Mechanical Properties of Unbound Perlis Limestone and Granite Aggregate Mixture for Road Application

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Abstract. The most important component of road construction is aggregate. As 70–80 percent of aggregates are used in road construction, the majority of aggregates used in Malaysia's road construction are granite aggregates. Due to the lack of substitutes for aggregates and the rise in demand, this may hinder the development of the road construction process. This research seeks to identify high-quality alternatives to granite aggregate that can be utilised to their full potential. Since there is no granite in Perlis, Malaysia, the mechanical properties of the Perlis limestone aggregates were evaluated to ensure that they can be used alone or in combination with granite aggregates in road construction. The AIV, ACV, and LAA tests were conducted on both individual samples of Perlis limestone and granite aggregate, as well as combinations containing various percentages of each. In all tested parameters, the results indicated that Perlis limestone aggregates were superior to granite aggregates. In addition, when Perlis limestone and granite were combined in an unbound state with the presence of limestone, the strength and resistance to abrasion and impact increased linearly. It is believed that incorporating Perlis limestone into unbound layers of road construction, such as roadbase and subbase, will enhance their performance.

1. Introduction

Numerous types of rocks exist, including igneous or magmatic rocks, metamorphic rocks, and sedimentary rocks. These rock types are distinguished by their dialling mode, mineralogical composition, crystalline structure, and texture. Due to their high silicate content, magmatic rocks are the most resistant and lasting of these groups. Metamorphic rocks are also considered with extremely high densities and mechanical strengths. Meanwhile, sedimentary rocks are characterized by a relatively large porosity and a distinct stratification, which results in low mechanical resistance which varies with the direction of force [1].

Granite and limestone are available in large quantities in most countries. In many countries, granite is the most frequently used aggregate for construction and road applications. Malaysia also produces

vast and diverse quantities of aggregates, the majority of which consist of granite and limestone and the remainder of which are basalt, diorite, and gravel [2]. Limestone is employed less frequently in heavy traffic paving structures as a result of the concentration of large companies and aggregate factories on granite as the primary ingredient [1]. In recent years, however, the idea of using limestone in road applications has gained traction, as testing samples of varying limestone quality revealed that high-quality limestone may outperform granite in terms of mechanical properties.

This research focuses on the investigation of the mechanical, and physical properties of unbound limestone and granite aggregate. The study will determine the characteristics of aggregate samples in order to meet the requirements in terms of hardness, strength, and abrasion resistance. Before being combined in different proportions in other samples, the mechanical properties of unbound limestone and granite aggregate will be evaluated separately to ensure accurate analysis of multiple samples.

2. Material and Method

The raw material for limestone aggregates was collected from the quarry at Sg. Batu Pahat, Perlis, Malaysia whereas granite aggregates were imported from Pendang, Kedah, Malaysia

2.1. Sample Preparation

Each type of test requires samples of different sizes and weights. The first step is sieving to the required sizes, then the aggregates are washed and dried in the oven for 2 to 4 hours until they reach their constant mass.

Table 1. Granite and Limestone Aggregate Mixture Percentage

No	Sample Name	% Granite (Mass)	% Limestone (Mass)
1	100G	100	-
2	80G:20L	80	20
3	60G:40L	60	40
4	50G:50L	50	50
5	40G:60L	40	60
6	20G:80L	20	80
7	100L	-	100

After the drying step, the preparation of separate samples and mixture samples of aggregates between Perlis limestone and granite was carried out based on Table 1. Three specimens were prepared for each sample and tested with three mechanical tests, which were Aggregate Impact Value (AIV) Test, Aggregate Compressive Value (ACV) Test, and Los Angeles Abrasion (LAA) Test.

2.2. Aggregate Mechanical Tests

The AIV test is conducted in accordance with BS 812: PART 112:1990. The aggregates are broken down into smaller bits as a result of the impact caused by vehicle movement on the road. The aggregates must be capable of withstanding impact fracture as a criterion. Aggregate impact value refers to the percentage weight loss of particles passing through a 2.36 mm sieve when subjected to 15 blows from a standard hammer and subsequent falling under approved test conditions. The aggregate impact value measures the aggregate's resistance to a rapid shock or impact. This may differ from the material's resistance to slow compressive stress. [4].

