DURABILITY OF CONCRETE CONTAINING LATERITE AGGREGATE AS PARTIAL COARSE AGGREGATE REPLACEMENT

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ABSTRACT

The most common type of coarse aggregate used for making concrete in Malaysia is crushed granite. Due to high demand of concrete, the granite aggregates used in construction industry depleting every year and might lead to increase in granite aggregates price. Therefore, studies need to be conducted to integrate other types of aggregate as partial coarse aggregate replacement in order to avoid aggregate depletion issue and environmental problem that would arise due to excessive use of this material. In the path to overcome this problem Malaysian researchers are conducting research on new construction materials with potential as coarse aggregate replacement in concrete. This thesis presents an experimental study on the effect of laterite aggregate content as partial coarse aggregate replacement towards the behavior of concrete in term of resistance to acid attack, corrosion attack as well as its moisture absorption properties. Mixes consisting a range of laterite aggregate content from (0 - 50%) was use to produce specimens that placed in water curing for 28 days before subjected to durability test. The entire experimental work was carried out according to existing standard. The results of the test conducted reveal that the resistance of concrete towards acid and corrosion decreases with increasing of laterite aggregate content in concrete. Furthermore, the moisture absorption tests indicate concrete with higher laterite aggregate content has high moisture absorption properties.

ABSTRAK

Jenis agregat kasar yang paling biasa digunakan dalam pembuatan konkrit di Malaysia ialah granit yang telah dihancurkan. Disebabkan permintaan yang tinggi untuk kegunaan konkrit, batu agregat granit yang digunakan dalam industri pembinaan semakin berkurangan setiap tahun dan mungkin membawa kepada peningkatan harga agregat granit. Oleh itu, kajian perlu dijalankan untuk mengintegrasikan lain-lain jenis agregat sebagai sebahagian penggantian agregat kasar untuk mengelakkan isu kekurangan agregat dan masalah alam sekitar yang akan timbul akibat penggunaan berlebihan bahan ini. Menuju ke arah untuk mengatasi masalah ini penyelidik Malaysia sedang menjalankan penyelidikan mengenai bahan-bahan pembinaan baru yang mempunyai potensi sebagai pengganti agregat kasar dalam konkrit. Tesis ini membentangkan kajian eksperimen kesan daripada kandungan agregat laterit sebagai pengganti agregat kasar secara separa ke atas ketahanan konkrit terhadap serangan asid, serangan kakisan serta penyerapan kelembapan. Campuran yang mengandungi pelbagai kandungan agregat laterit dari (0 - 50%) telah digunakan untuk menghasilkan spesimen yang tertakluk kepada pengawetan air selama 28 hari sebelum ujian ketahanan dilakukan. Eksperimen yang telah dijalankan adalah mengikut piawaian sedia ada. Keputusan ujian yang telah dijalankan mendedahkan bahawa rintangan konkrit terhadap asid dan kakisan menurun dengan peningkatan kandungan agregat laterit dalam konkrit. Tambahan pula, ujian penyerapan kelembapan menunjukkan konkrit dengan kandungan agregat laterit yang lebih tinggi mempunyai penyerapan kelembapan yang tinggi.

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LIST OF SYMBOLS

%	Percentage
°C	Celcius
kg	Kilograms
m	Meters
m^3	Meter Cubes
Mpa	Mega Pascal
mA	Mili Ampere
V	Voltage
hr	Hours
mnth	Month
pH	Concentration of Hydrogen ions
° N	Degree North
° S	Degree South
g/cm^3	Density
N/mm^2	Pascal

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
ACI	American Concrete Institute
BS	British Standards
BS EN	British Standard European Norm
OPC	Ordinary Portland Cement
POFA	Palm Oil Fuel Ash
AAS	Alkali Activated Slag
AIV	Aggregate Impact Value
PC	Plain Concrete
LC	Laterite Concrete
SDF	Strength Deterioration Factor
Mn	Manganese
V	Vanadium
H_2O	Water
HCl	Hydrocloric Acids
H_2SO_4	Sulfuric acid
SiO_2	Silica dioxide
Al_2O_3	Aluminum oxide
K_2O	Potassium oxide
Na_2O	Sodium oxide
CaO	Calcium oxide
FeO	Iron (II) oxide

