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

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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 used for any construction. The aggregates should not only be strong and durable, but also have adequate shape and size to make the pavement monolithic.

3.1 Aggregates

Aggregates used for the purpose of this research were granite, limestone, and river stone. The granite and limestone aggregates are obtained from Cahya Mata Sarawak (CMS) Resources located at 7th Mile, Kuching, Sarawak. Meanwhile, uncrushed river stone aggregate is obtained from Chop Soon Tak located at Jalan Batu Kawa, Kuching, Sarawak.

3.2 Physical and Mechanical Properties of Aggregates

The physical and mechanical properties of the aggregates used in the investigation are determined in a laboratory test. The tests involved flakiness index, elongation index, specific gravity, Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV) and Los Angeles Abrasion (LAA) as shown in Table 1.

Table 1 - Standard specification for aggregate tests

	Types of Tests	Standard Specification
Physical Properties	Flakiness Index	BS 812-105.1: 1989
	Elongation Index	BS 812-105.2: 1989
	Specific Gravity	ASTM C127-07 (Coarse Aggregate)
Mechanical Properties	Aggregate Impact Value	BS 812-112:1990
	Aggregate Crushing Value	BS 812-110:1990
	Los Angeles Abrasion Test	ASTM C131-06

3.3 Flakiness Index

The flakiness index of an aggregate can be defined as the proportion of particles by weight that have a least Dimension (Thickness) of less than 0.6 of their mean dimensions. The physical shape of coarse aggregate is critical to the performance of bituminous mixtures used in roadway pavements. The presence of flaky aggregates in bituminous mixes is an unwanted and harmful phenomenon due to their proclivity to break under wheel weight during the construction stage or throughout the pavement's service life. Additionally, the flaky pebbles will complicate reaching the requisite degree of compaction.

3.4 Elongation Index

Elongation index of an aggregate is the percentage by the weight of particle whose greatest dimension (length) is greater than one and four fifth times (1.8 times) their mean dimension. The elongation test is not applicable to sizes smaller than 6.3 mm.

3.5 Specific Gravity

Specific gravity test of aggregates is used to determine the aggregates' strength or quality while water absorption test is about the water being held and the water storage capacity of the aggregates. Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Generally, aggregates with lower specific gravity are weaker. These tests can be further distributed into bulk specific gravity, bulk saturated surface dry (SSD) specific gravity and apparent specific gravity test. Based on the parameters obtained in the test, the bulk specific gravity, bulk SSD specific gravity, apparent specific gravity, and water absorption of aggregates can be calculated.

3.6 Aggregate Impact Value (AIV)

British Standard 812 part 110 explains a method for determining aggregate crushing value (ACV) that provides a relative measure of aggregate crushing resistance under increased compressive load. ACV is used to determine the aggregate crushing value by compressive testing machine. The method applies to aggregates passing a test sieve of 14.0 mm and retaining on a test sieve of 10.0 mm. Crushing test aggregates are used to evaluate the strength of coarse aggregates. The aggregate crushing value provides a relative measure of crushing resistance under a compressive load that is gradually applied. To achieve high pavement performance, it should be preferred to use aggregates with low aggregate crushing value.

3.7 Aggregate Crushing Value (ACV)

British Standard 812 part 112 describe methods for the determination of the aggregate impact value (AIV) which gives a relative measure of the resistance of an aggregate to sudden shock or impact. The aggregate impact value provides a relative measure of an aggregate's resistance to a sudden shock or effect that varies from its resistance to a slow compressive load in some aggregates. The aggregate with an AIV percentage of less than 50% is safer to use in construction where those with a value of more than 50% are bad for construction. Calculating the AIV percentage of aggregate use for road construction is important as it will give us the road's ability to carry the load on it. The aggregate with an AIV percentage equal to or greater than 35 percent is known to be unsafe for road construction use. Resistance of the aggregates to impact is termed as toughness. Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyre wheels from one particle to another at different levels causes severe impact on the aggregates.

