua parameter lain adalah malar. Kiub konkrit telah diuji dengan ujian pemusnah pada akhirnya iaitu ujian mampatan untuk mengetahui kekuatan mampatan spesimen konkrit yang telah keras pada hari yang 3 ,7 dan 28 .Sebelum semua Sampel menjalani ujian yang pemusnah, prestasi konkrit telah ditentukan terlebih dahulu dengan melakukan ujian kemerosotan, ujian Ultrasonic Pulse Velocity, ujian Rebound Hammer dan ujian penyerapan air. Dari hasil kajian, sampel konkrit dengan 15% (A4) seramik sebahagian penggantian agregat kasar telah mencapai kekuatan yang optimum. Penemuan menunjukkan bahawa Konkrit Seramik yang mengandungi Seramik sebanyak 15% menunjukkan jumlah kekuatan yang tertinggi berbanding dengan specimen yang lain. Penambahan bahan seramik 15% telah membawa kepada pemadatan struktur dalam konkrit seramik dan mempamerkan kadar penyerapan air yang rendah.

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%	Percent
μs	Microsecond
MPa	Megapascal
kg	Kilogram
N/mm^2	Newton per millimeter square
kg/m^3	Kilogram per metre cube
km/s	Kilometre per second

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In accordance with conservation efforts, this research focuses on ceramic tile waste as partial aggregates replacement for concrete production prevention of environmental pollution and considers the elements of sustainable and cost-saving construction projects, especially material usage. As a developing country, construction sector is one sector that can build our economy and produce successful contractors. Despites this industry brings a lot of advantages to the country such as creating more job opportunity and brings a positive economic growth, but there are some issues that need attention from the public as well. Most of the construction and demolition waste in our country are not recycle but end up in landfills occupying valuable land not to mention the cost incurred in landfilling (Wen, 2007). However, many of the construction industry in Malaysia produce construction waste that contributes largely of solid waste. In general, solid waste material is a result of the construction work waste material or residual results from renovation of the building such as stone, wood, iron, cement and other waste materials. This research will focused on ceramic wastes obtained from the industry in Malaysia. Presently in ceramic industry the production goes as waste, which is not undergoing the recycle process yet. Conventionally, the coarse aggregate used in concrete productions are gravel, crushed stone, granite, and limestone.

1.2 PROBLEM STATEMENT

The demand of construction materials for project is increasing. Therefore, there is a need to explore alternative building materials from industrial waste materials that can be recycled. Ceramic tiles are often discarded as waste after defined as useless. But it can be recycled and can be used as a construction material in present world which is seeking for alternative construction materials which are economical, environment friendly as well as provides same quality as that of a normal aggregate made of regular aggregates (Jalali, 2010). Ceramic wastes can be used safely with no need for dramatic change in production and application process.

1.3 OBJECTIVES OF STUDY

This study was conducted to achieve the following objectives:

i) To study the strength developments hardened concrete with waste ceramic coarse aggregate.
ii) To determine the effect of various percentage of ceramic waste as partial coarse aggregates replacement towards compressive strength of concrete.
iii) To determine the water absorption of ceramic aggregate concrete containing various content of ceramic tile as partial coarse aggregates replacement material.

1.4 SCOPE OF STUDY

Ceramic tile waste use in this research was taken from old site factory .The scope of concrete use is in Malaysia construction industry. The experiment is only limit to five lab tests, Slump test, compression test, ultrasonic pulse velocity test, Rebound hammer test and water absorption test.

Slump test is used to determine the correct hydration of a batch of concrete. The slump is the distance the wet concrete settles after the slump cone is lifted off. It is essential test to test the workability of fresh concrete, this test very useful in detecting variations in the uniformity of a mix of given nominal proportions. All of the specimens were subjected to immerse in water tank for curing process for being test. Compressive test is to determine the strength of the concrete cube at the 3rd, 7th and 28th day of the casting period. The value obtained from the test must be higher than the standard specified strength for the concrete cube to pass.

Non-destructive test also need to be carry out (rebound hammer test and UPV test). Then, graph that plot from these tests need to be analyze to know the optimum percentage of Ceramic tile waste used in ceramic concrete.

