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EXPERIMENTAL STUDY ON THE PROPERTIES OF LOCAL COARSE AGGREGATE IN SARAWAK

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This project is submitted in partial fulfillment of
the requirements for the degree of Bachelor of Engineering with Honours
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ABSTRACT

The results of an experimental study on the properties of local coarse aggregate in Sarawak are presented. Three types of coarse aggregate samples were used namely limestone, granite, and microtonalite. The coarse aggregate samples were produced by six different quarries from Paku Quarry (limestone), Bestknown Quarry (limestone), Sebuyau PPES Quarry (granite), Pulau Salak Quarry (granite), Agrowell Sdn. Bhd. (microtonalite), and Stabar PPES Quarry (microtonalite). The basic properties of the coarse aggregates were determined by performing the following tests: (1) sieve analysis tests to determine the particle size and gradation in accordance with BS 812; (2) specific gravity tests to measure the specific gravity and percentage of water absorption in accordance with BS812; (3) flakiness and elongation tests to determine the flakiness and elongation index in accordance with MS 30: Part 5; (4) soundness tests to estimate the percentage of soundness loss subjected to weathering in accordance with ASTM Designation: C; and (5) Los Angeles tests to measure the percentage of durability loss against abrasion accordance with ASTM Designation: C. The laboratory test results were compared with the existing specifications for concrete and road works of Public Works Department Malaysia (JKR). Based on overall test results, the aggregates from certain quarries have better quality and thus suitable to be used as raw material in concrete and road works. Nevertheless, aggregates from some of the quarries did not achieve the limit requirements set by JKR.

ABSTRAK

Keputusan eksperimen kajian ini untuk menentukan kualiti batuan di Sarawak digunakan telah disampaikan. Tiga jenis sampel batuan bernama *limestone, granite and microtonalite* dihasilkan dari enam kauri berlainan lokasi, iaitu Paku Kuari, Bestknown Kuari, Sebuyau PPES Kuari, Pulau Salak Kuari, Agrowell Sdn. Bhd., dan Stabar PPES Kuari. Kualiti batuan dapat ditentukan dengan menjalankan eksperimen makmal berikut: (1) *sieve analysis* untuk menentukan saiz butiran batuan dan penggredan berdasarkan garis paduan dalam *British Standard 812*; (2) *specific gravity test* untuk menentukan ketumpatan berdasarkan garis paduan dalam *British Standard 812*; (3) *flakiness* dan *elongation test* untuk menentukan *flakiness* dan *elongation index* berdasarkan garis paduan dalam *Malaysia Standard 30: Part 5*; (4) *soundness untuk menganggakan peratusan kehilangan soundness* tertakluk terhadap perubahan cuaca berdasrakan garis paduan dalam *ASTM Designation: C*; dan *Los Angeles test* untuk menyukat peratusan kehiangan kekuatan berlawan degan penggeseran berdasarkan garis paduan dalam *ASTM Designation: C*. Keputusan yang diperolehi akan dibandingkan dengan garis panduan Jabatan Kerja Raya Malaysia. Berdasarkan keputusan yang diperolehi, batuan daripada beberapa kuari boleh dianggap sebagai batuan yang berkualiti dan sesuai digunakan sebagai batuan untuk konkrit and pembinaan jalan raya. Namun demikian terdapat juga batuan daripada sebilangan kuari tidak mencapai tahap minimum yang ditentukan oleh JKR.

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CHAPTER 1

INTRODUCTION AND SCOPE OF STUDY

1.1 INTRODUCTION

The general purpose of this project is to investigate the properties of coarse aggregates in Sarawak that can be used as a material for concrete and road works. Three types of coarse aggregates namely limestone, granite and microtonalite were selected from six different quarries. The main interest of the study is to produce a standard list of properties of local coarse aggregates in Sarawak that can be used as a guideline for selection of construction materials. Therefore, several tests were conducted in order to determine the basic properties of local coarse aggregate in Sarawak.

1.2 BACKGROUND

The numbers of quarries in Malaysia are increasing from year to year, which currently more than a hundred quarries in Malaysia that are actively producing various types of aggregates for the construction industry. Industrial Mineral Production Statistic & Directory of Producers in Malaysia (2002) stated that about 20% of the total amount quarries are from Sarawak. The main locations of the quarries are located in areas such as Kuching, Sibu, Bintulu, and Miri.

Aggregates play a very important role in the construction of buildings and roads. Thus, large amount of aggregates are produced every year to fulfill the needs of the construction field. The total of 84,934,240 tonnes of aggregate was produced by all quarries in Sarawak annually (Industrial Mineral Production Statistic & Directory of Producers in Malaysia, 2002).