In addition, the ACV test measures the aggregate's crushing strength. The test is conducted in accordance with BS 812: PART 112:1990. This test is important because it determines the extent of aggregate crushing, and aggregate with a low crushing rate should be chosen to obtain a high-quality, long-lasting pavement. Aggregates were subjected to a 400 KN loading in this test, and crushing value indicates the aggregate's ability to withstand crushing due to loading. The aggregates crushability increases as the crushing value rises. It is also used in the construction of roads and pavement because it provides a numerical measure of the aggregate's total strength, allowing researchers and engineers to determine the aggregate's effectiveness and potential for use. The ACV is a relative measure of an

aggregate's resistance to crushing when subjected to a gradually applied compressive load [3]. The aggregate crushing value is a proportionate measure of a crushing resistance to increased compressive loads.

The LAA test, on the other hand, measures the degradation of standard grading mineral aggregates caused by a combination of abrasion and grinding in a rotating steel drum containing a predetermined number of steel spheres [3]. The test was conducted per ASTM C131 specifications. During this test, eleven steel spheres of grading B were utilized.

2.3. Specific Gravity and Water Absorption Test

Specific Gravity and Water absorption test was carried out to determine physical characteristic of Perlis limestone and granite. Water adsorption provides information about the internal structure of the aggregate. Aggregates with high absorption are porous in nature and are usually considered unsuitable due to the effects of water on the strength of the aggregates. Highly absorb aggregates are not suitable until they pass the strength and hardness tests.

3. Results and Discussion

3.1. AIV Test Result

The AIV test result was tabulated in Figure 1. Trendline shown linear trend result for all samples. Highest percentage of AIV was 100G samples meanwhile lowest was 100L samples. It's shown, Perlis limestone are superior to granite in term of AIV since it had lowest AIV. However, all the samples were passed the requirement set by Public Work Department (PWD), Malaysia which states that the result of the AIV test must be less than 30 %.

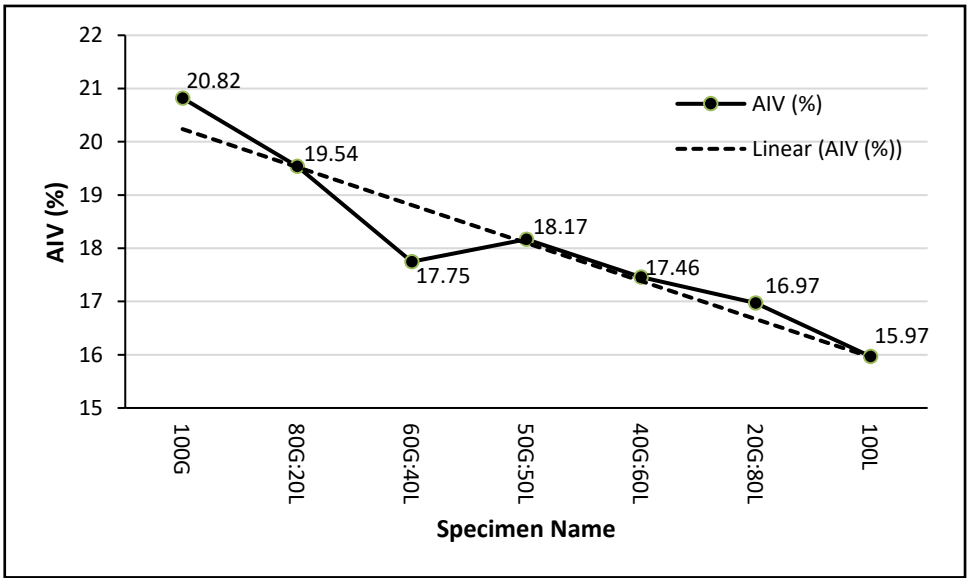

Figure 1. Result of AIV Test

Furthermore, the AIV was decreasing with increasing percentage of limestone in the mixture samples. It's shown by combining Perlis limestone with granite, the unbound sample can resist more impact than granite alone. Therefore, it was believe that by using Perlis limestone in unbound layer such as roadbase or subbase in road construction may improve its resistance to the impact from vehicle travel on the top.

3.2. ACV Test Result

Figure 2 shows the result of the ACV test for the seven samples. The result also shows linear trendline same as AIV. Sample name 100G shown highest ACV at 28.58% meanwhile the lowest ACV was the

sample name 100L at 25.34%. In addition, all the samples meet the PWD requirement for the crushing value for aggregates which not exceeding 30 % [8].