Ultrasonic pulse Velocity test basically consists of transmitting the mechanically generated pulses through concrete cube with the help of electro-acoustic transducers and measuring the velocity of the longitudinal waves generated by the applied pulses .UPV can be correlated to much desirable information pertaining to concrete, such as elastic modulus, strength and uniformity of concrete

The main reason of water absorption is to determine the water characteristics in ceramic concrete compare to typical concrete or control concrete.

1.5 SIGNIFICANCE OF STUDY

There are many inquiry and study that had carried carry out to improvise the quality of concrete production and to create various types of concrete that will be used for different purposes according to its suitability. Many researches had been conducted to intensify the quality or properties of the regular concrete by mixing or adding other materials into the natural conventional concrete. For this study, ceramic tile waste is used as partial coarse aggregates replacement to natural coarse aggregates. The study is essential because the proposed material to replace coarse aggregates is waste product from construction. If ceramic waste is suitable, it can be used in concrete production. This will reduce the waste material from construction as ceramic tile waste can be recycled for concrete production purposes. Besides, we can cut down the uses of natural aggregates that are produced from quarrying process which is non-environmental process and harmful to environment. The concrete's production cost can be reduced because the alternative material is waste material that is very low in cost.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This research is supported with the related reading material previous research about the Ceramic waste material which had been done as the references to describe more and explain the characteristic and application of Ceramic as partial replacement in the concrete production. So far the reutilization of ceramic wastes and has been practiced, but the amount of wastes reused in that way is still negligible. Hence, the need for its application in other industries is becoming absolutely very useful for getting benefit. Construction industry can be the end user of all ceramic wastes and in the same way can contribute Green building practices. Agricultural was and industrial waste was among two major wastes that use as replacement to the composition. Agricultural waste can be unused materials in form of solid and liquid.

2.2 CERAMIC WASTES AS THE PARTIAL REPLACEMENT FOR COURSE AGGREGATE IN CONCRETE PRODUCTION

In early time, reactions between limestone and oil shale had been discovered during spontaneous combustion occurred in Jerusalem to form a natural deposit of cement compounds. Over thousands of years, by the time these materials were improved upon, combined with other materials and change into modern concrete. Now days, concrete are made by using Portland cement, coarse aggregates, fine aggregates and water. The performance characteristics of concrete can be observed with change according to the different forces that the concrete will need to resist. The ingredients of concrete and their proportions are called the design mix. Large scale applications of concrete now day are construction of Petronas Twin Towers Kuala Lumpur. Time after time, lots of invention have been made to improve the quality of concrete in the concrete technology. With the improvement that they had made, the superstructure size in the construction can be reduce such as beam and column.

2.2.1 Properties of Ceramic Coarse Aggregate

Ceramics is one of the most ancient industries on the planet. The word Ceramics from the Greek word *keramikos* meaning "potters" clay. According to (Mustafa et al., 2008) the particle shape analysis of ceramic waste coarse aggregate has diverse particles shape with the crushed stone normal concrete. The important specification of coarse aggregate are its shape, texture and the maximum size , as in further ceramic waste aggregate was found to be smoother than that of ordinary crushed stone aggregate. Surface texture and mineralogy affect the binder between the aggregates and the paste as well as the stress level at which micro cracking begins, the aggregate strength becomes influential in the case of higher-strength concrete. Ceramic wastes retain characteristics suitable for use as pozzolanic materials and thus are suitable for use in the making of concrete. (Zimbili et al., 2014).

Figure 2.1: Ceramic Coarse Aggregates

2.2.2 Properties of Concrete That Were Made from Ceramic Waste Coarse Aggregate.

Fresh ceramic waste coarse aggregate and quarry dust fine aggregates concrete more less cohesive and workable than conventional concrete because high water absorption of ceramic waste (Abdullah et al., 2006). Besides that, the compressive strength for ceramic coarse aggregate concrete varied from 15 - 30 N/mm^2. Research completed by (Torgal, 2010) found that large differences in early curing ages and smaller differences at long curing ages.