Fe_2O_3	Iron (III) oxide
MgO	Magnesium oxide
TiO_2	Titanium dioxide
P_2O_5	Phosphorus pentoxide
MnO	Manganese (II) oxide
H_2S	Hydrogen Sulfide
C_2S	Dicalcium silicate
C_3S	Tricalcium silicate
C-S-H	Calcium Silica Hydrate gel
$Ca(OH)_2$	Calcium Hydroxide
CaSO4.2H2O	Gypsum
3CaO.Al2O3.3CaSO4.32H2O	Ettringite

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Malaysia is set to becoming a fully developed country by the year 2020. The needs for construction industry development are critical for infrastructure development and national development to reach this goal. The economic considerations demand maximum use of locally available material since they are the cheapest among the various constituents of material. Construction in Malaysia use mostly concrete, because it is cheap and made using locally available material.

Concrete is generally made of aggregate, cement and water. Through this combination of materials, approximately 70 to 80 percent of the volume of concrete is occupied by the aggregate. The aggregate itself is categorized as fine and coarse aggregate. Aggregates for concrete may be obtained from natural sources or may be artificially produced. Since concrete is the most important part in structural construction, the aggregate content should be in a form of good strength for structural purposes. Naturally aggregates have a pronounced influence on the properties of fresh as well as hardened concrete.

The most common types of aggregate generally used for making concrete in Malaysia are crushed granite. Production of granite aggregates required skills and labor in order to crush granite from boulder into small size aggregates. Extensive use of granite aggregates in construction also will eventually run out Malaysia's granite supply and might lead to increase in granite aggregates price (Hainin et al., 2012). Therefore, Suitable material should be found to replace the use of granite aggregates, to prevent this problem.

The availability of laterite aggregate has initiated research to investigate the possibility of using this material as partial coarse aggregate replacement in concrete production. Although, preliminary studies indicates that, the use of suitable amount of this material can produce concrete with good strength, but the durability of concrete containing laterite aggregate remain unknown.

1.2 RESEARCH PROBLEM

Limestone and granite are two types of aggregates commonly used in construction industry. In Malaysia, mostly crushed granite rocks are used as coarse aggregates in concrete production because of good physical properties, hard, tough, high compressive strength and durability of granite against chemical attack. The consumption of granite as coarse aggregate in concrete production is very high. Several developing countries including Malaysia have encountered some strain in the supply of natural granite in order to meet the increasing needs of infrastructural development in recent years (Ramana, 2007). Extensive use of granite in construction industry in Malaysia for coarse aggregates in concrete will lead to depletion of granite in the near future (Hainin et al., 2012). A situation like this would cause increase in the price of granite and the cost of concrete. Therefore, discovery of other material that can be used as partial coarse aggregate replacement would reduce the consumption of granite aggregate in concrete production.

1.3 OBJECTIVE

The objectives of this research are as follows;

i. To determine acid resistance of concrete containing laterite rock as partial coarse aggregate replacement
ii. To determine corrosion resistance of concrete containing laterite rock as partial coarse aggregate replacement
iii. To investigate moisture absorption of concrete containing laterite rock as partial coarse aggregate replacement

1.4 SCOPE OF STUDY

This research is conducted to compare the durability performance between granite aggregate concrete (plain concrete) and concrete with 10%, 20%, 30%, 40%, 50% replacement of laterite aggregates as coarse aggregates, when exposed to acidic and chloride environment. Other than that, moisture absorption of concrete with 0%, 10%, 20%, 30%, 40%, 50% replacement of laterite aggregates as coarse aggregates also determined in this research. Basically this research has been conducted to investigate the effect of laterite aggregate content when used as partial coarse aggregate replacement towards the behavior of concrete in term of resistance to acid attack and corrosion attack as well as its moisture absorption properties.

A total of thirty six cubes (150x150x150mm) were cast for acid resistance test and thirty six cylinders (80mm diameter, 160mm height with 12mm bar embed 120mm inside concrete) were cast for corrosion resistance test. Then, another eighteen cubes (150x150x150mm) were cast to determine the moisture absorption of concrete containing different level of coarse aggregate replacement. All the specimens were subjected to water curing for 28 days before subjected to durability testing.

1.5 SIGNIFICANCE OF RESEARCH

This research is carried out to provide additional knowledge on durability performance of concrete with laterite aggregates as partial coarse aggregates replacement in aggressive environment. Success in integrating this material in concrete production would reduce the cost concrete and reduce the high dependency of the construction industry on granite aggregate supply.