3.8 Los Angeles Abrasion (LAA)

ASTM designation: C131-06 explains a standard test method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine. The Los Angeles Abrasion test is a measure of mineral aggregates degradation in standard gradations resulting from a combination of acts like abrasion or erosion, impact and grinding in a revolving steel drum with a specified number of steel balls. The abrasion test of Los Angeles (L.A.) is a standard test system used to assess aggregate strength and abrasion properties. Aggregate abrasion characteristics are vital because in order to produce a high-quality HMA, the constituent aggregate in HMA must resist crushing, degradation and disintegration. To ensure a satisfactory quality in the pavement for the aggregate, it must be able to resist its long-term abrasive effect. The weak aggregates ground easily to dirt, while hard aggregates are rather resistant to crushing. As an indicator of the relative quality or competence of mineral aggregates, the LAA check is commonly used. Hardness is an important property of aggregates used in construction of highways and railroads.

3.9 Wetting and Drying

During the aggregate testing phase of this study, there are two conditions: one is without wetting and drying processes, i.e., the normal condition, which serves as the control condition, and another is with wetting and drying processes of 4, 7, and 14 cycles, which serves as the wet-dry condition. Wetting and drying are methods that are used to examine the effect of environmental conditions on aggregate qualities. The wet-dry situation replicates the real weathering condition experienced by aggregates in service. Allowing aggregates to sit in inclement weather, such as sunny or rainy days, can affect the mechanical qualities of the aggregate materials, lowering their durability. The physical and mechanical qualities of aggregates such as granite, limestone, and uncrushed river stone are determined in their natural state prior to wetting and drying operations. To create a wet-dry condition, the aggregates are first placed in a bucket and soaked in water for a day. After 24 hours of soaking, the aggregates are dried for a day on an open surface. One cycle is equal to one day of wetting and one day of drying. The study will conduct four, seven, and fourteen cycles of soaking and drying on aggregates, requiring eight, fourteen, and twenty-eight days of testing for each cycle. Granite, limestone, and uncrushed river stone were all used to test the soaking and drying process. After determining the influence of the wetting and drying procedures, the aggregates' mechanical properties are determined.

4. Results and Discussion

4.1 Comparison Between the Physical Properties of Materials

Table 2 shows that granite has a flakiness index of 7%, which is lower than uncrushed river stone at 11% and limestone at 13%. All aggregate materials have a flakiness index of less than 25%, which is allowed by JKR. Granite and limestone have 10% elongation indices, while uncrushed river stone has 16%. The elongation index of these aggregates is also acceptable, providing the JKR value is below 30%. The flakiness and elongation indices are affected by the aggregates' origin and quarries' manufacturing processes.

Using laboratory jaw crushers can produce flaky and elongated materials. Using a commercial crusher plant, however, may result in a systematic reduction of aggregate size. The aggregates from these sources had low flakiness and elongation index in the tested samples. The materials are also non-flaky and non-elongated, signifying improved interlocking performance. Granite absorbs the least water (0.413%), followed by limestone (0.490%) and uncrushed river stone (0.909%). The amount of water in aggregate materials is determined by how much water they absorb. More water-filled pores in aggregate particles promote water absorption. The aggregates' density and porosity increase. Less water absorption equals less porosity, making granite more durable and stronger than limestone and uncrushed river stone.

Because JKR's water absorption requirement is less than 2%, any aggregates can be used in pavement design. Prior to testing the aggregate's mechanical properties, its specific gravity was measured. Higher specific gravity aggregate is more difficult to work with and fragile. Table 3 shows that granite has a bulk specific gravity of 2.675, higher than limestone and uncrushed river stone. The volume of water permeable spaces inside an aggregate determines its bulk specific gravity. Porosity-rich aggregates have lower bulk specific gravity, increasing water absorption. The findings of water absorption tests demonstrate that uncrushed river stone absorbs more water than granite and limestone. Specific gravity also proxies aggregate density, which is the most important factor in aggregate strength. Less cavities and cracks with denser aggregates. It suggests a robust aggregation. Granite outlasts limestone and uncrushed river stone. Saturated Surface Dry (SSD) specific gravity and apparent specific gravity of materials are calculated. Due to the inclusion of water within permeable gaps, SSD bulk specific gravity is higher than bulk specific gravity. Granite's bulk SSD specific gravity is 2.686, as given in Table 3. Granite has the highest bulk SSD specific gravity (2.650), followed by limestone and uncrushed river stone (2.600). Compared to limestone and uncrushed river stone, granite has less water permeable gaps. The apparent specific gravity is the highest of the aggregate specific gravities because it is based solely on mass. Table 3 shows that granite has an apparent specific gravity of 2.705, limestone 2.671, and uncrushed river stone 2.638. This also proves granite's superiority over limestone and uncrushed river stone.

