THE USE OF BRICK WASTE AS COARSE AGGREGATES PARTIAL REPLACEMENT IN CONCRETE PRODUCTION

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ABSTRACT

Issue related to the scarcity of good and quality of coarse aggregate has kept the construction industries into a crisis in findings an alternative to overcome this situation. The issue is worsening as the current aggregate used in the construction industries are non-renewable aggregates from the quarrying activities. Fast development in the recent years indeed has increased the need of coarse aggregate in the alarming rate. Besides that, the growth of the construction industry has also produced lots of product mainly the waste materials. In fact, land filling is the most common waste management practice in Malaysia. The high amount of construction waste generated from the construction industries has caused a scarcity of the landfill area. The study is conducted to investigate the use of brick waste as a coarse aggregate replacement in concrete production. The aim of this study is to determine the suitability of brick waste as partial replacement of coarse aggregate in concrete production. Furthermore, to investigate the mechanical and physical properties of brick waste concrete, and to compare the performance of brick waste as partial replacement of coarse aggregate in concrete with the conventional concrete (control sample). In order to fulfil the objective, there are tests that were conducted to determine concrete performance, such as compressive strength test, flexural test, and water penetration test. The data were collected and analyzed to satisfy the study on brick waste as an alternative in coarse aggregate partial replacement in concrete production. With the different mix proportion in percentages of the brick waste as coarse aggregate replacement of, 0, 5.0, 7.5, 10.0 and 12.50% in the equivalent strength of grades 25, the result was analyzed. From the results, it indicates that the optimum strength was achieved at 5.0% brick waste mix proportion and higher compared with the control sample, 0% brick waste mix proportion. The results also indicate that the optimum strength of brick waste concrete has achieved the grade 25 of concrete.

ABSTRAK

Isu yang berkaitan dengan kekurangan kuantiti dan kualiti agregat kasar telah menyebabkan industri pembinaan terdedah kepada krisis dalam mencari alternatif untuk mengatasi keadaan ini. Isu ini menjadi lebih buruk lagi kerana agregat yang digunakan dalam industri pembinaan ketika ini adalah agregat daripada aktiviti kuari yang tidak boleh diperbaharui. Pembangunan pesat dalam beberapa tahun kebelakangan ini sememangnya telah meningkatkan keperluan agregat kasar dalam kadar yang membimbangkan. Di samping itu, pertumbuhan industri pembinaan juga telah menghasilkan banyak produk terutamanya bahan-bahan buangan. Malah, pengisian tanah adalah amalan pengurusan sisa yang paling biasa di Malaysia. Jumlah sisa pembinaan yang tinggi yang dihasilkan daripada industri pembinaan telah menyebabkan kekurangan kawasan tapak pelupusan. Kajian ini dijalankan untuk mengkaji penggunaan sisa bata sebagai pengganti agregat kasar dalam pengeluaran konkrit. Tujuan kajian ini dijalankan adalah untuk menentukan kesesuaian sisa bata sebagai pengganti separa agregat kasar dalam pengeluaran konkrit. Tambahan pula, untuk menyiasat sifat-sifat mekanikal dan fizikal sisa bata konkrit, dan untuk membandingkan prestasi sisa bata sebagai pengganti separa agregat kasar dalam konkrit dengan konkrit konvensional (sampel kawalan). Bagi memenuhi objektif, terdapat beberapa ujian yang telah dijalankan untuk menentukan prestasi konkrit, seperti ujian kekuatan mampatan, ujian lenturan, dan ujian penembusan air. Data dikumpul dan dianalisis untuk memenuhi kajian mengenai sisa bata sebagai alternatif agregat kasar penggantian separa dalam pengeluaran konkrit. Data dikumpul dan dianalisis untuk memenuhi kajian mengenai sisa bata sebagai alternatif dalam agregat kasar penggantian separa dalam pengeluaran konkrit. Dengan kadar campuran yang berbeza dalam peratusan sisa bata itu sebagai pengganti kasar agregat, 0, 5.0, 7.5, 10.0 dan 12.50% dalam kekuatan bersamaan gred 25, keputusan ujian dianalisis. Daripada keputusan ujian, ia menunjukkan bahawa kekuatan optimum dicapai pada 5.0% campuran sisa bata dan ianya lebih tinggi berbanding dengan sampel kawalan, 0% campuran sisa bata. Keputusan ujian juga menunjukkan bahawa kekuatan optimum sisa bata konkrit telah mencapai gred 25 konkrit.