1.6 LAYOUT OF THESIS

Chapter one elaborates the introduction and the research problem that lead to this current research. Other than that, the objectives of the research, scope of study, and significance of research also described in this chapter. Chapter two of writing focuses on the aggregates and its importance in concrete. Furthermore, it also explains about the definition, properties, availability of granite and laterite aggregate in Malaysia and also its usage in concrete production. Towards the end of this chapter, durability of concrete, towards acid attack and corrosion attack are also briefly explained.

Chapter three discusses in detail the material, equipment and procedures followed in carrying out the experimental work to achieve the objective as set in this research earlier. The procedure for the testing of the concrete durability in terms of acid attack, corrosion resistance and moisture absorption is also included in this chapter. Chapter four discusses and analyzes all the data collected from the laboratory testing. In term of presentation, the analyzed data is recorded in corresponding table and presented using different graphical means to show the relationship between the tested parameters. In the discussion part also, the possible logical reasons are discussed pertaining to how the durability of the concrete can be affected under different reasons.

Chapter five generally concludes all the findings obtained from different test conducted on the samples in this project. Conclusion has been done after completing all the analysis of data collected from the experimental work highlighted in chapter of methodology. Recommendations for future research are also presented in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Concrete is the most commonly used construction material on earth. Concrete's versatility, durability, and economy have made it the world's most used construction material. Concrete are used in the construction of highways, streets, parking lots, parking garages, bridges, high-rise buildings, dams, homes, floors, sidewalks, driveways, and numerous other applications. The manufacturing of concrete is a very simple process. Concrete is plastic and malleable when newly mixed, yet strong and durable when hardened. These qualities explain why concrete are used to build skyscrapers, bridges, sidewalks, highways, houses and dams.

Over the years, technologies related to concrete have improved significantly. Other new developments include high strength concrete using waste material like POFA and PFA with higher compressive strength, self-compacting concrete which eliminate the need for costly and time-consuming compaction, lightweight concrete made with special lightweight aggregate and even the use of bamboo as reinforcement in developing countries (Irish Concrete Society, 2013). The future of concrete focuses on sustainability, the reuse of materials alongside very high strengths.

Encouragement in green technology by government around the world in past few years has motivated researcher in concrete technology to produce concrete using waste material and environment friendly material. Laterite aggregate are formed by natural weathering process available abundantly in monsoon and sub-monsoon country has shown great potential as aggregate replacement material in concrete. So far studies have been conducted by replacing laterite aggregate as partial fine aggregate (Felix ,2010) , laterite aggregate as fine aggregate replacement and fly ash as cement replacement (Joseph, 2012), laterite aggregate as partial course aggregate replacement (Muthusamy, 2012) and laterite aggregate as partial coarse aggregate with silica fume in concrete by Evalesh in 2009. However the is no research conducted on durability of concrete containing laterite aggregate as partial coarse aggregate replacement.

2.2 AGGREGATES IN CONCRETE AND IMPORTANCE OF AGGREGATES IN CONCRETE

An aggregate is rock like material of various sizes and shapes, used in the manufacturing process of concrete. Generally, aggregate occupy 70 to 80% of the volume of concrete. Type and content of aggregate greatly influence properties of concrete. Aggregate in characteristic hard, strong, free of undesirable impurities (clean), chemically stable and durable. Aggregate are produced from crushing and processing of mineral quarried stone. According to ASTM C125-07, (2007) aggregate is defined as a granular material such as sand, gravel, crushed stone or iron blast-furnace slag, used with a cementing medium to form hydraulic-cement concrete or mortar. Another researcher elsewhere (Alexander et al., 2005) identified aggregates as mineral constituents of concrete in granular or particulate form, usually comprising both coarse and fine fractions.

Aggregates are generally thought of as inert filler within a concrete mix. But a closer look reveals the major role and influence aggregate plays in the properties of both fresh and hardened concrete. Changes in gradation, maximum size, unit weight, and moisture content can all alter the character and performance of concrete mix (George, 2002). Since aggregates occupy three quarters of the volume of concrete, it is therefore its performance is of utmost importance. Not only may the aggregate limit the strength of concrete, as weak aggregate cannot produce strong concrete, but the properties of aggregate greatly affect the durability and structural performance of concrete (Neville, 1981). Aggregates exercise important influence on concrete strength and stiffness, providing rigidity to the material that is necessary for engineering use. This simply means that stronger aggregates are often preferred to be used to produce concrete having higher strength with high resistance to all possible attacks (Alexander et al., 2005). Finally, we can delineate aggregate as granular material used to produce concrete, with variety of shape, clean, strong, hard, chemically stable and durable characteristic.

