STUDY ON EFFECT OF CRUSHED TILE AS COARSE AGGREGATE REPLACEMENT IN CONCRETE

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ABSTRACT

As a developing country, more and more old buildings torn down to be replaced by new buildings in line with current technological advances. At the same time, construction and demolition (C&D) waste will also increase. Therefore, rather than allow the C&D waste without the benefit, it is also can be used as coarse aggregate in concrete. C&D waste which is include concrete rubble, tile and waste bricks can be use as alternative material for concrete mix. This research is discussed about using crushed tile which is one of C&D waste as coarse aggregate in concrete mixing. The performances in term of engineering properties of concrete using crushed tile as coarse aggregate replacement were investigated. There are four series of concrete mix design with 0%, 5%, 10% and 15% were designated as Sample A, B, C and D. 36 number of cube sample with dimension of 150 mm x 150 mm x 150 mm and 12 number percentage cylinder sample with diameter 150 mm and height 300 mm were produced. The result of this research can be identified after laboratory testing such as workability test, compression test and splitting tensile test. Result of workability test shows that all tests are high in workability category. It was found that at age 28 days the compressive strength values for sample B is increased 4.08% than sample A. Splitting strength results were similar and higher compare to control sample.

ABSTRAK

Sebagai sebuah negara membangun, semakin banyak bangunan lama yang dirobohkan untuk digantikan dengan bangunan baru selaras dengan kemajuan teknologi semasa. Pada masa yang sama, sisa pembinaan dan perobohan juga akan meningkat. Oleh itu, daripada membiarkan sahaja sisa pembinaan dan perobohan tanpa dimanfaatkan sebaiknya, ia juga boleh digunakan sebagai agregat kasar dalam konkrit. Sisa pembinaan dan perobohan yang termasuk runtuhan konkrit, jubin dan batu bata sisa boleh digunakan sebagai bahan alternatif untuk campuran konkrit. Kajian ini membincangkan mengenai penggunaan jubin yang dihancurkan juga merupakan salah satu sisa pembinaan dan perobohan sebagai agregat kasar dalam bancuhan konkrit. Sifat kejuruteraan konkrit yang menggunakan jubin yang dihancurkan sebagai pengganti agregat kasar telah dikaji. Terdapat empat siri campuran konkrit iaitu 0%, 5%, 10% dan 15% telah ditetapkan sebagai Sampel A, B, C dan D. 36 bilangan sampel kiub dengan dimensi 150 mm x 150 mm x 150 mm dan 12 bilangan sampel silinder dengan diameter 150 mm dan ketinggian 300 mm telah dihasilkan. Hasil kajian ini dikenalpasti selepas ujian makmal seperti ujian kebolehkerjaan, ujian mampatan dan ujian "Splitting Tensile Strength". Keputusan ujian kebolehkerjaan menunjukkan bahawa semua ujian adalah tinggi dalam kategori kebolehkerjaan. Pada usia 28 hari nilai kekuatan mampatan sampel B meningkat 4.08% daripada sampel A dikenalpasti. Manakala ujian "Splitting Tensile Strength" mempunyai kekuatan yang sama dan lebih tinggi berbanding dengan sampel kawalan.

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LIST OF ABBREVIATIONS

BS	=	British Standard
kg	=	Kilogram
N	=	Newton
N/mm^2	=	Newton per millimeter square
mm	=	Millimeter
s	=	Seconds
h	=	Hour
L	=	Litter
m^3	=	Meter cube
kg/m^3	=	Kilogram per meter cube

CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementations materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures. Concrete is the most important things in term of quality control. Quality of concrete depends on the constituent materials, their proportions, mixing, transporting, placing, compaction and curing of concrete. The concrete with proper mix proportion has the needed workability and develops the targeted compressive strength. Efficient concrete mixers are needed to mix the ingredients and to produce a cohesive and workable concrete. Concrete admixtures play an important role in providing the needed workability for transporting and placing the concrete in the formwork. Once the concrete is placed and consolidated by compaction in the formwork, protected and cured properly, it should be a good quality concrete, and is expected to perform satisfactorily in the service life. However, research has shown that aggregate in fact plays a substantial role in determining workability, strength, dimensional stability, and durability of the concrete. Also, aggregates can have a significant effect on the cost of the concrete mixture. Recycled aggregates (from construction, demolition and excavation waste) are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.