Table 2 - Physical properties of aggregate materials

Physical Properties	Laboratory Standard Specification	Experimental Value			Public Work Department Standard Specification
		GT	LS	UCRS	
Flakiness Index (%)	BS 812-105	7	13	11	< 25%
Elongation Index (%)	BS 812-105	10	10	16	< 30%
Water Absorption (%)	ASTM C127	0.413	0.490	0.909	< 2%

Table 3 - Specific gravity of aggregate materials

Specific Gravity Test	Laboratory Standard Specification	Aggregate Site	Experimental Value		
			GT	LS	UCRS
Bulk specific gravity	ASTM C127	Passing 14 mm retained 10 mm	2.675	2.637	2.576
Bulk SSD specific gravity			2.686	2.650	2.600
Apparent specific gravity			2.705	2.671	2.638

4.2 Mechanical Properties of Materials in Normal Condition

The mechanical parameters of granite, limestone, and uncrushed river stone aggregates are described in Table 4 for the normal condition and Table 5 for 4, 7, and 14 wet-dry cycles. In normal conditions, the Aggregate Impact Value (AIV) for all three aggregates is less than 30%. The AIV of granite is 7.70%, followed by limestone (11.66%) and uncrushed river stone (13.15%). These are the aggregates' specific gravity and water absorption. Good specific gravity and low water absorption percentage of granite indicate little porosity and high strength.

In contrast to limestone and uncrushed river stone, which are more porous and rapidly disintegrate under sudden impact, granite aggregates have a lower AIV. All three aggregates also meet the JKR-recommended ACV of less than 30%. Uncrushed river stone has the lowest ACV (17.58%), compared to granite (20.70%) and limestone (27.04%). Due to its size, uncrushed river stone can endure slow crushing. The ACV test uses an aggregate size range of 14 mm to 10 mm, which is small compared to granite and limestone.

Uncrushed river stone is rounded with low flakiness and elongation. Avoid disorientation by mixing uncrushed river stone aggregates in a steel cylinder device. Uncrushed river stone aggregates can easily fill the spaces between them when loaded gradually. The uncrushed river stone aggregates resist crushing better than granite and limestone, resulting in a lower ACV. However, the aggregate size range utilised to evaluate granite and limestone was much larger than that used to test uncrushed river stone. Because limestone is more elongated than granite and uncrushed river stone, it has a higher ACV. Because aggregate disorientation increases the space between particles, limestone aggregate is more prone to fracturing when slowly crushed. Limestone is also more porous than granite, promoting aggregate breakdown under crushing pressures and thus a higher ACV. The Los Angeles Abrasion (LAA) value of granite is 23.68%, while limestone is 28.57% and uncrushed river stone is 29.38%. JKR proposes that the standard LAA value is less than 25%, which can only be achieved through LAA testing granite aggregate. LAA values of over 25% for limestone and uncrushed river stone indicate abrasion and attrition resistance. This is because limestone and uncrushed river stone absorb more water than granite. Because limestone and river stone are porous, abrasion and impact in the LAA machine swiftly break aggregate particles. Calcite is abundant in both limestone and uncrushed river stone, contributing to its fragility. Uncrushed river stone and limestone have a higher LAA.

Table 4 - Normal condition

	Normal Condition					
	AIV		ACV		LAA	
	Standard Req.	Exp. Value	Standard Req.	Exp. Value	Standard Req.	Exp. Value
UCRS	< 30%	13.15	< 30%	17.57	< 25%	29.38
GT		7.70		20.70		23.68
LS		11.66		27.04		28.56

Table 5 - Wet-dry condition

Wet-Dry Cycle		Wet-Dry Condition					
		AIV		ACV		LAA	
		Standard Req.	Exp. Value	Standard Req.	Exp. Value	Standard Req.	Exp. Value
4	UCRS	< 30%	12.01	< 30%	17.94	< 25%	27.85
	GT		9.10		20.33		24.01
	LS		12.91		26.97		28.30
7	UCRS		11.93		17.50		27.94
	GT		9.27		20.52		22.73
	LS		11.94		24.66		28.15
14	UCRS		10.14		16.63		26.28
	GT		7.73		18.77		23.42
	LS		10.76		24.11		28.33

4.3 Comparing Mechanical Properties of Each Material Based on Test Condition

The data from Table 4 and Table 5 are presented as a bar graph for comparison between normal and wet-dry conditions. In theory, more weathering cycles mean less durability. Long-term exposure to damp or dry conditions weakens aggregates. The Aggregate Impact Value (AIV) of uncrushed river stone decreases after 4, 7, and 14 cycles.