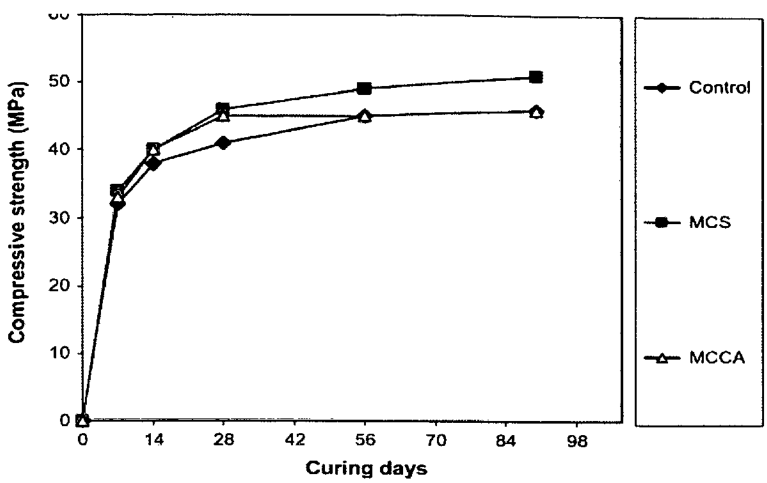

Figure 2.2 : Compressive Strength Development

Source: F. Pacheco Torgal and S. Jalali (2010)

The result indicate that compressive strength of both concrete with replacement ceramic coarse aggregates (MCCA) and Ceramic sand (MCA) are higher than conventional concrete (control). The results are very promising but underperformed in water absorption under vacuum test.

In the of cement partial replacement (Levat et al., 2009) found that substitution of ceramic waste percentages of below 30% had no negative effects on the mechanical behavior of Portland cement, thus demonstrating the viability of reusing ceramic roofing tile waste in the production of pozzolanic cements.

The result below shows the mean value 36 test that have been done, Fresh ceramic waste coarse aggregate was more cohesive and workable than conventional concrete the fact that due to the lower water absorption and smooth surface texture (Bakri, 2008).

Table 2.1: Result compression test for 7 days with different water cement ratio.

W/c Ratio	Type of Ceramic Waste Aggregate	Slump Test (mm)	Compressive Strength (MPa)
0.4	Flower pot	45	17.46
	Tiles	30	13.81
	Clay Brick	45	4.63
	Conventional Concrete	85	21.53

W/c Ratio	Type of Ceramic Waste Aggregate	Slump Test (mm)	Compressive Strength (MPa)
0.5	Flower pot	45	18.78
	Tiles	30	12.44
	Clay Brick	40	5.24
	Conventional Concrete	45	19.26

2.2.2.1 Water absorption properties .

According to the (Tavakoli, 2012), Comparison between the water absorption new concrete and the control samples was made with the ceramic tiles consisting percent of 0, 10, 20, 30, and 40 that were substituted for coarse aggregates. The absorption capacities (AC) represent the maximum amount of water the aggregates can absorb. For common aggregate, the absorption capacities are order of 0.5% to 2%. Absorption capacities greater than 2% often indication that the aggregates in concrete may have a potential durability problem (Nawy, 2008)

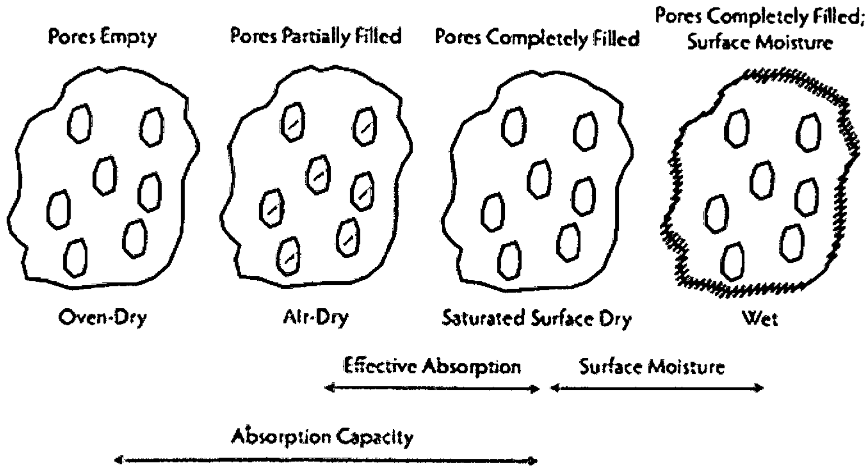

Figure 2.3: Aggregates water absorption capacity

2.2.3 The Types of Ceramic Waste

Based on previous research done by (Pachero, 2009), reutilization of ceramic waste already been practiced but the amount of waste reused in that way is still negligible .Ceramic waste divided by two categories: First, all fired wasted generated by the structural ceramic factories that use only red pastes such as brick, block and roof tiles. Second, all fired wasted produced in stoneware ceramic white paste such as wall, floor tile and sanitary ware.