2.3 GRANITE AGGREGATE

2.3.1 Definition

Granite is the most common type of igneous rock known to the public. It is widely used in concrete production due to its good engineering properties, which normally refers to the high compressive strength, hard, tough, versatile and durable. Besides, it is a kind of material which is easily accessible. It is a widely occurring type of intrusive igneous rock which usually having medium to coarse grained texture. This is because it hardens deep underground and having relatively slows cooling, which then allows crystallization of the minerals to grow large enough to be easily seen by the naked eye (Chang, 2011).

Granites are formed of an aggregate of crystals which are molded together without any interspaces between them or which enclose one another. The magnificent crystalline of granite is a striking characteristic. These minerals occur in different proportions, giving granite its own color, texture and structural characteristics. In addition, hornblende, magnetite, hematite, pyrite, zircon, garnet, corundum and other minerals may be present in smaller amounts, adding to the unique coloration and texture of each granite deposit (Raguin, 1965).

2.3.2 Physical Properties of Granite

In terms of physical properties granite is a unique material. Granite has almost negligible porosity ranging between 0.2 to 4% (Jai International, 2013). Granite is the hardest building stone and hardness of granite that lends it excellent wear. Granite is used in the production of concrete because of these qualities. The colour of granite aggregates is usually depends on its chemical composition. The colour of granite aggregate is usually red, pink, gray or white.

Granite aggregate usually exist in two type of structure form which is holocrystalline or fully crystalline and partially crystalline. According to (Okhrimenko, 1995) granite aggregate has density between 2.63 to 2.69 g/cm^3 and compressive strength between 170 to 180 Mpa. Research conducted by (Akpokodje, 1992) reveals that the absorption properties of granite aggregate is about 0.52 and has specific gravity of 2.78. Another important physical properties of aggregate is aggregate impact value. Granite aggregate has dry impact value of 17.60 and wet aggregate impact value of 19.15.

2.3.3 Chemical Properties of Granite

Granite contents a large percentage of Silica dioxide (SiO_2) and aluminum oxide (Al_2O_3). Granite is primarily composed of feldspar, quartz along with various other minerals in varying percentage. The composition of granite is varying one from another, depend on the parent material and location of the granite rock formation occur. Nominal chemical composition of various oxides in granite which differs from one granite sample to another is illustrated in Table 2.1.

Table 2.1: Chemical composition of granite

Chemical content	Composition (%)	
	Blatt & Tracy (1996)	**Swanson (2006)**
Silicon dioxide, SiO_2	72.04	69.9
Aluminium oxide, Al_2O_3	14.42	14.8
Potassium oxide, K_2O	4.12	4.0
Sodium oxide, Na_2O	3.69	3.3
Calcium oxide, CaO	1.82	2.2
Iron(II) oxide, FeO	1.68	1.7
Iron(III) oxide, Fe_2O_3	1.22	1.6
Magnesium oxide, MgO	0.71	1.0
Titanium dioxide, TiO_2	0.30	0.4
Phosphorus pentoxide, P_2O_5	0.12	0.2
Manganese(II) oxide, MnO	0.05	0.1

Source: Blatt & Tracy (1996), Swanson (2006)

2.3.4 Use of Granite in Concrete

Concrete structure is made up of cement, aggregate and water. In building construction the aggregates commonly used are limestone and granite. Three quarters of concrete is made up from aggregate, thus the selection of aggregate should be in the prime condition. Granite has been used as coarse aggregate for century in the production of concrete because of its excellent physical and chemical properties. Concrete with granite as coarse aggregates is proven has high compressive strength than most available material. Furthermore, construction industry also started to produce concrete using crushed granite as fine aggregate replacing sand. Use of crushed granite fines or crushed rock fines as an alternative to sand in concrete production has been highlighted by previous researcher Murdock, (1991).

2.3.5 Availability of Granite Aggregates in Malaysia

According to Malaysian geological study in West Malaysia, Granite is mostly available at Titiwangsa mountain range, some at East Coast and South Malaysia. Although granite is available in large quantity in Malaysia, in form of mountains and rock but it doesn't ensure, continues supply of granite in the future. Extensive use of granite in construction industry will eventually run out Malaysia's granite supply and might lead to increase in granite aggregates price (Hainin, 2012). Other than production of concrete, granite also used as furniture, landscaping, road base, concrete aggregate, fill, stone facings, monuments, countertops, wall tile, sculpture, floor tile, rock climbing activities and much more. So, depletion of granite supply in the future is inevitable. Geological distribution of granite aggregate in Malaysia is illustrated in Figure 2.1.