Generally, the common types of aggregates used in Malaysia are granite, microtonalite, limestone, basalt, quartzite and sandstone. Meanwhile in Sarawak, the major types of aggregates that are commonly used in construction are limestone, granite, microtonalite and sandstone (Industrial Mineral Production Statistic & Directory of Producers in Malaysia, 2002). However, a standard list of aggregate properties of the aggregates supplied by Sarawak quarries is not available from any government departments.

1.3 SCOPE OF PRESENT STUDY

The aims of this study are to investigate the basic properties and performances of local coarse aggregate from selected quarries in Sarawak, and to produce a standard list of properties of local coarse aggregates in Sarawak that can be used as a guideline for construction purposes. In accordance with the aims of the study, the main objectives were listed as below:

1. To conduct a series of sieve analysis tests to determine the particles size and gradation in accordance with BS812.
2. To conduct a series of specific gravity tests to measure the specific gravity and percentage of water absorption in accordance with BS812.
3. To conduct a series of flakiness and elongation tests to find the flakiness and elongation index in accordance with MS30.
4. To conduct a series of soundness tests to estimate the percentage of soundness loss subjected to weathering in accordance with ASTM: C.
5. To conduct a series of Los Angeles abrasion tests to evaluate the percentage of durability loss against abrasion loss in accordance with ASTM: C.

1.4 OUTLINE OF PROJECT REPORT

Chapter 2 presents the definition of aggregate, sources of natural aggregates, processes of aggregate production, and application of coarse aggregates as construction materials. Moreover, this section also identifies the properties of coarse aggregates and the specification in JKR Standard for concrete and road works.

Chapter 3 provides the details on the methodology of the experimental works on coarse aggregate samples, which were collected from the selected quarry.

Chapter 4 describes the results obtained from the laboratory works. The analysis of the test results is based on JKR standard requirements for concrete and road works are provided in this section.

Finally, Chapter 5 contains conclusions and recommendations for future experimental works.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The main purpose of this chapter is to describe in details definition of aggregate, sources of natural aggregates, processes of aggregate production, and application of coarse aggregates as construction materials. This chapter also identifies the basic properties (i.e. physical, mechanical and chemical properties) of coarse aggregates.

2.2 DEFINITION

In civil engineering field, the term aggregate means a mass of crushed stone, gravel, sand, and others. It is predominantly composed of individual particles, but in some cases, clays and silts are also included. Aggregates are granular mineral particles used either in combination with various types of cementing material to form concrete, or alone as road bases, and backfills. Aggregates are the typical materials used in Portland cement concrete and asphalt concrete mixtures. It is also used as an underlying material for asphalt surfaces, road bases and subbases, filling under floor slabs, drainage structures, and gabion material (Atkins, 2003).

2.3 SOURCES OF NATURAL AGGREGATES

2.3.1 Aggregate geology

Rocks can be classified into three basic types namely igneous, sedimentary and metamorphic. Igneous rocks are formed from molten magma, and are divided into two main categories: extrusive and intrusive igneous rocks. The magma that cools at the surface of the earth produces extrusive igneous rocks, while the cooling in the crust of the earth produces intrusive igneous rocks. Due to the fact that the extrusive rocks cool much more rapidly than the intrusive rocks, the former have fine grain sizes whereas the latter have larger grain sizes. The classification of igneous rock are based on its composition of silica content, specific gravity, color, and the presence of free quartz (The Wikipedia Encyclopedia, 2005).

Sedimentary rocks are formed from deposits of disintegrated existing rocks or from the inorganic remains of marine animals. Wind, water, glaciers, or direct chemical precipitation transport and deposit layers of the material that become sedimentary rocks, resulting in a stratified structure. Natural cementing binds the particles together (The Wikipedia Encyclopedia, 2005).

Metamorphic rocks are igneous or sedimentary rocks that have been drawn back into the earth's crust and exposed to heat and pressure, reforming the grain structure with grain sizes ranging from fine to coarse (The Wikipedia Encyclopedia, 2005).

Igneous and metamorphic rocks are usually very hard and they are excellent aggregates for most purposes. Limestone and dolomite are quite common sedimentary rocks and they are softer than igneous rock. Even so, they are still acceptable as aggregates. All three classes of rock are used successfully in civil engineering applications. The suitability of aggregates from a given source must be evaluated by a combination of tests to check physical, mechanical and chemical properties. It must also be supplemented by mineralogical examination.

2.3.2 Types of aggregates

Aggregates may be classified as natural or manufactured. Natural aggregates are taken from natural deposits without changing their nature during production, with the exception of crushing, sizing, grading, or washing (Harold, 2003). Table 2.1 shows the classification of natural aggregates according to rock type from BS 812: Part 1 (1975). Manufactured aggregates include blast furnace slag, clay, shale, and lightweight aggregates.

