PERFORMANCE OF CONCRETE USING AGGREGATE LATERITE AS AGGREGATE REPLACEMENT

MUHAMAD HAFIZZAN BIN MUHAMAD ZAIDI

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Faculty of Civil Engineering And Earth Resources
Universiti Malaysia Pahang

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ABSTRACT

The study on the alternative materials for use as coarse aggregate in concrete mixed should be done in order to prepare on the shortage of granite someday and to know the performance of the alternative material in concrete. Aggregates are the most mined material in the world. The extraction and use of aggregates from natural resources has been questioned at an international level because of the depletion of quality primary aggregates. This can be overcome if other type of aggregate such as laterite aggregate can be as a solution. The main objective of this researcher is to determine specific gravity and water absorption of aggregate, its compression strength and splitting tensile strength. The result is getting by doing in laboratory testing. A total of four batches of concrete are produced, in which one of it is normal concrete and the other is concrete with difference percentage of laterite aggregate which is 15%, 25% and 35% of normal aggregate. In this study, the mixed of concrete used in this research is for grade $35N/mm^2$ and the water/cement ratio is 0.57. For specific gravity and water absorption, two samples for each aggregate are used. In compression testing, about 36 cubes of concrete with 150mm square in dimension are used for 7, 14, and 28 days curing. 12 cylindrical sample of concrete are used for splitting tensile test at age 28 days. The results show that the strength of laterite concrete for sample B, C, D are 25.643MPa, 29.130MPa, 26.553MPa respectively for age 28 days. It also proves that aggregate granite of higher in specific gravity than laterite aggregate with granite have 2.77 and 2.56 for laterite aggregate. Granite aggregate have lower water absorption than laterite aggregate with 0.70% and 10.66% respectively. In tensile strength, sample A, B, C and D are 2.131MPa, 2.460MPa, 2.113MPa and 2.313MPa respectively.

ABSTRAK

Kajian tentang bahan alternatif untuk digunakan sebagai batu baur kasar dalam campuran konkrit perlu dilakukan dalam usaha untuk mengatasi kekurangan granit suatu hari nanti dan mengetahui prestasi bahan alternatif dalam konkrit. Batu baur adalah bahan yang paling banyak dilombong di dunia. Pengambilan dan penggunaan batu baur daripada sumber alam telah dipersoalkan di peringkat antarabangsa kerana kehabisan batu baur berkualiti. Ini boleh diatasi jika lain-lain jenis batu baur seperti batu baur laterit boleh menjadi sebagai satu penyelesaian. Objektif utama kajian ini adalah untuk menentukan graviti tentu dan penyerapan air batu baur, kekuatan mampatan dan kekuatan tegangan. Hasilnya adalah dengan melakukan ujian makmal. Sebanyak empat sampel konkrit dihasilkan, di mana salah satu daripada konkrit biasa dan yang lain adalah konkrit dengan peratusan perbezaan batu baur laterit dengan nisbah 15%, 25% dan 35% daripada batu baur biasa. Dalam kajian ini, campuran konkrit yang digunakan adalah 35N/mm^2 gred dan nisbah air-simen adalah 0,57. Bagi graviti tentu dan penyerapan air, dua sampel untuk setiap batu baur digunakan. Dalam ujian mampatan, 36 kiub konkrit dengan 150mm digunakan bagi 7, 14, dan 28 hari. 12 sampel silinder konkrit digunakan untuk ujian tegangan pada usia 28 hari. Hasil kajian menunjukkan bahawa kekuatan konkrit laterit bagi sampel B, C, D adalah 25.643MPa, 29.130MPa, 26.553MPa masing-masing untuk umur 28 hari. Ia juga membuktikan bahawa granit agregat yang lebih tinggi dalam graviti tentu daripada agregat laterit dengan granit mempunyai 2.77 dan 2.56 untuk agregat laterit. Agregat granit mempunyai penyerapan air yang lebih rendah daripada agregat laterit dengan masing-masing 0.70% dan 10.66%. Dalam kekuatan tegangan, sampel A, B, C dan D adalah 2.131MPa, 2.460MPa, 2.113MPa dan 2.313MPa masing-masing