Conventional concrete aggregate consists of sand (fine aggregate) and various sizes and shapes of gravel or stones. However, there is a growing interest in substituting alternative aggregate materials, largely as a potential use for recycled materials. Crushed tile is one of substituting alternative aggregate material which an industrial and construction waste that can cause environmental pollution. Therefore the possible utilization of this material would reduce environmental pollution. Even though aggregate typically accounts for 70% to 80% of the concrete volume, it is commonly thought of as inert filler having little effect on the finished concrete properties.

Crushed tile can be use as coarse aggregate to decrease cost and it also supports environmental health. The amount of tile waste on earth is enough for use as an aggregate in concrete. Tile is produced from natural materials sintered at high temperatures. There are no harmful chemicals in tile. Waste tiles cause only the apparition of pollution. These waste materials can be recycled to save money. Crushed tile aggregate, CTA, is a material especially proposed for the buildings constructed in hot climates. The unit weight of concrete is decreased with use of the CTA compared to the control concrete. CTA was examined and no noteworthy negative effects on the strength of the concrete were found.

1.2 Problem Statement

As a developing country, more and more old buildings torn down to be replaced by new buildings in line with current technological advances. At the same time, construction and demolition (C&D) waste also increase. Therefore, rather than allow the C&D waste without the benefit, it is also can be used as coarse aggregate in concrete. C&D waste which is include (concrete rubble, tile and waste bricks). The statistic of C&D waste in Seberang Prai from 2001 to 2003 is 5253.7 tonne (Faridah et al, 2004). Crushed tile is an industrial waste that is one of C&D waste that can cause environmental pollution in term of various toxic substances. This issue related to environmental conservation have gained great important in our society in recent years (Xue et al., 2009). I recommend that waste tile can be used as an alternative construction material for coarse aggregate in concrete in order to help save the existing resources and at the same time can decrease the number of C&D waste and also can help reduce environmental pollution.

1.3 Objective

The main objectives of the study are:-

i. To determine the workability of concrete containing 0%, 5%, 10% and 15% crushed tile.
ii. To determine the compressive strength of concrete containing 0%, 5%, 10%, 15% of crushed tile aggregate.
iii. To determine the splitting tensile strength of concrete containing 0%, 5%, 10% and 15% of crushed tile aggregate.

1.4 Scope of Study

This study concentrated on investigation of the engineering properties of concrete by using crushed tile and also to study the compressive strength of concrete and splitting tensile strength with different percentage by mass of aggregate tile and also plain concrete as a control mix.

In concrete performance, each series of concrete were designed for grade 30 (1:1:2 - cement: sand: aggregate) with constant water cement ratio (w/c) of 0.57 will be conducted. The plain concrete compose of cement, water, aggregate and sand were considered as a control mix without replacing with crushed tile aggregate. There are four series of concrete mix design with 0%, 5%, 10% and 15% were designated as Sample A, Sample B, Sample C and Sample D respectively.

The concrete were casted and poured into mould and the hardened concrete was taken out from the mould after 24 hours. 36 number percentage cube sample 150 mm x 150 mm x 150 mm and 12 number percentage cylinder sample with diameter 150 mm and height 300 mm were produced and cured in water before testing. Then, the hardened concrete was cured in water for 7, 14, and 28 days for all mixes. The compressive strength tests at 7, 14 and 28 days and splitting tensile test at 28 days were conducted after the specimens matured due to curing period for entire specimens. Mix proportion as illustrated in Table 1.1 and Table 1.2 showed all the standard and specifications for corresponding test.