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LIST OF SYMBOLS

%	Percentage
X	Times
/	Divided
F	Maximum applied load
L	Beam length
b	Beam width
d	Beam depth
a	Distance from Maximum applied load to support
±	Plus Minus

LIST OF ABBREVIATIONS

BS	British Standard
mm	Millimetre
EN	English
N/mm^2	Newton per Millimetre square
MPa	Mega Pascal
Kg/m^2	Kilogram per Metre square
W/c	Water to cement ratio
$Ca(OH)_2$	Calcium hydroxide
SiO_2	Silicon dioxide
Al_2O_3	Aluminium oxide
CaO_2	Calcium dioxide
MgO	Magnesium oxide
Fe_2O_3	Iron trioxide
SO_3	Silica trioxide
OPC	Ordinary Portland cement
3R	Reduce, Recycle, Reuse
Psi	Per square inch
m^3	metre cube
BWMP	Brick Waste Mix Proportion

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Coarse aggregate can be defined as inert granular materials such as gravel, crushed stone and sand. Coarse aggregate is one of the essential ingredients apart of water and cement in concrete production. It consists about 60 to 75 percent of total concrete production (Nmai, 1999). Coarse aggregate comes from particles greater than 4.75 mm but commonly in a range between 9.5 mm to 37.5 mm. Therefore, the selection of coarse aggregate is vital for a good concrete mix such as it need to be clean, tough, and strong particles that free room absorbing chemicals. Furthermore, coarse aggregate also is significant due to its properties will affect the modulus of elasticity. As the coarse aggregate that contains higher modulus elasticity will resulting the concrete stronger in strength of modulus elasticity.

Conventionally, the coarse aggregates used in concrete productions are gravel, crushed stone, granite, and limestone. Aggregates properties are playing a big role in concrete as it can affect the strength, the durability and workability of plastic concrete, and density of hardened concrete (Nmai, 1999). The stripping of the land by quarrying process that keeps widespread without supervision has caused to a depletion of natural aggregate. Thus, it is affecting the environment to landslide and land erosion also to a global warming.

However, this issue that more related to environmental conservation have been gaining a vital in our society through recent year (Xue, 2009). Furthermore, more attention to environmental issues has been focused seriously by the decision-makers in political, economic, and social sectors nowadays. Thus, proper waste management system has been done to synchronize in our ways of living and live.

The process that most effectively as an alternative to conserve a natural resources is by reusing waste products of mental synthesis. Most authorities and researchers have lately focused more on having a privilege of reusing the wastes in environmentally and economically affordable ways (Aubert, 2006). The consumption of waste product in construction materials is one of such visionary effort.

Other than that, the increasing of the cost of construction materials that keeps increasing days by days due to high demand, high price of energy and inadequacy raw materials. Moreover, the increase in transportation cost due to raw materials, demand, environmental restrictions, it is necessary to search functional replacement for conventional building materials in the construction industry (Pappu, 2006).

In order of saving a conservation of natural resources, the consumption of alternative component in construction materials is a global concern now and for the bright future prospect. This resulting the development and extensive research works towards discovering a new formula and invention of ideas that required for inventing a sustainable and environment friendly construction materials. The present study and more focusing on idealized the potential use of brick wastes as a replacement in the concrete production of construction materials.

1.2 PROBLEM STATEMENT

The scarcity of good and quality coarse aggregates has now become an issue that keeps pressing hard to construction sector mostly in many construction processes. Natural coarse aggregates are generally extracted from larger rock formations through a process of open excavation, also known as quarrying process (Auhor, 2012).

The data taken from European analysis has shown that 3,000 tonnes of aggregates are needed for a new school construction, while a new sports stadium can require up to 300,000 tonnes of aggregates (Comission, 2010). The existing aggregate used are non-renewable coarse aggregate also the reason for the scarcity of aggregate. It takes many years for a natural coarse aggregate to be reformed again after being excavated. With the lack of it resources will affect the production of a good concrete. Furthermore, the aggregate quarrying process causes a negative effect to environment. This is due to the quarrying process will strip the land and depletion of natural resources.

With the construction project is keeps increasing years after years, the production of natural resources has been affected to depletion. Construction waste has become a global issue faced by researchers and practitioners around the world lately. More specifically, it has a primary effect on construction cost, time, productivity and sustainability aspects (Rahman I. A., 2012). The waste that been generated through every year, have resulting environmental troubles and global warming problems in the world. As a developing country, Malaysia also has been affected by this construction waste problem in the same situation with the rapid development of the construction sector.