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LIST OF ABBREVIATIONS

BS	=	British Standard
ASTM	=	American Society for Testing and Materials
w/c	=	Water-cement ratio
CP	=	Code of Practise
kg/m^3	=	Kilogram per meter cube
MPa	=	Mega Pascal
g/m^3	=	Gram per meter cube
^oC	=	Celsius
^oF	=	Fahrenheit
h	=	Hour
g	=	Gram
Kg/m^3	=	Kilogram per meter
N	=	Newton
N/mm^2	=	Newton per millimeter square
mm	=	Millimeter
kN	=	Kilonewton

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CHAPTER 1

INTRODUCTION

1.1 Background

Concrete is one commonly material that have been used in construction all over the world. It been used in various structures in all types of civil engineering works such as low and high-rise building, infrastructure, military building, environment protection, and local or domestic developments (Limbachiya, 2004). Concrete are composed of cement (Ordinary Portland Cement), inert particulate substance that known as an aggregate and also including admixtures that are bond by water (Mary, 2011). Usually, for aggregates can be known as coarse aggregate that made of gravel or crushed rocks such as limestone, or granite and also a fine aggregate such as sand. The combinations of those materials, approximately 60 to 75% of volume of concrete are occupied by aggregate (ACI, 2007). For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete.

Since aggregates content are 60 to 75% of volume concrete, the aggregate properties can give effect to performance of concrete such in workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete (ACI, 2007). The aggregate serves as reinforcement to add strength to the overall composite material.

Natural gravel and sand are usually excavated from a river, lake, or seabed. Crushed aggregate is produced by crushing quarry rock. To get those aggregate, it must followed it process. The process are consists of crushing, screening and washing the aggregate to get clean aggregate and gradation. To get better quality, a benefaction process such as jigging or heavy media separation can be used.

Traditionally aggregates have been readily available at economic prices and of qualities to suit all purposes. However, for purely economic reasons the question of using aggregates from igneous rock and other types of standard rock as concrete aggregates in many parts of the world has proved too expensive even for the best civil engineering jobs (Madu, 1980). This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection. In light of this, the availability of natural resources to future generations has also been realized (Mary, 2011).

Therefore, an increasing need to study the performance of other types of rocks which can be used as concrete aggregates. The new sources aggregates must obtain easily within most localities. In this study, the scope of research focused on the use of laterite stone as coarse aggregate in concrete.

1.2 Problem Statement

Concrete have been used widely in construction even in Malaysia. Concrete have been known since an ancient times. Aggregates are the most mined material in the world. Concrete production is rapidly increasing along with demand of construction material. Consequently millions of tones are being removed from sand and gravel deposits both on land. For example, In Malaysia, Sarawak is large production of aggregate with production capacity at 2 million tons per annum. Malaysia has been exported aggregate to Singapore with nearly 1.2 million tons of granite aggregates. In others country, two billion tons of aggregate are produced each year in the United States. Production is expected to increase to more than 2.5 billion tons per year by the year 2020. The extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection. Therefore, the availability of natural resources to future generations has also been considered. Therefore, other type of aggregate such as Laterite aggregate can be a solution for these problems. Laterite aggregate are readily and cheap and could lead to reduction use of normal aggregate.

1.3 Objectives

The main objectives of the study are:-

i. To determine specific gravity and water absorption of aggregate.

ii. To determine the compressive strength of concrete containing 0%, 15%, 25%, 35% of laterite aggregate as aggregate replacement.

iii. To determine the splitting tensile strength of concrete containing 0%, 15%, 25% and 35% of laterite aggregate.