Table 1.1: Mix Design for 1 m^3

Material	Sample A	Sample B	Sample C	Sample D
Cement (kg)	400	400	400	400
Sand (kg)	827	827	827	827
Coarse Aggregate (kg)	933	866.35	839.7	793.05
Crushed Tile Aggregate (kg)	0.00	46.65	93.3	139.95
Water (L)	225	225	225	225

Table 1.2: Standard and Specification Test

Testing	Standard and Specifications
Slump Test	BS 1881: Part 102: 1983
Compaction Factor Test	BS 1881: Part 103: 1983
Vebe Test	BS 1881: Part 104: 1983
Concrete Compression Test	BS 1881: Part 116: 1983
Splitting Tensile Strength Test	BS 1881: Part 117: 1983

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures. According to wikipedia, the word concrete comes from the Latin word "concretus" (meaning compact or condensed), the perfect passive participle of "concrescere", from "con-" (together) and "crescere" (to grow). Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a robust stone-like material. Concrete is used to make pavements, pipe, architectural structures, foundations, motorways/roads, bridges/overpasses, parking structures, brick/block walls, footings for gates, fences and poles and even boats. Concrete is used more than any other man-made material in the world. As of 2006, about 7.5 billion cubic meters of concrete are made each year—more than one cubic meter for every person on Earth. According to wikipedia, Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are used mainly for this purpose. Recycled aggregates (from construction, demolition and excavation waste) are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted. Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative "exposed aggregate" finish, popular among landscape designers. The presence of aggregate greatly increases the robustness of concrete above that of cement, which otherwise is a brittle material and thus concrete is a true composite material. Redistribution of aggregates after compaction often creates inhomogeneity due to the influence of vibration. This can lead to strength gradients.

2.2 Concrete Aggregate Substitute

Conventional concrete aggregate consists of sand (fine aggregate) and various sizes and shapes of gravel or stones. However, there is a growing interest in substituting alternative aggregate materials, largely as a potential use for recycled materials. While there is significant research on many different materials for aggregate substitutes (such as granulated coal ash, blast furnace slag or various solid wastes including fiberglass waste materials, granulated plastics, paper and wood products / wastes, sintered sludge pellets and others), the only two that have been significantly applied are glass cullet and crushed recycled concrete itself.

According to NAHB Research Centre, even though aggregate typically accounts for 70% to 80% of the concrete volume, it is commonly thought of as inert filler having little effect on the finished concrete properties. However, research has shown that aggregate in fact plays a substantial role in determining workability, strength, dimensional stability, and durability of the concrete. Also, aggregates can have a significant effect on the cost of the concrete mixture.

Certain aggregate parameters are known to be important for engineered-use concrete: hardness, strength, and durability. The aggregate must be "clean," without absorbed chemicals, clay coatings, and other fine materials in concentrations that could alter the hydration and bond of the cement paste.

It is important to note the difference between aggregate and cement, because some materials have found use both as a cementitious material and as aggregate (such as certain blast furnace slags). Materials that have been researched or applied only as cement substitutes are addressed in another Technology Inventory article - Cement Substitutes.

Aggregate composed of recycled concrete generally has a lower specific gravity and a higher absorption than conventional gravel aggregate. New concrete made with recycled concrete aggregate typically has good workability, durability and resistance to saturated freeze-thaw action. The compressive strength varies with the compressive strength of the original concrete and the water-cement ratio of the new concrete. It has been found that concrete made with recycled concrete aggregate has at least two-thirds the compressive strength and modulus of elasticity of natural aggregate concrete.

Field-testing has shown that crushed and screened waste glass may be used as a sand substitute in concrete. Nearly all waste glass can be used in concrete applications, including glass that is unsuitable for uses such as glass bottle recycling. Some of the specific glass waste materials that have found use as fine aggregate are "non-recyclable" clear window glass and fluorescent bulbs with very small amounts of contaminants. Possible applications for such waste-glass concrete are bike paths, footpaths, gutters and similar non-structural work.

Lack of widespread reliable data on aggregate substitutes can hinder its use. To design consistent, durable recycled aggregate concrete, more testing is required to account for variations in the aggregate properties. Also, recycled aggregate generally has a higher absorption and a lower specific gravity than conventional aggregate.