Fig. 1 shows that the AIV for uncrushed river stone in normal condition (13.15%) drops by 1.14 percent in four cycles (12.01%), by 1.22 percent in seven cycles (11.93%), and by 3.01 percent in fourteen cycles (10.14%). Granite AIV increases 1.40 percent from normal to 4 cycles, and 1.57 percent from 4 cycles to 7 cycles. However, the impact resistance of granite under 14 cycles is virtually identical to that under normal conditions, with only a 0.03 percent difference. From 11.66 percent in the normal state, the AIV of limestone increases to 12.91 percent in four cycles and 11.94 percent in seven cycles. The AIV for limestone drops by 0.90 percent when 14 cycles with 10.76 percent limestone are compared to usual.

On the other hand, Fig. 2 shows that the Aggregate Crushing Value (ACV) of uncrushed river stone is similar after 4, 7, and 14 cycles. ACV for uncrushed river stone increases by 0.37 percent from normal (17.57%) to four cycles (17.94%), then decreases by 0.07 percent and 0.94 percent to seven cycles (17.50%) and fourteen cycles (16.63%). The ACV test result for granite shows a steady deterioration from normal to 4, 7, and 14 cycles. It drops from 20.70% to 20.33% after 4 cycles, then 0.18% and 1.93% after 7 and 14 cycles, respectively. Also, with limestone, ACV decreases from usual to 4, 7, and 14 cycles. Normal ACV for limestone is 27.04 percent, and after four cycles it is 26.97 percent.

The ACV for limestone drops from normal to 7 cycles with 24.66 percent and 14 cycles with 24.11 percent. Fig. 3 shows that the LAA test for granite aggregate yields mixed results. Normally, the LAA value for granite is 23.68 percent, but after four cycles, it rises to 24.01 percent, and then drops to 22.73 percent and 23.42 percent, respectively.

The LAA value for uncrushed river stone declines from 29.38 percent in normal condition to 27.85 percent after 4 cycles, 27.94 percent after 7 cycles, and 26.28 percent after 14 cycles, respectively. The LAA changes little between normal, 4, 7, and 14 cycle conditions for limestone. Normal limestone has a LAA of 28.56 percent, which drops to 28.30 percent after four cycles, and then to 28.15 percent after seven cycles, a 0.41 percent decrease. Difference between normal and 14 cycles LAA values is 0.23%.

Wet-dry conditions do not significantly modify the mechanical properties of aggregate materials. Normal and wet-dry circumstances show a gradual reduction of impact, crushing, and abrasion resistance. The wet-dry state is not a cause, but the percentage difference between the test findings is. In this investigation, aggregate samples are only wet-dry for up to 28 days. No significant weathering is observed in fresh andesitic aggregate materials for less than 15 years, with recorded signs of weathering beginning four months into the weathering processes. This shows that short-term wet-dry conditions have no effect on aggregate materials' mechanical properties. There is a small variation between wet and dry test findings. The bulk of aggregate samples break down into shards and dust during AIV, ACV, and LAA tests, resulting in a little weight change after testing. As a result, the results of the four, seven, and fourteen-cycle wet-dry tests vary widely.