The statistics of construction waste that's been produced have shown estimated that almost 10 to 30 percent originates from construction and demolition activities globally (Fishbein, 1998). A study shows that over 28 per cent urban solid waste is originates from construction and industrial waste in the central and southern regions of Malaysia (Nasir, 1998). Landfill is the one of the common ways to organize waste disposal. According to Department of National Solid Waste Management in 2009, there are a total 289 landfill in Malaysia including 176 contribute to operational landfill while 113 is non-operational landfill (Nagapan, 2012). The increasing of construction waste that keeps increasing on a large scale of area year by year causes the construction waste are dumped to the landfilling area and minimize the capacity of landfilling to support the construction waste. Demand of houses and major infrastructure keeps the amount of construction waste getting increased (Nasaruddin, 2008).

It was reported in 2009 Malaysian construction industry productivity increased to a 5 per cent (Malaysia Productivity Corporation, 2009). This statistic shows that the construction waste generation will keep increasing year after year. If this situation is not being overcome, it will result landfilling is full with construction waste and more landfilling needed to be produced to fulfil the require construction waste. In addition, many landfills have decided to close rather than receiving new waste due to the number of waste generated yearly is far more rapidly than the natural degradation process (Idrus, 2008).

From a researchers conduct on 30 construction sites, six types of materials were identified, such as concrete (12.32%), metal (9.62%), brick (6.24%), plastic (0.43%), woods (69.10%), and other waste (2%) (Faridah, 2004). Even though brick waste is not the higher amount of waste in construction, but it contributes an increasing of waste material from construction. More likely this waste can be treated by reusing for construction. The issue, scarcity of landfill also will put a decision maker in local and state authorities in critical situations to a make a tough decision to prevent these problems. Thus, waste utilization has become an alternative solution to overcome the problem for disposal of waste (Bahoria, 2013).

As stated above it seems that the use of brick waste as alternative coarse aggregate for concrete production is one of the good alternatives to overcome the problem stated. It has actually been applied in many countries, and including in Australia. The use of recycled waste has been proven to be practical for low-strength concrete and for a limited extend for some structural grade concrete (Author, 2008). Instead of minimizing the brick waste produced, it can increase the strength and performance of concrete production. While it also helps minimize the land fill scarcity problem.

1.3 OBJECTIVES OF STUDY

The aim of this study is to investigate the use of coarse aggregate in concrete production. Brick wastes are broken into sizes ranging from 2.36 to 20 mm. Three objectives have been listed as shown below to achieve the aim of this study;

Objective 1: To determine the suitability of brick waste as partial replacement of coarse aggregate in concrete production.

Objective 2: To investigate the mechanical and physical properties of brick waste concrete

Objective 3: To compare the performance between concrete with brick waste as coarse aggregate partial replacement and conventional concrete (control concrete).

1.4 RESEARCH METHODOLOGY

In order to conduct this study successfully, the methodology of this study is summarized as shown below;

1. To determine the suitability of brick waste as a coarse aggregate partial replacement in concrete production. There are tests that needed to determine the suitability of brick waste as alternative in concrete production that is compressive strength test. The purpose of this test is to study the strength that concrete can achieve by both conventional and control concrete.
   If the brick waste concrete can achieve the limit target strength, then brick waste can be considered equally suited as alternative coarse aggregate.
2. To investigate the mechanical and physical properties of brick waste concrete. The test is flexural test. It is to identify the mechanical behavior of concrete as a natural ability to resist deformation under load. From this test we will identify how strong the bond that brick waste can bong to cement phase. The quantity of brick waste should be measured approximately to get a good bond and give a higher strength during the flexural test.
3. To compare the performance between concrete with brick waste as coarse aggregate partial replacement and conventional concrete (control concrete).

The tests that will be conducted to overcome this objective are compressive strength test, flexural strength test, water absorption test and water penetration test. Both conventional concrete and control concrete will be tested to compare which concrete will have higher performance during each test.

1.5 SCOPE OF STUDY

There will be a test that will be conducted to estimate the effectiveness of waste brick as a replacement for natural coarse aggregate such as compressive strength test, flexural strength test, water absorption test and water penetration test. The test is conducted to estimate the result of the performance, durability and limitation of conventional concrete compare with control concrete.