A further classification would be to divide the aggregate into two types: fine and course. For concrete aggregate, fine aggregate is defined as aggregate passing a 3/8-in (9.5mm) sieve and almost entirely passing a No.4 (4.75mm) sieve and predominantly retained on the No. 200 (75μm) sieve. Coarse aggregate is defined as aggregate predominantly retained on the No. 4 (4.75mm) sieve or that portion of an aggregate retained on the No. 4 (4.75) sieve. Meanwhile, for bituminous concrete mixtures the dividing line between fine and coarse aggregate is the No.8 (9.5mm) or the No.10 (11.8mm) sieve (Harold, 2003).

2.3.3 Local coarse aggregate available in Sarawak

In Sarawak, there are many group classifications of coarse aggregates for uses as construction materials. Such as limestone, sandstone, granite and microtonalite was commonly used (Industrial Mineral Production Statistic & Directory of Producers in Malaysia, 2002). The locations for all quarries in Sarawak are shown in Figure 2.1. The group classifications of aggregates from different quarries in Sarawak are tabulated in Table 2.2 (JKR, 1999).

2.4 PROCESSES OF AGGREGATE PRODUCTION

According to Kenneth & George (1988), a good aggregate processing is to obtain aggregate of the highest quality at the least cost. The processes include, crushing, transportation, washing, screening, and sizing which begin with the blasting and quarrying of material that ends up being stockpiled or delivered to the site.

The primary blasting operation will produce blocks of various sizes, some of it may be too large to be sent directly to the crusher. In that case, the larger blocks may be reduced by secondary blasting; small charges being inserted into shot-holes drilled in the blocks, and fired on the quarry floor. After the blasting process, it is then transported by rail, truck, or conveyor belt to the processing plant.

At the processing plant, unacceptable or deleterious materials are removed as its may be harmful to the final product for which aggregates are to be used. One method of removing deleterious materials (clay, mud, leaves, etc.) is to wash the raw material. Sometimes conveyor belts are used to haul the aggregates through flumes that are flushed with water.

The next process is to reduce the size of the stone or gravel by using crushers. The old jaw crusher comprises a fixed jaw and a reciprocating jaw, which is more suitable for hard rocks while the new crusher has a higher capacity than the old jaw crusher. The usual practice is to reduce the size of rock at a ratio of 1:6 or less.

The final process in the production of crushed rock aggregate is screening, which separates the aggregate into oversize and underside fraction. Vibratory sieves are used to sizing for coarse material whereas hydraulic classification devices are for fine material. The screens vary in design, capacity, and efficiency. About 70% of material will pass through the screening process, so that the goals of high efficiency and capacity are met. In most cases, scrapping will take place to remove the oversized particles. The example of flowsheet for quarry is shown in Figure 2.2.

2.5 COARSE AGGREGATE AS CONSTRUCTION MATERIALS

2.5.1 Aggregates for Portland cement concrete

In general, the more densely the aggregates can be packed, the better the strength, weather resistance, and economy of the concrete. Aggregates occupy about

70 to 75 % of the volume of the hardened mass in Portland cement concrete. The aggregates act as a filler to reduce the amount of cement paste and to increase the ability of concrete. Aggregates gradation becomes a key factor to control the workability of the plastic concrete (Michael & John, 1999).

A blend of fine and coarse aggregate is used in Portland cement concrete to achieve an economical mix. In order to fulfill the requirement for satisfactory aggregates as state in British Standard 812, the maximum size of coarse aggregates in reinforced concrete should be easily fit into the forms and between the reinforcing bars. It should not be larger than one-fifth of the narrowest dimension of the forms or one-third of the depths of slabs nor three-quarters of the minimum distance between reinforcing bars.

2.5.2 Aggregates as a base-course material

The importance of aggregates as underlying materials or base courses contributes to the stability of the structure, provides a drainage layer, and protects the structure from frost damage. Stability is a function of the interparticle friction between the aggregates and the amount of clay and silt "binder" material in the void between the aggregates particles. But, the large amount of clay and silt content will block and affect the ability of drainage paths between the aggregates particles.

Gradation is the key factor in the success of aggregates as a base course (Michael & John, 1999).

2.5.3 Aggregates for road pavement

Aggregates as basic material for road construction which constitutes over 80% of the volume of pavement materials in road pavement such as asphalt cement, and bituminous. The bitumen or asphalt cement acts as a binder to hold the aggregates together but does not have enough strength to lock the aggregate particles into position. Therefore, the strength and stability of road pavement depend on the interparticle friction between aggregates itself.

The aggregates have the main stresses imposed by traffic such as a low crushing loads and rapid impact loads and have to resist wear. In addition, the aggregates used in the wearing course should be able to resist the polishing action of traffic. Accordingly, the aggregates must have high strength and high resistance to impact and abrasion, polishing and skidding, and frost action.