1.4 Scope of Study

This study concentrated on investigation of the properties of laterite aggregate and also to study the compressive strength of concrete with different percentage by mass of aggregate laterite and also plain concrete as a control mix.

The laterite stone for this study are collected from Rantau Panjang, Kelantan in Malaysia East Cost. The aggregate are come in large stone and grinded to size 20mm with same to normal aggregate.

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 was conducted. The concrete that only compose of cement, water, aggregate and sand were considered as a control mix without replacing with Laterite aggregate. Three series of proportion of aggregate laterite are considered. Concrete mix design with laterite aggregate as aggregate replacement were composed as an unconventional mixes comprises of 0%, 15%, 25% and 35% from the total weight of normal aggregate. Mix proportion as illustrated in Table 1.1. Design form are attached at appendix A.

Table 1.1: Mix Proportion of 1m^3 of Concrete

Material	Sample A (0%)	Sample B (15%)	Sample C (25%)	Sample D (35%)
Cement (kg)	400	400	400	400
Fine Aggregate (kg)	827	827	827	827
Coarse Aggregate (kg)	933	793	700	606
Laterite Aggregate (kg)	0	140	233	327
Water (Litre)	225	255	255	255

The concrete were cast and poured into 27 mould with size 150mm x 150mm x 150mm for each mould and three cylinder mould with diameter 150mm and height 300mm. The hardened concrete was taken out from the mould after 24 hours. Then, the hardened concrete was cured in water for 7, 14, and 28 days for all mixes. The compressive strength tests and splitting tensile test were conducted after the specimens matured due to curing period for entire specimens. The testing is followed, as accordance to BS 1881: Part 119: 1983 for compression test and BS 1881: Part 117:1983 for Split Cylinder Test.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Concrete is a man-made material, is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as cement, well graded fine and coarse aggregates and water. Active ingredient in concrete is cement and water while an aggregate is inert material. Aggregate occupy mostly in volume of concrete. Thus it is important that the aggregate must be of good quality, strong and resistant that affect the concrete.

Concrete has a high compressive strength, can resist to high temperature, more durability, and have low maintenance. However, concrete is materials that are brittle with have low tensile strength as compared to its compressive strength. To prevent this, reinforcement is provide in concrete to resist tensile strength.

2.2 Concrete

Concrete is a construction material widely used around the country. The concrete is permanent, resistance to decay, moisture, fire resistance, and not corroded easy to placing (Schwartz, 2000). The behavior of concrete that strong and durable make concrete has been used in construction widely than other material such as wood and steel. Concrete is a composite material composed of a cement and other raw material such as coarse aggregate and fine aggregate and also water. By the process of hydration (reaction with water) Portland cement mixed with sand gravel and water produces the synthetic rock we call concrete (Mehdi, 2007).

The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. A chemical reaction process starts between materials. In cement, its consist about 75% calcium silicate of Portland cement that react with water and forming two new compounds calcium hydroxide and calcium hydrate (Mehdi, 2007).

For concrete, it characteristic strength at 28 day is the most common design strength for any structural building (Bamforth, 2008). The strength of concrete are providing from a suitable design mix proportion of concrete. Mix design given the desire strength and workability. According to Shirley, strength of concrete is determined at age 3, 7, 14, 28, 56 or 90 days. In CP 110, its classified concrete using ordinary portland cement are tested for it strength at age 28 days.

In addition, the concrete mix design can be used and shall meet the recommendations of the Code of Practice CP 114. Grade concrete that to be used as shown in Table 2.1. This table is used for replace Table 4 of the Code of Practice CP 114. Compressive strength is an indication of where the compressive strength at day 28 is used for placing concrete in a particular class.