1) Slump test is the test to measure the workability of concrete during fresh state. In more specifically this test is performed to evaluate the consistency of the concrete at specific batch. It also used as determining that the correct quantity of water has been added to the mixture. The test is carried out in accordance to BS-EN 12350-2, testing fresh concrete, slump test. This replaces BS 1881: Part 102.
2) The compressive strength test is commonly one of the tests to identify the strength of concrete. By using this test, the cube was cured and should achieve the strength test above 25 MPa or N/mm^2 at 28 days based on the British standard· The effective strength test is usually 28 MPa.
   It was tested for both conventional and control concrete to distinguish which one is higher in compressive strength. The test was carried out according to BS EN 12390-3:2002.
3) The flexural strength test is to determine the mechanical behavior of concrete as a material's ability to resist distortion under load. This test also will be conducted for both conventional and control concrete. The angular in shape of the waste crushed material and its rough surface will give and advantages for a better bond during mixing with cement phase, which could increase the flexural strength performance. The test was carried out in accordance to BS 1881: Part 118, 1983.

4) Water penetration test measures the permeability and porosity level of the concrete. Through this test the permeability of concrete to absorb water will be determined by method soap bottom of the concrete under water for about 10 mm and the concrete performance will be tested either it can achieve the target strength or not. As the increase in water penetration indicates a higher permeability. This test was carried out in accordance with BS 12390 Part 8, 2009.

1.6 SIGNIFICANCE STUDY

Determining the suitability of brick waste as alternative coarse aggregate in concrete is very important for these researches convince people that brick waste material can be reused in the construction process. The analysis of the test is required to identify the result whether it is satisfactory the requirement or not. This is due to result from the test will show that whether brick waste can achieve the minimum required for compressive strength test and even higher. The compressive strength will be present for age 7, 14 and 28 days, respectively.

The test to identify physical and mechanical properties of brick waste concrete is vital to improvisation the properties of coarse aggregate by brick waste alternative in concrete production. By carrying on the flexural strength test, the ability of concrete to resist distortion under load can be set. We can conclude that how many in per cent brick waste is needed to make its properties in brick concrete strong and can achieve the resistance to deformation load.

The entire test was conducted for both brick waste concrete and control concrete. This test is very important to distinguish the result for both conventional and control concrete due to make a concrete conclusion on brick waste as a good alternative for coarse aggregate replacement. If the test doesn't achieve the requirement, then to objective propose will be effected. To overcome this situation, brick waste quality was chosen wisely to make a good outcome during the test. Most of the entire test is following the requirement according in the British Standard.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature review was a preliminary and primary survey to view related overall study. The literature review is made to understand and to obtain background of the research topics beginning of the subject title. There are various studies that have been conducted on concrete diversifying the sources of materials. Furthermore, there are various types of aggregates that has been set consist of industrial waste, construction waste such as crush brick, brick waste, concrete side, and more. From the previous study it shows that materials used in the study consist of waste materials. It can be shown by using the aggregate production waste such as brick waste that has been taken in many countries like in Europe and America. These materials are usually available from the work of the demolition of buildings and structures.

The alternative for replacement of coarse aggregate actually has been introduced since 50 years ago after a second world war. It is due to materials disposal problem that has happened when there many concrete stacks after the war. Thus, they come out with the ideas to use waste, construction materials as a new aggregate as a choice to cast aside the waste materials.

In this study will focus more on a brick waste as a coarse aggregate replacement in term of its characteristics and performance. Most of the information getting for the preparation of this literature review come from the study through journal, articles, websites, newspaper and previous student's thesis.

2.2 CONCRETE

Concrete is a composition of material from coarse granular material such as coarse and fine aggregate mixing in a hard matrix of material that is cemented that fills the space of aggregate particles with an additive and bind them together (Saidi, 2007). It has been known widely in function for building foundations, architectural structures, walls, pavements and most of it in the construction industry.

It is important to identify the amount of each material mixing in production of concrete. This is to make certain that the concrete that will be produced is a quality concrete. Furthermore, to produce a high quality concrete it is important to give a careful attention in a technic of mixing concrete. Thus, the quality of each material being used, mixing rate, mixing skills, compaction skills affect the quality of concrete (Hanifa, Komposisi sisa bahan binaan dalam projek pembinaan perumahan, 2008).As what's been discuss before this, the strength and performance of concrete are very much dependent quality material, mix design and cement ratio. For instance, the higher cement ratio will scale down the durability of the concrete.