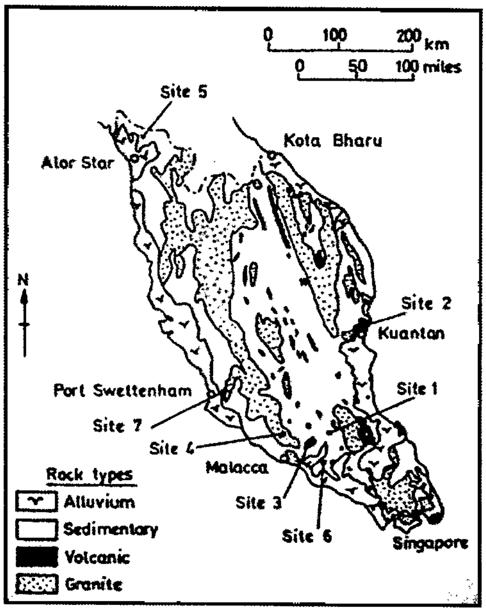

Figure 2.1: Geological distribution of granite

Source: West and Dumbleton (1969)

2.4 LATERITE AGGREGATE

2.4.1 Definition

Bishopp (1937) defined laterite as the end or apical product of a process of rock degradation which may stop short at the formation of the hydrated silicates like clays or lithomarges, or continue to hydrate according to chemical and physical environment and nature of the parent rock. On the other hand, Maignien (1966) defined laterite as sesquioxide rich, highly weathered, clayey material that changes irreversibly to concretions, hard pans or crusts, when dehydrated and the hardened relics of such material mixes with entrapped quartz and other diluents.

As for Gidigasu (1976), it was locally used by the natives as brick for building and hence he named it laterite from a Latin word "later", meaning brick. Alexander et al., (1962) compiled the physical, chemical and morphological definitions from various researchers and then redefined laterite as a highly weathered material, rich in secondary oxides of iron, aluminium, or both, it is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite, and it is either hard or capable of hardening on exposure to wetting and drying.

A modern interpretation on laterite states that laterite are the products of intensive and long lasting tropical rock weathering which is intensified by high rainfall and elevated temperatures (Schellmann, 2013). Research done by McFarlane (1976) shows that if there exist a sufficient amount of iron under suitable condition and the iron is properly arranged in clay, upon exposed to extreme conditions of wetting and drying will form a hardened mass, which is laterite.

2.4.2 Physical Properties of Laterite

The colours can vary from ochre through red, brown, violet to black, depending largely on the concentration of iron oxides (Mukerji, 1988). The darker the laterite, the harder, heavier and more resistant to moisture it is. Fresh laterites are generally reddish or orange in colour. Upon exposed to continuous weathering, changes of chemical compound of the laterite soil will then leads to colour change. A colour change indicates the degree of maturity and is due to the various degrees of iron, titanium and manganese hydration.

Laterite has specific gravity ranges from 2.9 to 4.4, which is greater than granite's specific gravity around 2.7. Laterite's absorption properties are around 3 to 9 % but granite absorption properties is less than 0.6 %. When comparing Aggregate Impact Value (AIV) of laterite and granite, granite has lower AIV in dry and wet state. The Aggregate Impact Value of laterite aggregate in wet condition is between 30 to 44% and in dry condition AIV is between 25 to 49 %. Moreover, abrasion of granite is smaller than abrasion of laterite which is between 3.5 to 20 %.

2.4.3 Chemical Properties of Laterite

As for the chemical compositions, the main content of laterite aggregate is silicon dioxide (SiO_2) and aluminium oxide (Al_2O_3). These two types of chemical will normally exist in a bigger portion compare to other chemical composition like Manganese (Mn), Titanium (Ti) and Vanadium (V) in some of the most common lateritic aggregate with their hydrated iron oxides minerals (Posnjak and Mervin, 1919). The composition of laterite is varying one from another, depend on parent material and the location of the laterite formation occur. Percentage of oxide compound composition in laterite by (Swanson, 2006) and (Flanagan, 1973) is shown in Table 2.2.