Table 2.1: Nominal Mix (Source: Spesifikasi Piawai Untuk Kerja-Kerja Bangunnan)

Nominal Mix	Compression Strength , N/mm^2		Aggregate Size, mm	Minimum Cement Content per Cubic Meter
	7 day	28 day		
1:1:2	20	30	19	380
1:1.5:3	17	25.5	19	361
1:2:4	14	21	19	321

There are three type of concrete such as lightweight concrete, normal concrete and heavyweight concrete. According to BS 5328, lightweight concrete can be classified as concrete has a density not more than 2000kg/m³. For normal concrete, its density is between 2000kg/m³ and less than 2600kg/m³. In heavyweight concrete, it has density more than 2600kg/m³.

2.2.1 Properties of Concrete

Concrete is a mixed of Portland cement, water, and aggregates. Concrete become in plastic state when all raw materials are mixed together. It hardens and freezes with presence of water. Concrete changes from a plastic state to a solid state in 2 hours and then concrete continues to gain strength day by day in curing state (Charles, 2012).

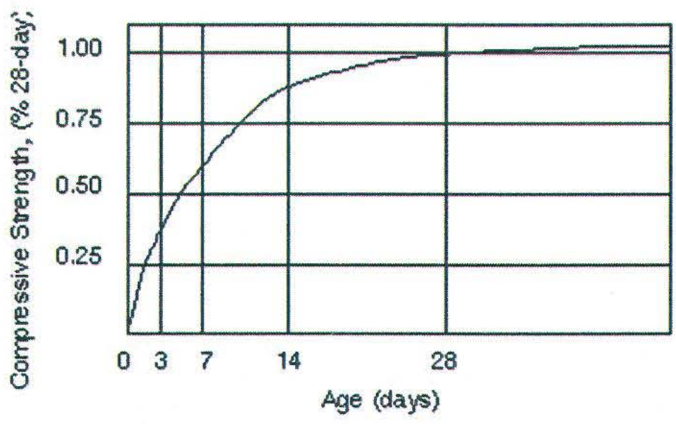

Figure 2.1: Typical Strength-Gain Curve (Source: Charles, 2011)

The main use of a concrete is to resist a compressive load because the concrete is very weak for tensile loads. Concrete has relatively high compressive strength, but significantly lower tensile strength, and as such is usually reinforced with materials that are strong in tension such as steel (Mosley, 1999). According to Mehdi (2007), concrete only have strength in tension about 8% to 12% from its compression strength. Concrete are normally fail in tensile stress when apply in compression. Since concrete is weak in tension, concrete may have a crack due to such shrinkage and temperature changes (Charles, 2012).

The compressive strength of the concrete are depended in many factors. The most important in concrete strength is water-cement ratio. According to Charles (2012), lower water cement ratio can give high strength of harden concrete. A minimum water-to-cement ratio is necessary to ensure a chemical reaction in concrete which is hydration process is completely reacting. A typical value of cement water ration is range 0.4 to 0.6 in order to achieve workability so that fresh concrete can be placed in the formwork (Charles, 2011).

2.3 Aggregate in Concrete

Aggregate is an important material in concrete that give major influence to characteristic of concrete. According to Rakesh (2005), aggregate is a material that bonds together by cement and its form a concrete. Aggregates are inert granular materials such as sand, gravel, or crushed stone.

Aggregates, which are 60 to 75 percent of the total volume of concrete, are divided into two categories aggregate such as fine and coarse aggregate. Coarse aggregate are using in concrete because to minimize cost and to prevent shrinkage of concrete when dry (Shirley, 1992). Shirley state, all aggregates must be of the type of strong, durable, clean and not webbed and contain no harmful substances, sufficient to minimize the effects on the strength and durability of concrete and reinforcement.

For example, if the surface of aggregate contains other particle can decrease the bonding between concrete mixed.

According to Max Schwartz (2000), aggregate, gravel, crushed stone lager than ¼ inch across is considered as coarse aggregate. For Fine aggregate which is include sand, the size is smaller than ¼ inch across. Fine aggregates consist of natural sand or crushed stone. Natural gravel and sand are taking from a pit, river, lake, or seabed. Crushed aggregate is produced by crushing quarry rock.

