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IJIE

http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Evaluating the Weathering Effect on Granite, Limestone and Uncrushed River Stone Aggregates for Road Constructions

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DOI: https://doi.org/10.30880/ijie.2023.15.09.005
Received 8 May 2023; Accepted 1 September 2023; Available online 28 November 2023

Abstract: The lack of excellent aggregate materials has become a major issue in Sarawak. River stone, abundant in many places of Sarawak, can be used as an alternative aggregate material, minimising the reliance on high-quality aggregates like granite in the production of an affordable and sustainable road pavement. Weathering also deteriorates aggregate materials. This project aims to investigate the durability of granite, limestone, and uncrushed river stone aggregates with regards to weathering effects. The aggregates are subjected to two conditions, i.e., normal condition (without wetting and drying cycles) and wet-dry condition (with wetting and drying cycles). The physical properties of aggregates are determined by the Flakiness Index, Elongation Index, and Specific Gravity. Weathering effects on aggregates are determined using laboratory tests such as Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV), and Los Angeles Abrasion (LAA). Weathering cycles have been found to have a minor impact on aggregates in the short term. Overall, the test results indicate that wetting and drying circumstances have a negligible effect on aggregates over a short period of time. The materials' physical attributes all meet JKR requirements. The Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV), and Los Angeles Abrasion (LAA) values are nearly constant across the wet-dry state for all aggregate kinds. Despite the wet-dry situation, the AIV, ACV, and LAA tests demonstrate that specific aggregate materials retain their durability when compared to other aggregate materials. As a result, granite is the most durable aggregate in terms of AIV and LAA when compared to limestone and uncrushed river stone, while uncrushed river stone is more durable in terms of ACV when compared to granite and limestone.

Keywords: River stone, substandard aggregates, alternative aggregate materials, aggregate weathering

1. Introduction

Construction aggregate, commonly known as aggregate, is a large category of coarse to medium-grained particulate material used in construction. It includes sand, gravel, crushed stone, slag, recycled concrete, and geosynthetic aggregates. Aggregate is a collective word for natural elements such as sand, gravel, and crushed stone that are used to create composite materials (such as asphalt concrete and portland cement concrete). Aggregate constitutes between 92 and 96 percent of Asphalt Concrete (AC) and approximately 70 to 80 percent of Portland cement concrete [1]-[14]. It is also often used as a base material for roads, railroads, and foundations to create a strong foundation or road/rail base with predictable, uniform properties (e.g., to assist minimise differential settling beneath a road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete. Aggregates are an important structural component of pavements, and their properties dictate the pavement's performance and serviceability during its life. As a result, numerous researchers have highlighted the significant impact of unbound granular materials (UGMs) on the engineering performance of pavements [3], [4], [6], [7], [9], [15]-[17],

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[19]. Consequently, using durable, tough, and fatigue-resistant aggregates is a primary goal when constructing long-lasting pavements [5], [8] ,[13], [15], [16], [21], as poor material selection during construction can result in extremely costly rehabilitation work in the future [6], [15], [16]. In general, both wear resistance (particle disintegration due to crushing stresses) and decay resistance (i.e. resistance to weathering under the complicated ambient field conditions encountered by UGMs) have an effect on the durability characteristics of materials [5], [9], [15], [16].

The durability of materials has an effect on the other engineering features of aggregates to a greater or lesser extent [13]. As a result, it is critical that laboratory-based durability testing for aggregates replicate real-world conditions as precisely as feasible [15], [16], [20].

The physical properties of aggregates are closely associated with rock deterioration, commonly known as weathering. All the weathering processes can affect the quality of building stones and aggregates [18]. The longer the rock is exposed to weathering, the more it is altered, resulting in poorer aggregate quality. In order to reduce the weathering effect on aggregate, aggregates need to be impervious to prevent the aggregates break apart and causing impulsive pavement distress. Fookes et al. [6] defined weathering as the deterioration of construction materials within engineering time which occurs naturally, influenced by hydrosphere, atmosphere, and human activities. Weathering involves two major processes, i.e., physical weathering and chemical weathering. Bartley [1] described weathering of rock as a process that changes the state of a rock physically and chemically when it is allocated in a place with environment that differs from the environment where it was formed. Physical weathering combined with imposed loading can have severe impact on the deterioration of aggregate materials, however, chemical weathering can also have a significance impact when aggregate materials are in service especially in wet and hot climates. Physical weathering separates aggregates into fragments without changing the mineral constituents while chemical weathering decomposes mineral constituents into secondary mineral products that can either be stable or metastable [6].

Durability and soundness are the term used to in order to identify the aggregate weathering resistance characteristic. In physical weathering, cyclical stresses of wetting-drying process break down aggregate materials into small components [6]. When used for pavement construction, the disintegration of aggregate materials takes place during compaction and the deterioration continues as when the pavement is in service [1]. Compaction and traffic loading imposed during the service life of road materials exacerbate the effect of weathering processes [16]. In consequence, microfractures are develop and as an outcome from the cyclical wetting-drying processes, granular integration happens. Sangsefidi et al. [16] stated that weathering promotes material loss and formation of micro-cracks which consequently increase pore volumes. When aggregates matrix is altered due to physical weathering, there is lack of connection in between rock particles due to microfractures that leads to internal erosion. Chemically weathered rocks, according to Fookes et al. [6], alter in volume as a result of water absorption into the rock fabric. Repetition of wetting processes results in the development of water molecules within the rock fabric, which can exert expanding stresses on rock minerals.

Generally, road pavement construction begins with the application of granular materials such as aggregate to the existing ground structure. Typically, this aggregate is left for several days prior to the construction of the subsequent road pavement layer. Abandoning the aggregate for an extended period of time may result in aggregate deterioration due to environmental variables such as wetting and drying processes. This may have an effect on the aggregate's strength, notably on its mechanical and physical qualities. However, JKR road practise does not have a standard specification promoting the use of natural materials such as limestone and river stone in road construction. Additionally, the JKR Standard Specification for Road Works specifies that the coarse aggregate used in asphaltic concrete for road pavements shall be crushed hard rock with an angular shape. Also, as stated in Arahan Teknik Jalan 5/85 Manual on Pavement Design by Jabatan Kerja Raya [10]-[12], the materials used for coarse aggregates shall be crushed rock or crushed gravel that are free of any foreign materials.

As such, the purpose of this research is to determine the strength of various types of aggregate in order to create asphalt mixtures for road pavement. The investigation will be conducted to determine the physical and mechanical properties of natural aggregates such as limestone and uncrushed river stone, as well as the effect of wetting and drying processes on these natural aggregates in comparison to high-quality aggregates such as granite.

2. Objective

The objective of this study is to investigate the mechanical and physical properties of granite, limestone, and uncrushed river stone aggregates and to determine the effect of environmental factors on the properties of granite (GT), limestone (LS), and uncrushed river stone (UCRS) aggregates.

3. Methodology

For each application the aggregate is exposed to a different set of physical and chemical degrading forces. Some of the forces that an aggregate may be exposed throughout its service life are abrasive, tensile, shear, and compressive forces, sulphate exposure, wetting and drying cycles, and freezing and thawing cycles [14]. The load transfer capacity of pavements is greatly influenced by aggregates. It is therefore important that they be extensively tested before being