The chemical composition of fired ceramic is not different from the raw material to make this product. Only the mineralogical composition is modified when the materials are heated. Red paste shows high proportion of iron oxide that is responsible for the red color of brick

Table 2.2: Mineralogical composition of ceramic wastes

Sample type	Majors element	Minors	Trace
Ceramic brick	Q	He ,C ,Ah ,Mv ,R	Fd
Overheated brick	Q,Fd4	Mv, Cr, Ah, R, He	Lm, G
White roof tile	Q,Mv,Fd4	Ah, He, Cr	G, Hr, Cs, R
Red roof tiles	Q.I(MV)	C, Fd	Ah, He
Ceramic table for cover	Q, Fd	An, He , R	SF, Cr, Mu, Hr,
White stoneware tile	Q,Fd4	Cr, ICN, G , Px	Zr, Mu, He, Ti
Red stoneware tile	Q,Fd1	Cr, Mu , Px	Ah, Zr, He, Mg, Lm
China stoneware tile	Q	Fd1, Cr, Px	Cu, He

Q, quartz ; Fd, feldspars; Fd1, albite Ca, ord; Fd2, anorthite Na, ord; Fd3, orthoclase; Fd4,anorthoclase; Ah, anhydrite; C, calcite; Co, cordierite; Cs, celsian; Cr, cristobalite; Cu, corundum; E, esseneite; G, gehlenite; Ha, hauyne; He, hematites; Hr, hercynite; I, illite; Lm, lime; M, mullite; Mg, magnetite; Mv, muscovite; Px, piroxene; SF, franklinite; Ti,titanite and Zr, zircon

2.2.4 Other Applications of Ceramic Waste Substitution

Ceramic are made from natural substantial which have a high proportion of clay minerals. So, the manufacturing process involved in ceramic materials needs high firing temperatures which may effective the clay minerals, enhance them with pozzolanic properties and forming hydrated outputs related to those obtained with other active materials.

2.2.4.1 Asphalt Aggregates

First of all, a lot of researches about the suitability of ceramic materials for use in the construction of public works were carried out. Researched made by (Fatima, 2014) ceramic waste as a filler material in Semi-Dense Bituminous Concrete. This study focuses on a laboratory evaluation of the mechanical performance of asphalt concrete mixes using Ceramic Waste as filler. It was decided that ceramic industrial waste can be exploited as a replacement for conventional mineral fillers in bituminous mixes. The utilization of ceramic waste in the asphalt concrete mixes may answer the compelling disposal problem to save the environment.

2.2.4.2 Pozzolanic cement replacer

As expected Quartz and Feldspars are main element, essentially belong to ceramic wastes. Investigations have been carried out by researchers in the past shows that for 20% cement replacement ceramic waste substitution of cement are represents 3.75% of the cost of Portland cement. This indicates saving of around 17% in the cost of Portland cement in concrete. The cost of cement represents almost 45% of the concrete cost. Therefore, overall cost of concrete will be reduced by more than 7.5%. The manufacturing process involved in ceramic materials have need high firing temperatures which may activate the clay minerals, enabling them with pozzolanic properties and create hydrated products similar to those obtained with other active materials.(Cristiano,2014)

2.3 AGGREGATES

Aggregates composed 60 -75 % of production of concrete. Act as inert filler materials used in production of concrete. These diagrams show various aggregates weight classification and it mainly used for production purpose (Halit, 2014).