Research has revealed that the 7-day and 28-day compressive strengths of recycled aggregate concrete are generally lower than values for conventional concrete. Moreover, recycled aggregates may be contaminated with residual quantities of sulfate from contact with sulfate rich soil and chloride ions from marine exposure.

Glass aggregate in concrete can be problematic due to the alkali silica reaction between the cement paste and the glass aggregate, which over time can lead to weakened concrete and decreased long-term durability. Research has been done on types of glass and other additives to stop or decrease the alkali silica reaction and thereby maintain finished concrete strength. However, further research is still needed before glass cullet can be used in structural concrete applications.

2.3 Crushed Tile Aggregate

The amount of tile waste on earth is enough for use as an aggregate in concrete. Tile is produced from natural materials sintered at high temperatures. There are no harmful chemicals in tile. Waste tiles cause only the apparition of pollution. However some parts of tiles are used in cotto as flooring and also flooring in tennis courts, walkways, cycling paths and gardens as a ground material. (Topcu & Canbaz, 2007) say that each year approximately 250,000 tons of tiles are worn out, while 100 million tiles are used for repairs. These waste materials can be recycled to save money. Crushed tile aggregate, CTA, is a material especially proposed for the buildings constructed in hot climates. The unit weight of concrete is decreased with use of the CTA compared to the control concrete. In previous investigations CTA was examined and no noteworthy negative effects on the strength of the concrete were found. The weakest bonds were between CTA and mortar, therefore failure occurred in this surface. The strength of concrete was increased with the addition of minerals and chemical waste. The use of CTA decreases costs and it also supports environmental health.

2.4 Tile

A tile is a manufactured piece of hard-wearing material such as ceramic, stone, metal, or even glass. Tiles are generally used for covering roofs, floors, walls, showers, or other objects such as tabletops. Alternatively, tile can sometimes refer to similar units made from lightweight materials such as perlite, wood, and mineral wool, typically used for wall and ceiling applications. Less precisely, the modern term can refer to any sort of construction tile or similar object, such as rectangular counters used in playing games (see tile-based game).

According to (Wikipedia, 2012) the word is derived from the French word *tuile*, which is, in turn, from the Latin word *tegula*, meaning a roof tile composed of fired clay. Tiles are often used to form wall and floor coverings, and can range from simple square tiles to complex mosaics. Tiles are most often made from porcelain, fired clay or ceramic with a hard glaze, but other materials are also commonly used, such as glass, metal, cork, and stone. Tiling stone is typically marble, onyx, granite or slate. Thinner tiles can be used on walls than on floors, which require thicker, more durable surfaces.

2.5 Construction Waste

A significant part of waste generation is caused by the building and construction industry. Construction companies benefit from reduced waste generation by lower deposition costs and lower purchasing costs of virgin materials. Table 2.1 show the amount of construction and demolition (C&D) waste about 30 construction site (operated between August 2001 until January 2003) in Seberang Perai, Pulau Pinang is 5253.7 tonne. (Faridah et al., 2004)

Table 2.1: Quantities of Waste Material Composition from Construction and Demolition Activities from Questionnaires.

Material	Construction		Demolition	
	Weight (tonne)	% Total Amount	Weight (tonne)	% Total Amount
Concrete	754.40	15.45	95	25.68
Metals	475.00	9.73	110	29.73
Bricks	402.30	8.24	85	22.97
Plastics	37.20	0.76	10	2.70
Glass	0.00	0.00	10	2.70
Woods	3118.00	63.85	45	12.16
Others	96.80	1.980	15	4.05
TOTAL	**4,888.70**	**100**	**370**	**100**

(Source: Faridah et al., 2004)

2.6 Workability Test for Fresh Concrete

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like superplasticizer. Raising the water content or adding chemical admixtures will increase concrete workability. Excessive water will lead to increased bleeding (surface water) and/or segregation of aggregates (when the cement and aggregates start to separate), with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low slump, which cannot be readily made more workable by addition of reasonable amounts of water.