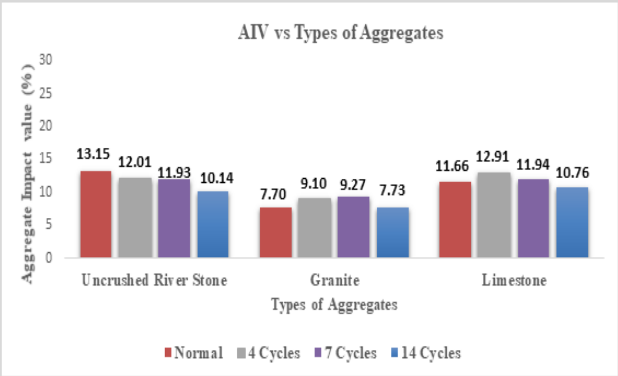

Fig. 1 - AIV against type of aggregates

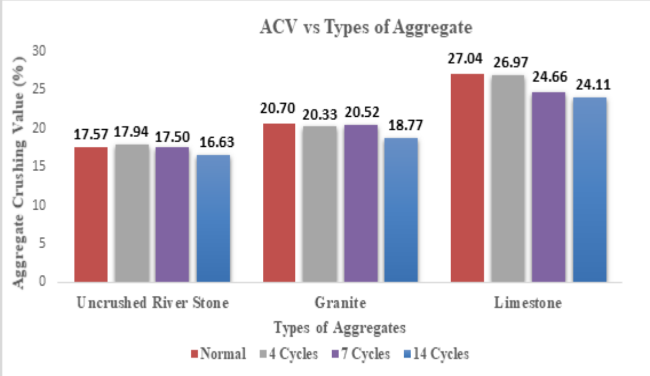

Fig. 2 - ACV against type of aggregates

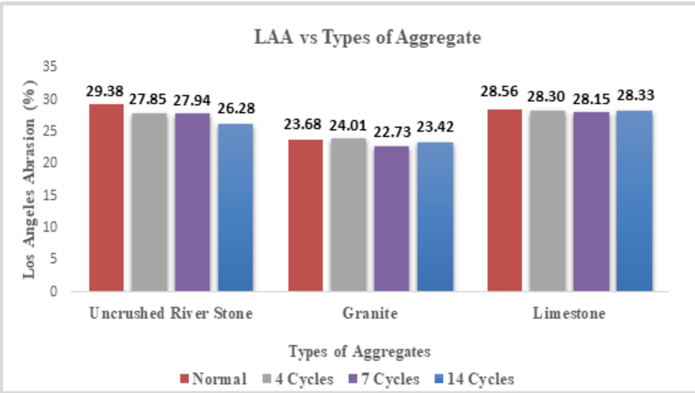

Fig. 3 - LAA against type of aggregates

4.4 Comparing Mechanical Properties Between Materials Based on Test Condition

The mechanical properties of aggregates are compared in Fig. 4 to Fig. 6 depending on the testing conditions. In the typical condition, uncrushed river stone has the greatest Aggregate Impact Value (AIV), followed by limestone and granite. As illustrated in Fig. 4, the pattern of results changes slightly in 4, 7, and 14 cycle settings, with the AIV for river stone now slightly lower than that for limestone. Due to traffic loading, in-service aggregates are constantly pulverised, resulting in aggregate fragmentation. The resistance to rapid impact is proportional to the AIV score. Porosity, which is related to the number of voids inside the aggregate, determines its ability to bear impact. When aggregates are subjected to a quick shock, impact pressures within the aggregates are generated, causing the aggregate to fragment. Aggregates with a higher water absorption capacity are more porous, as they include more water permeable spaces. Both uncrushed river stone and limestone absorb a lot of water, which means they are more porous than granite, resulting in a higher AIV.

Additionally, despite weathering, granite remains the most durable aggregate when compared to limestone and uncrushed river stone in terms of AIV test. The Aggregate Crushing Value (ACV) indicates the aggregate's resistance to crushing when compressed slowly. Highly porous aggregates are prone to crushing under traffic loads, resulting in minute fragments of shattered aggregate. Despite its high-water absorption, uncrushed river stone has the lowest ACV, indicating that it is more resistant to crushing than granite and limestone, as illustrated in Fig. 5. This is because uncrushed river stone has a rounded shape, which facilitates interlocking when a gradual load is applied. Because granite and limestone aggregates are more uneven in shape, they become disoriented under compressive load.

Granite, which has a higher specific gravity than limestone, has a dense internal structure, volume, and surface, all of which contribute to its hardness. Granite's significant quartz content further enhances its compressive strength. As a result, granite is more resistant to crushing than limestone. Granite has the lowest Los Angeles Abrasion (LAA) value when compared to limestone and uncrushed river stone, as illustrated in Fig. 6.