2.3.1 Granite Aggregate

Granite is one of the most common types of igneous rock. (Das, 2010). In construction, granite are normally use in concrete because of it engineering properties. It is because granite has high compressive strength, durable, hard and tough.

According to Marcus, the compressive strength from uniaxial compression test of granite is about 141.1MPa. Other than that, granite or igneous rock is suitable for most type of engineering project. The interlocking between mineral crystals gives the rock great strength. It can provide a good support for any building. Besides, he state that granite have low water absorption because of dense interlocking of crystals within the rock and very little water can move through.

Granite can be classified in term of texture as *Phaneritic* (medium-coarse-grained). All the grains are roughly the same size and interlock to form a tight mass. The large size of the crystal grains suggests a slow rate cooling (Marcus, 2008).

Granite can be found in pink color or in grey color. It depends on the mineral absent in rock itself. Minerals that are found in granite are quartz, feldspars, hornblende and micas. Granite is nearly always massive (lacking internal structures), hard and tough, and therefore it has gained widespread use as a construction stone. Table 2.2 shows the physicomechanical characteristics of granites and marble.

Table 2.2: Physicomechanical Characteristics Of Granites And Marble (Source: Okhrimenko And Sidorko, 1995)

Characteristic	Korostishiv gray granite	Tokov red granite	Koelgin white marble
Structure	Holocrystalline	Crystalline	Tranular
Porosity, %	0.90	0.86	0.50
Density, g/cm^3	2.68	2.63	2.70
Mineralogical composition, %	Quartz - 28 Plagioclase - 31 Microcline - 36 Biotite - 5	Quartz – 49 Feldspar – 47 Mica - 4	Calcite – 98 Impurities - 2
Grain size, mm	0.75	5.0	0.20
$E \cdot 10^{-5}$, MPa	0.62	0.75	0.40
Poisson's ratio	0.25	0.23	0.26
Schreiner hardness Pω, MPa	2700	2600	790
Compressive strength σco , MPa	170	180	63.5

2.3.2 Laterite Aggregate

Concrete is a man-made material, is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as cement, well graded fine and coarse aggregates and water. Concrete has a high compressive strength, built-in-fire resistance, durability, and low maintenance. However, concrete is an inherently brittle materials with lower in tensile strength compared to compressive strength, requiring a lot of reinforcement.

According to Madu (1980), with increasing price of aggregates from igneous rock and others type of rock, a need of study the performance other types of rock to replace the normal aggregates in concrete. The laterite stones, crusts etc., form one such group of rock.

Lateritic aggregates resulting from a laterite soil that weathered. Laterite soils are formed in the tropics region through weathering process that is forming iron, aluminum, and manganese and titanium oxides. In weathering process, the silicate minerals are break down by this process and form clay minerals such as kaolinite and illite (Lemougna, 2011). Because of weathered process, the soil become hard and has bonding between particles of soil and become rock or aggregate. In laterite soils, the crusts of slag like concentrations or nodules are absent. They are plastic to friable soils, red, or reddish-yellow or yellow-brown in colour (Salem, 2009).

In over the world, laterite stone use widely in building construction. Laterites and Lateritic Stones abound in the tropical and semi-tropical areas of the world, more than the igneous and other standard rocks which are used as concrete aggregates and road chippings (Madu, 1980). They are readily available and more economical compared to other natural stones like igneous rock (Lawane, 2011). Laterite are been introduced into the world since 1807 to describe as a ferruginous, vesicular, unstratified and porous material with yellow ochres due to presence of high iron content formed. It from Malabar, India (Salem, 2009).

2.4 Effect of Properties of Aggregate to Concrete Performance

Properties of aggregate have a significant effect on the behavior of fresh and hardened concrete. When determining the strength of normal concrete, aggregates are stronger than the other components in concrete mixed. The properties of aggregate is shape and texture, size gradation, it moisture content, specific gravity, soundness and bulk unit weight.