In this study an attempt has been made to find the suitability of the ceramic industrial waste as a possible substitute for conventional crushed stone coarse aggregate. Experiments were carried out to determine the workability of concrete using crushed tile coarse aggregate. Fresh concrete contained ceramic waste is less cohesive and workable compared to conventional concrete because high water absorption of ceramic wastes (tiles), (Mustafa et al., 2006). Table 2.2 shows workability category of fresh concrete.

Table 2.2: Workability Category

Workability category	Slump (mm)	Vebe time (s)	Compacting factor
Extremely Low	0	Over 20	0.65-0.70
Very Low	0-10	12-20	0.70-0.75
Low	10-30	6-12	0.75-0.85
Medium	30-60	3-6	0.85-0.95
High	60-180	0-3	0.95-1.00

(Source: BS 1881: Part 102, Part 103 and Part 104, 1983)

2.6.1 Slump Test

Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete following the BS 1881: Part 102: 1983 test standards. Slump is normally measured by filling an "Abrams cone" with a sample from a fresh batch of concrete. The cone is placed with the wide end down onto a level, non-absorptive surface. It is then filled in three layers of equal volume, with each layer being tamped with a steel rod in order to consolidate the layer. When the cone is carefully lifted off, the enclosed material will slump a certain amount due to gravity. A relatively dry sample will slump very little, having a slump value of one or two inches (25 or 50 mm). A relatively wet concrete sample may slump as much as eight inches. Figure 2.2 shows type of slump of fresh concrete. The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of too wet a mix. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate, (Wikipedia, 2012). Previous study result for slump test using ceramic waste coarse aggregate concrete is 99 mm for gred 35 and water cement ratio is 0.55 (Senthamarai & Devadas, 2005).

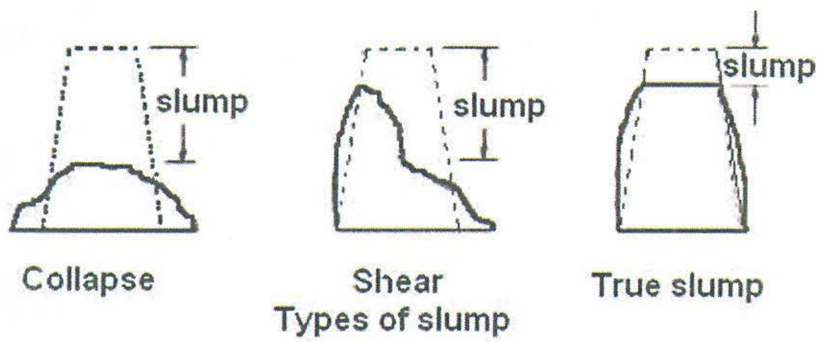

Figure 2.1: Type of Slump
(Source: Wikipedia, 2012)

2.6.2 Compacting Factor Test

The workability of concrete has been defined as the amount of work required to place the concrete and to compact it thoroughly. It is simpler to apply standard amount of work to the concrete and to measure its degree of compaction is defined as compacting factor which is measured by the density ratio. The test is suitable for concrete with a maximum size of aggregate up to 40 mm and it is described by BS 1881: Part 103:1983. The apparatus consist essentially of two hoppers, each in the shape of frustum of a cone and one cylinder, the three being above one another, about 1.2 m high.

$$\text{Compacting factor} = \frac{\text{Mass of partially compacted concrete}}{\text{Mass of fully compacted concrete}} \qquad \text{Equation 1}$$

2.6.3 Vebe Test

Vebe is a good laboratory test. This is in contrast to the compacting factor test where error may be introduced by the additional advantage that the treatment of concrete during the test is comparatively closely related to the method of placing in practice. The test is covered by BS 1881: Part 104: 1983.

2.7 Effect of Crushed Tile to Compressive Strength of Concrete.

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed. Compressive strength is often measured on a universal testing machine; these range from very small table top systems to ones with over 53 MN capacity. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

This study deals with the experimental studies made on compressive strength of concrete made with construction waste (crushed tile). As far as strength are concerned, the basic trend in the behavior of concrete containing crushed tile is not significantly different from that of conventional crushed stone aggregate concrete (Mustafa et al., 2006). Compressive strength was unchanged when ceramic waste was used to partially replace conventional crushed stone coarse aggregate (Senthamarai & Devadas, 2005).