A lower LAA value suggests a more resistant mineral aggregate to grinding and impact operations. Granite is made of quartz minerals, which provide the material with the necessary hardness to withstand abrasive forces. Despite the wet-dry conditions, the figure illustrates that granite is more durable than limestone and uncrushed river stone. Calcite is found in abundance in both limestone and uncrushed river stone. When abrasion and impact are coupled in the LAA machine, this mineral becomes brittle and easily disintegrates. Additionally, both limestone and uncrushed river stone have a high-water absorption percentage, indicating that there are more spaces between aggregate particles and a high porosity. Thus, when compared to granite, limestone and uncrushed river stone have higher LAA values. Additionally, despite being placed in a wet-dry state, the LAA values for limestone and uncrushed river stone do not meet the required value.

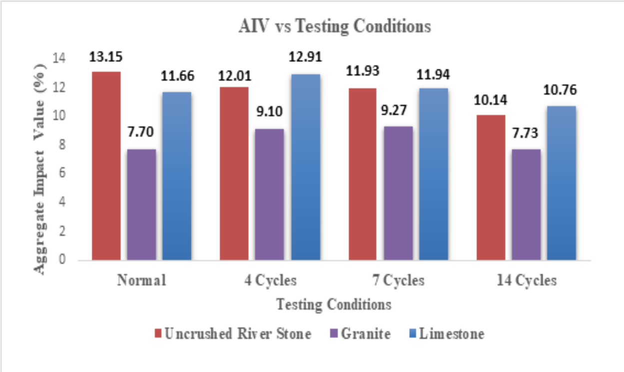

Fig. 4 - AIV against testing conditions

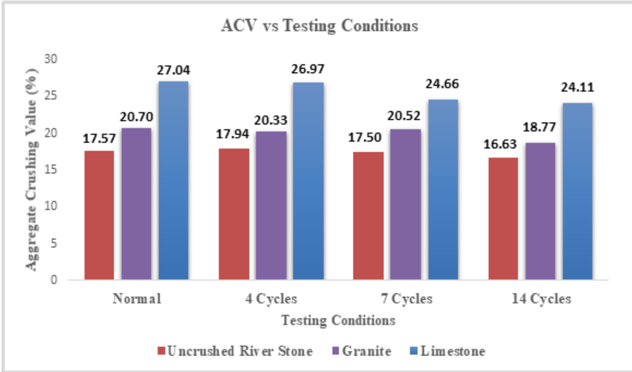

Fig. 5 - ACV against testing conditions

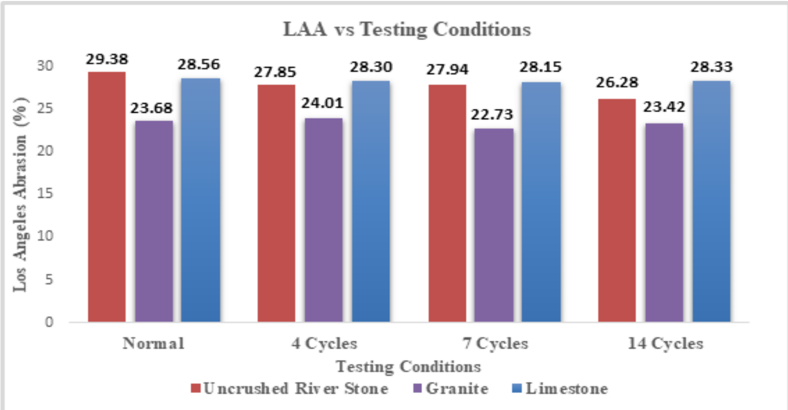

Fig. 6 - LAA against testing conditions

5. Conclusion

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. In theory, aggregate durability reduces as weathering cycles lengthen, and this study found the following:

- When wet-dry conditions are compared to normal conditions, the mechanical characteristics of all materials exhibit a modest drop.
- In comparison to limestone and river stone, granite has the lowest AIV in normal and wet-dry conditions of 4, 7, and 14 cycles.
- Throughout the cycles, the ACV of uncrushed river stone remains the lowest, followed by granite and then limestone.
- All AIV and ACV test results for granite, limestone, and uncrushed river stone meet JKR standards.
- The test results for the LAA test of granite meet the standard criterion of less than 25%, with the exception of LAA values for limestone and uncrushed river stone, which are greater than 25%.

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