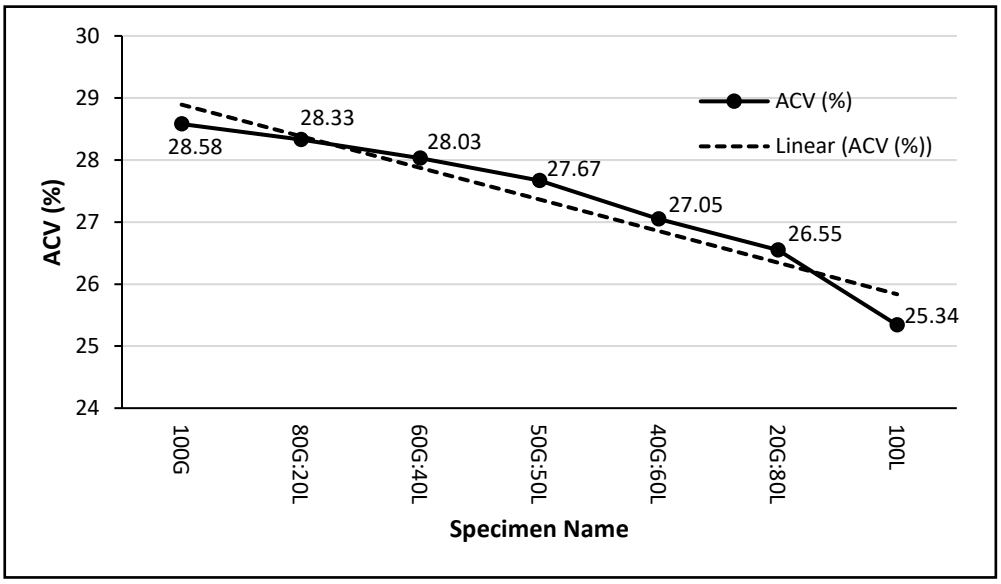

Figure 2. Result of ACV Test

Since the lower the ACV prove better strength, hardness, and stability to withstand loads, so the results shown indicate that by combining Perlis limestone with granite was found to have better strength than granite itself. Therefore, by using Perlis limestone or combining Perlis limestone it was believe will improve the strength of unbound road pavement layer.

3.3. LAA Test Result

LAA test is a test that determines the quality of aggregate in effective way and simulates the practical method for the collision of aggregate particles with each other and with any moving loads. Figure 3 shows the result of the LAA test for the seven samples.

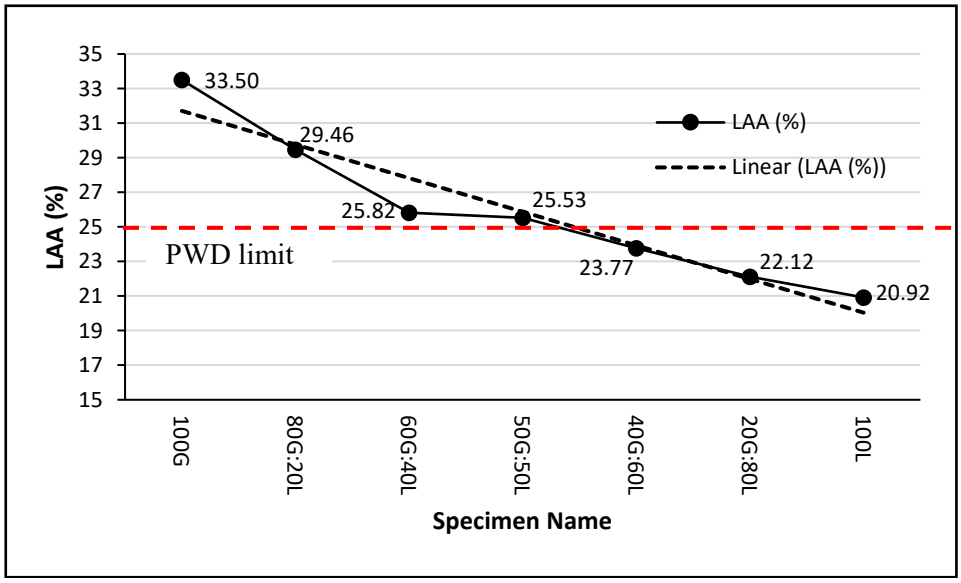

Figure 3. Result of LAA Test

The results showed the sample name 100G, 80G:20L, 60G:40L and 50G:50L have failed to meet PWD requirement where the LAA value shall not more than 25%. However, three sample meet PWD requirement which were 40G:60L, 20G:80L and 100L. Furthermore, result also shown linear trendline same as AIV and ACV. It prove that, by combining Perlis limestone with granite aggregate improved unbound aggregate resistance to abrasion.