2.4.1 Effect of Shape and Texture of Coarse Aggregate

Concrete is more workable when smooth and rounded aggregate is used instead of rough angular or elongated aggregate. Shape and surface texture of aggregate are effect the properties of fresh concrete more than the properties of hardened concrete. The surface of the aggregate should be angular and sharp. According to Schwartz (2000), rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Thus, water-cement ratio must be increase due to the increment of water content.

Table 2.3: Particle Shape Classification of BS 812: Part 1: 1975 (Source: Salem, 2009)

Classification	Description	Examples
Rounded	Fully water-worn or completely shaped by attrition	River or seashore gravel; desert, seashore
Irregular	Naturally irregular, or partly shaped by attrition and having rounded edges	Other gravels; land or dug flint Laminated rock
Flaky	Material of which the thickness is small relative to the other two dimensions	
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rocks of all types;talus;crushed slag
Elongated	Material, usually angular, in which the length is considerably larger	--

Table 2.4: Surface texture of aggregates (Source: Salem, 2009)

Surface texture	Characteristics	Examples
Glassy	Conchoidal (i.e curved) fracture	Glassy or vitreous materials such as slag or certain volcanics
Smooth	Water-worn of smooth due to fracture of laminated or fine-grained rock	Alluvial, glacial or windblown gravels and sands; fine-grained crushed rocks such as quartzite, dolomite, etc.
Granular	Fracture showing more or less uniform size rounded grains	Sandstone, coarse grained rocks such as certain granites etc
Rough	Rough fracture of fine-or medium-grained rock containing no easily visible crystalline constituents	Andesite, basalt, dolerite, felsite, greywacke
Crystalline	Containing easily visible crystalline constituents	Granite, gabbro, gneiss
Honeycombed	With visible pores and cavities	Brick, pumice, foamed slag, clinker, expanded clay

2.4.2 Effect of Specific Gravity

Specific gravity is calculated by determining the densities using the displacement of water. Specific gravity of aggregate are tested using standard ASTM C 127.

The apparatus that used in this test are a balance with nearest to 1.0 gram, four sample containers, 4 water tank and sieve apparatus. The procedure is followed:

i. The test sample was dried to a constant weight at a temperature of 110 ± 5°C (230 ± 9°F), cooled in air at room temperature for 1 to 3 h. Then, the aggregate immersed in water at room temperature for a period of 24 hours.

ii. After 24 hours, the test sample was removed from the water and rolled in a large absorbent cloth until all visible films of water were removed. The larger particles were wiped individually. Test sample then weighed in the saturated surface-dry condition. Weight were recorded to the nearest 1.0 g.

iii. After weighing, the saturated-surface-dry test sample immediately placed in the sample container and its weight in water were determined. Care been taken so that all entrapped air were removed before weighing by shaking the container while immersed.

iv. The test sample was dried to constant weight at a temperature of 110 ± 5°C, cooled in air at room temperature 1 to 3 h until the aggregate is comfortable to handled and weighed. This weight was recorded as A in the calculations.

$$\text{Bulk Specific Gravity} = \frac{A}{(B - C)} \quad \text{--------Equation 2.1}$$

where:

A = weight of oven-dry test sample in air, g,

B = weight of saturated-surface-dry test sample in air, g, and

C = weight of saturated test sample in water, g

The specific gravity results are reported to the nearest 0.01 and the absorption result to the nearest 0.1%.

Specific gravity is not necessarily related to aggregate behavior. However, it has been found that some aggregates compounds of shale, sandstone, and chert that have somewhat low specific gravity may display poor performance, particularly in exposed concrete (Pedro, 2004) (i.e., low permeability is an indicator of poor durability).

2.4.3 Effect of Water Absorption

Most normal-weight aggregates (fine and coarse) have absorption capacities in the range of 1–2% by weight of aggregate (Abdulrahman, 2009). Most aggregate particles have voids, which are natural pores that are filled with air or water. These