Normally, concrete with the minimum compressive strength of 20 MPa or N/mm2 and above is suited for structural use such as shaft, column, shear wall and slab, while concrete with the compressive strength less than 20 MPa or N/mm2 are only suited for non-structural role.

Likewise, when the quality of the concrete does not fulfill such requirements that have been set, and handling is not practiced with care will result in lots of wastage to occur. Since concrete can be applied in various construction works, then it can be categories as follows:

a) Reinforced concrete (foundation, structural member and footing done on-site)

b) Pre-cast concrete (concrete that's been already drawn from the mill)

c) Concrete masonry units (hollow blocks, concrete form in a mold)

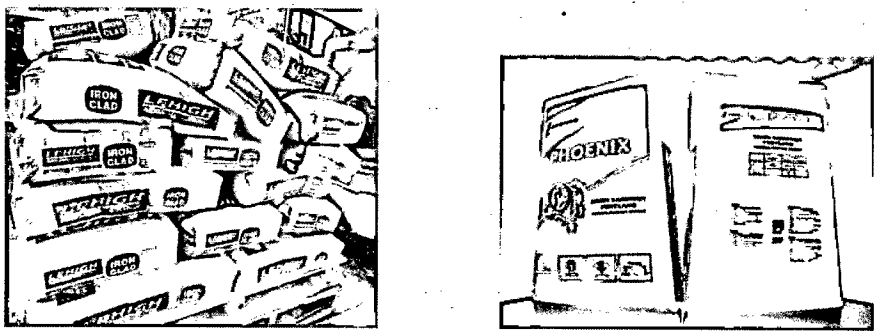
2.2.1 Cement

Cement is a material that has a cohesive and adhesion properties that enable binding chunks of rock into one cohesive body. There are dissimilar cases of cement made at factory for specific purposes and to conform to the specific demands. When the void between the aggregates is minimized, then the need for cement to fill the empty space can be reduced to maintain the workability and the strength of concrete. And so, the optimal mixing ratio of aggregates will produce a concrete with minimal quantity of cement contain. Therefore, the lower water and cement quantity of water and cement ratio (w/c) constant, would result a more durable concrete.

Even though cement is only contributed 10% of the concrete volumes in mixing, it is an active substance and a material that can be controlled scientifically. Cement consists of a mixture of silicate and aluminate compounds of calcium metal in a certain proportion. The ratio of chemical substances in each type of cement influences the properties of the cement. The types of cement that are often used in the construction industry such as:

1) OPC, Ordinary Portland cement
2) Modified cement
3) Rapid hardened cement
4) Low heat cement
5) Sulfate resistance cement

Cement wills trough a chemical reaction process when it is mixed with water after concreting is done. It then will fill the hollows of the other ingredients so it becomes compact (Neville A. , 2005). Cement is a basic ingredient in concrete, mortar and plaster production. Cement binder that binds that binds the component materials of coarse and fine aggregates to a piece or solid body. The highest chemical materials contain in a Portland cement are CaO_2 and SiO_2 and others consist of Al_2O_3, Fe_2O_3, MgO, and SO_3.