2.8 Splitting Tensile Strength of Concrete.

The splitting test is well-known indirect tests used for determining the tensile strength of concrete. The test consists of applying compressive line loads along the opposite generators of a concrete cylinder placed with its axis horizontal between the platens as shown in Figure 2.2 (Gambhir, 2004). From previous study it was observed that, as far as the as the splitting strength is concerned, the concrete with crushed tile as coarse aggregate gave values nearer and higher to that of conventional aggregate concrete (Sekar et al., 2011).

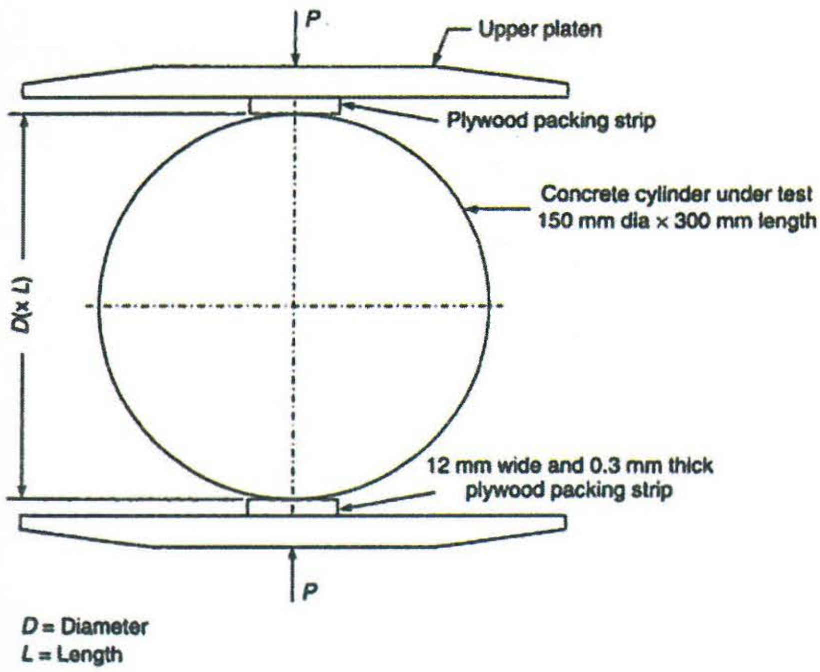

Figure 2.2: Loading Arrangement for Split Tensile Test
Source: (Gambhir, 2004)

2.9 Properties of Ceramic Waste Coarse Aggregate

The properties of ceramic waste coarse aggregate are presented in Table 2.3. The surface texture of the ceramic waste aggregate was found to be smoother than that of crushed stone aggregate (Senthamarai & Devadas, 2005). Generally, ceramic waste aggregate showed properties close to those of natural crushed stone aggregate.

Table 2.3: Aggregate Properties

Properties	Ceramic waste	Crushed stone
Specific gravity	2.45	2.68
Maximum size (mm)	20	20
Fineness modulus	6.88	6.95
Water absorption 24 h (%)	0.72	1.2
Bulk density (kg/m^3)	-	-
Loose	1200	1350
Compacted	1325	1566
Voids-loose (%)	50	48
Voids-compacted (%)	45	44
Crushing value (%)	27	24
Impact value (%)	21	17
Abrasion value (%)	28	20
Soundness test: weight loss after 30 cycles (%)	3.3	6.8

(Sources: Senthamarai & Devadas, 2005)

CHAPTER 3

METHODOLOGY

3.1 Introduction

Regarding the objectives, laboratory works need to be done to obtain the data and information related to the project. The data is the reference of study experiment that has to be done. After discussion of study objectives in introduction part, some experiment need to be done in order to achieve that objective given such as workability, compressive and splitting tensile strength. Information and material from the experiment will help to collect the information regarding the study and also can help to achieve the study objective. Several planned before laboratory work will make sure our work more regulated nicely and systematic.