Table 2.3: Aggregates Weight

Weight	Examples of Aggregates Used	Uses for the Concrete
ultra-lightweight	vermiculite, ceramic	can be sawed or nailed, also used for its insulating properties
lightweight 12 (kN/m3)	expanded clay, shale or slate, crushed brick	Lightweight concrete for structures.
normal weight 23-26 (kN/m3)	crushed limestone, sand, river gravel, crushed recycled concrete	used for normal concrete projects.
heavyweight 25-29 (kN/m3)	steel or iron shot; steel or iron pellets	used for making high density concrete for shielding against nuclear radiation

Source: Halit Yazici 2014

The selection of aggregates is very important because due to properties that will affect the strength, toughness, mixing ratio, economical concrete production. When the void between the aggregates is minimized, then the need for cement to fill empty spaced can be reduced to maintain the workability and the strength of concrete. The lower water and cement quantity in water and cement ratio water cement ratio (w/c) resulting more durable concrete.

An aggregate has been categories into two types such as coarse aggregate that have a size more than 5mm and fine aggregate with a size less than 5mm (Pilus, 2005). Coarse aggregates usually gravel and crush stone .The sizes are up to maximum size permitted for the job for example a boulder.

Classification of aggregates base on size and dimensions:

- Coarse aggregate which retained on the No.4 (4.75mm) sieve. The function of the coarse aggregate is to act as the main load-bearing component of the concrete
- Fine aggregates which passing No.4 (4.75mm) sieve and predominately retained on the No.200 (75μm) sieve. The fine aggregates serve the purpose of filling all the open space in between the coarse particles.

In this study, the use of ceramic waste product as alternative coarse aggregate is proposed. Due to it contributes to higher productivity to concrete production and by the replacement will help in minimizing the use of natural resources of coarse aggregate.

2.3.1 Properties of Aggregates

Properties of aggregates are vital to determined are compressive strength, bond strength, aggregates shapes, aggregate surface and size, aggregates permeability aggregates reaction of chemical. Aggregates used for concrete are making good quality should be selected based on several criteria attributes.

2.3.1.1 Strength

Tensile strength of soil aggregates refers to the stress of force per unit area requires breaking an aggregate. Ability of aggregates to resist the maximum destructive force without being mechanically fractured .Aggregates strength also influenced the micro scale physical behavior of concrete such as erosion, infiltration and permeability. (Lal, 2006)

2.3.1.2 Aggregates grain shape

There are variety shapes of aggregates such as round, irregular, angular, flaky and long. It can be conclude that, the use of long and flaky aggregates in the concrete production requires higher water cement ratio (w/c) than round shape aggregates. That make aggregates with a shape of round and irregular is more suitable for making good concrete mixing as the effect of water and cement ratio play an important role to the strength of concrete. The proper shape must be taken wisely

Table 2.4: Aggregates shapes properties

Aggregates shapes	Voids in a concretes	Interlocking behavior characteristics	Mixing workability
Rounded	33-35 %	Poor locking between the aggregates and reduce strength of concrete	High workability
Irregular	35-37%	The interlocking provided by this type not up to the required level but better than rounded aggregates.	Medium workability
angular	37-40%	Interlocking is good	Low workability, need more cement paste for workable concrete with high strength

3.3.13 Impermeability

The distribution ot liquid moving through a concrete is controlled by the properties of the constituent materials of which the concrete is made .If the coarse aggregates is relatively porous as is the case is lightweight aggregates the liquid movement will occur in aggregates (Reinhardt, 1997). Impermeable characteristic is vital in consideration to construct of certain structures like a water tank, reservoir, and other structure that holds or store water

2.4 PREVIOUS RESEARCH OF COARSE AGGREGATES REPLACEMENT MATERIAL.

Recycled the industrial waste and agricultural waste plays an important role to preserve the natural resources such as granite aggregates. Coarse aggregates can be replaced by following material.

2.4.1 Recycled Tires

Study made by (Liew 2014) ,compressive strength decreased 32% with 10% replacement of coarse aggregate and dropped further with higher replacement levels. This consequence in only two mixtures with 10% tire chips by volume of coarse aggregate met the Class P concrete compressive strength requirement at 28 days of age. Both cement content and tire chips content affected the compressive strength of the rubberized mixtures. The mixtures with low cement content had lower compressive strengths. A reduction in compressive strength was observed with increase of tire chips content. As the rubber aggregate increased, the unit weight decreased linearly regardless of the cement content.