Overall results shown same trend, by combining Perlis limestone with granite aggregate were improved unbound aggregate mechanical properties in hardness, strength and abrasion. By increasing percentage of Perlis limestone in the unbound granite aggregate will improve mechanical properties. In this study, Perlis limestone are more superior than granite aggregate in strength, hardness and abrasion. Therefore, we believe by using Perlis limestone will increase the quality of unbound layer of road construction such as roadbase and subbase. The finding are contradicted from other limestone mechanical properties studied focusing in AIV, ACV and LAA reported elsewhere [7].

3.4. Specific Gravity and Water Absorption Test

The volume of water that can be absorbed into the pore structure of aggregates is measured through absorption. Aggregate lifespan and the amount of asphalt binder absorbed may both be predicted, the increase in mass generated by water in the pores of a substance is known as aggregate absorption In addition, aggregate with high water absorption values is not durable. In contrast, a lower percentage of water absorption indicates that the aggregate possesses superior properties. Table 2 shows the result of specific gravity and water absorption of aggregate.

Table 2. Result of Specific Gravity and Water Adsorption

Description	Aggregate Type		PWD Requirements
	Limestone	Granite	
Specific gravity	2.756	2.631	-
Water absorption (%)	0.686	0.560	Less than 2 %

The results revealed specific gravity for granite and limestone aggregate, where it was 2.631 for granite, while the result of limestone aggregate is higher, which is 2.756. The results obtained in the water absorption test are excellent, as the result of the limestone aggregate is 0.686 %, and the result of the granite aggregate is 0.56 %. This indicates a low absorption by the two types of aggregate, water absorption of aggregate shall not exceed 2 % as stated in PWD [8]. Therefore, both samples have successfully passed the requirements by PWD. This indicates a lower absorption by the two types of aggregate, which confirms at the first an excellent physical properties, and leads to good mechanical properties also in loads resistance, hardness, and strength.

4. Conclusion

As conclusion, it is no doubt from this studied, Perlis limestone are more superior mechanical properties than granite in the tested parameters. From the mixture of Perlis limestone and granite in unbound condition, with the present of limestone the strength, durability and resistant in abrasion improved linearly. From the finding, it is will counter the misconception that all the limestone have fragile and weak properties which is not relevant to Perlis limestone. Furthermore, the unbound mixture Perlis limestone and granite can resist more impact, more strength and abrasion resistance than granite alone. Therefore, by combining Perlis limestone in unbound layer of road construction such as roadbase and subbase will improved their performance. On the other hand, this finding can help to increase the usage of Perlis limestone and reducing the imported of granite aggregate which contribute to higher construction cost.

References

[1] Răcănel C, Dicu M, Lazăr Ş M and Burlacu A 2015 *Romanian J. of Transport Infrastructure* 1(1)

36-49.
[2] Md Yusoff N 2008 *The Effect Of Different Aggregate Types And Gradation On The Characteristics Of Bituminous Mixtures* (Universiti Teknologi Petronas)
[3] Muniandy R and Sohadi R U R 2001 *Highway Materials: A Guide Book for Beginners* (Malaysia: Universiti Putra Malaysia Press)
[4] BS 812 - 112 1990b *Methods for determination of aggregate impact value*
[5] BS 812-110 1990a *Methods for determination of aggregate crushing value*
[6] ASTM C131/C131M 2014 *Standard test method for resistance to degradation of small size coarse aggregate by abrasion and impact in the Los Angeles machine*
[7] Hasita S, Hoy M, Suddeepong A, Horpibulsuk S, Yeanyong C, Arulrajah A, and Mohammadinia A 2021 *J. of Materials in Civil Eng. 33*(1) 04020432
[8] PWD 2008 *Standard Specification For Road Works Section 4: Flexible Pavement* 1(4) 53