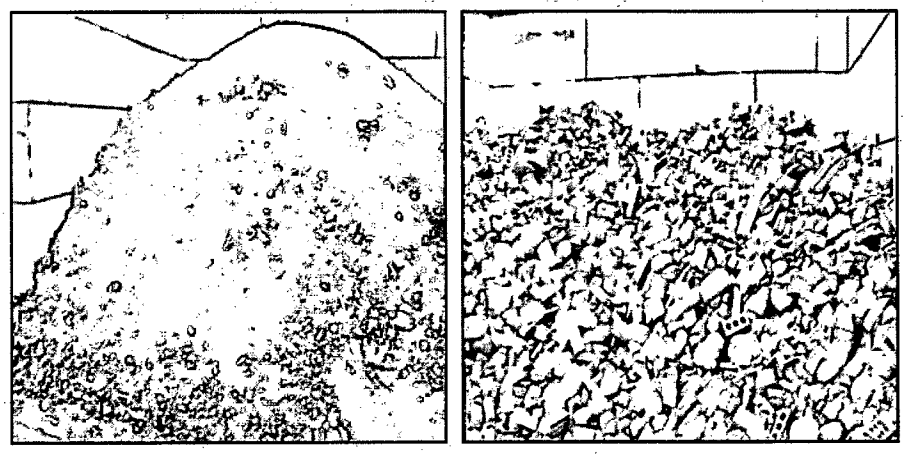
(a) Lehigh brand (b) Phoenix brand

Figure 2.1: Cement according to brands

2.2.2 Aggregates

Aggregates play an important role in concrete as aggregate is one of the materials instead of water, cement and other additive in concrete production due to aggregate compose 75% of production of concrete. It likewise means that concrete production, largely depending on aggregate properties. The properties of aggregates are compressive and bond strength, shape and surface, size, permeability and rarefaction of chemicals. Other than that, the physical properties of aggregates such as relative density, density loam, porosity and moisture absorption, soundness and resistance to acid and alkali attack also affect the strength of aggregate in concrete production (Aziz, 2006). The choice of aggregates for concrete mix is something very significant due to the properties that will bear upon the strength, toughness, mixing ratio, and so thus it economical to the concrete producing.

In general, a good aggregates is an aggregate containing details of stability and durability and do not contain ingredients that will bring adverse effects to the concrete such as dust, mud, salt and others (Tan Boon Tong, 2005). With a high demand of aggregate due to increase in the construction industry, it will make the shortage of aggregate in market to occur.



(a) Fine aggregate **(b)** Coarse aggregate

Figure 2.2: Types of Aggregates

2.2.2.1 Aggregate Production Process

Aggregate has been used in several of uses, such mixing with cement to produce a concrete. The size of aggregate that has been use of concrete mixing depends on the function of the concrete use of. An aggregate has been categories into two types such as coarse aggregate that have a size more than 5 mm and fine aggregate with a size less than 5 mm (Pilus, 2005).

The aggregate storage in inappropriate places such as beside sand or stack stone will causes the waste generation occurs at the construction site and aggregate that being mixed with those materials will caused it left unattended in a storage area (Ibrahim, 2004).

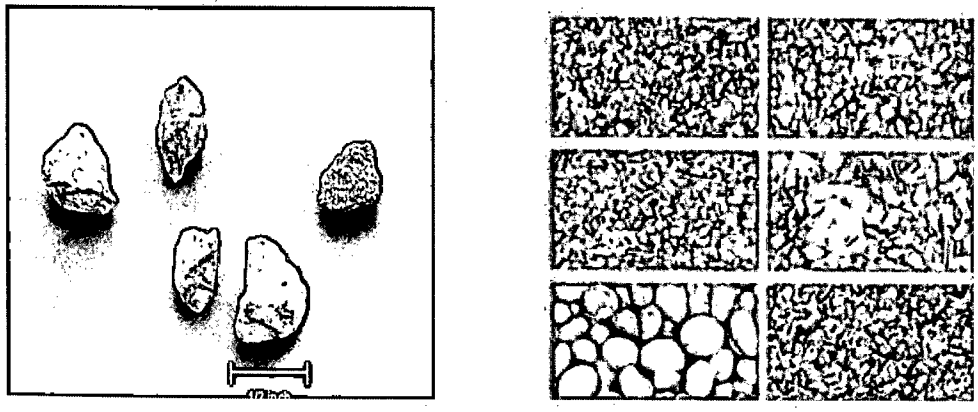
The naturally formed aggregates can be sorted according to the type of rocks. The usual types of aggregates that are often used in Malaysia are composed of rocks of granite, limestone, sandstone and conglomerate. Among the aggregates that are referred to are as shown in the Table 2.1.

Table 2.1: The types of aggregates according to group

Group of rocks	Type of rocks
Group Basalt	Basalt, Andesite, Dolerite, Spilit
Group Granite	Gneiss, Granite, Syenit
Group Limestone	Dolomite, Limestone, Marble
Group Coarse sandstone	Conglomerate, Agglomerate, coarse sand and Sandstone
Group Schist	Phyllite, Schist, Slate

2.2.3 Coarse Aggregate

Coarse aggregate comes from an aggregate production process that has been separated into a specific class. The size of coarse aggregate is usually more than 5 mm or specifically the coarse aggregate is aggregate that not passing sieve size 4.75 mm. Coarse aggregate that has been practiced in concrete mixing normally consists of three normal sizes such as 10 mm, 20 mm, and 40 mm. Furthermore, coarse aggregate consists of following types such as hard rock or gravel which are crushed by grinding process and rock that has been derived from natural breakdown (Gambhir, 2004).



(a) Size of coarse aggregate **(b)** different types of coarse aggregate

Figure 2.3: Details of coarse aggregates