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Experimental Investigation to Find the Strength of Ballast

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Abstract. In general, superstructure properties are easier to define. So many researchers and practitioners pay more attention to this structure. In contrast, substructure properties vary widely and are more difficult to study. This particular reason makes the substructure part get less attention and less studied. Although ballast is only part of the substructure, it plays an important role in keeping the railway track in position. Therefore, research about ballast behaviours still needs to be developed. Objective of this research is to use Los Angeles Abrasion (LAA) and Aggregate Impact Value (AIV) test to analyse the strength of nature rock (NR), slag (S) and their different combination. Four different types of samples have been prepared for testing. LAA and AIV test has been performed to assess the strength of the ballast. Finally, the result shows that the combination of slag and nature rock showed good results, even not really significantly. The result for 25%NR+75%S (LAA test) and 1NR+2S (AIV test) is 7,41% and 6,02%,respectively.

Keywords: ballast, LAA, AIV, slag, nature rock

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1. Introduction

The substructure properties are more varies and difficult to define than those of the superstructure. This particular reason makes the substructure part get less attention and less studied. Although ballast is only part of the substructure, it plays an important role in keeping the railway track in position. Therefore, research about ballast behaviours still needs to be developed.

The physical and mechanical characteristics of individual particles significantly influence the behaviours of ballast under both static and cyclic loading. Typically, the size of ballast grains varies in the range of 10-60 mm. Overall characteristics of the granular mass that govern ballast behaviours include particle size distribution, void ratio (or density) and the degree of saturation [1]. Some ballast materials that are often used include granite, basalt, limestone, slag and gravel [2].

Los Angeles Abrasion (LAA) test was used to artificially obtain deteriorated ballast particles [3]. A material's tendency to fracture or abrade during an abrasion test is a function of material type, particle shape, and gradation. In the LAA test, gradation is fixed; therefore, the results will reflect material type and particle shape [4], [5], [6]. Aggregate Impact Value (AIV) is another index parameter that can used

to measure the hardness of the rocks or crushed stones. AIV test provides a relative measure of the resistance of an aggregate to sudden shock or impact [7].

Materials considered to be good ballasts should have properties such as hard, dense, and angular shapes. The angular property with sharp corners will provide interlocking qualities which will grip the sleeper firmly to prevent movement. Furthermore, the stronger the aggregate will certainly make the rail track more stable and also reduce the replacement time of the ballast. In general, slag has better hardness and stability compared to nature rock. The only drawback is that slag has more weight than nature rock. However, a comprehensive lab result is still needed to verify the strength between slag and natural rock.

Researchers have previously done research on mixing materials for asphalt and concrete mixes, but for railway ballasts no one has done this. It is assumed that mixing on the railway ballast material will increase the strength of the ballast itself. Slag has a shape that tends to be rounded, thus reducing the interlocking style. Therefore, in this study, an attempt has been made to mix the slag and nature rock that has a sharp shape corner to support the interlocking style on the railway ballast. If this mixing results in a good result, then ballast durability can be increased so the costs can be reduced and routine maintenance cycles can be extended. Besides that, slag has a pore that allows water to enter, it has possibility to expand due to magnesia and loose lime contained in it. So, this study checked whether it was decreasing its strength or not. Objective of this research is to use LAA and AIV test to analyse the strength of nature rock, slag and their different combination.

2. Methods

2.1. Ballast Sample Preparation

For LAA test, four different types of samples were used. The first and second sample are 100% nature rock and 100% slag. The third sample is the mixed between nature rock and slag by volume: i) 75% nature rock, 25% slag; ii) 50% nature rock, 50% slag; iii) 25% nature rock, 75% slag. Then the last fourth sample is submerged slag which has been submerged in water at 60° for 3 days and dried in the oven for 4 hours at 110°. The procedure base on ASTM C535.

For AIV test, four different of samples were also used, 100% nature rock, 100% slag and then for making combination between nature rock and slag, three layers has been used:

i) For 75% nature rock, 25% slag: from bottom 2 layers of nature and 1 layer of slag;
ii) For 50% nature rock, 50% slag: from bottom first layer of nature rock, second layer is half slag half nature rock then third layer is of slag;
iii) For 25% nature rock, 75% slag: from bottom first layer is of nature rock and the others two slag.

2.2. Testing Methods

Standard method of LAA and AIV is used for testing. To find the abrasion value,

$$loss = \frac{W_a - W_b}{W_a} x100 \quad (1)$$

where, W_a is the original weight of the sample (5 kg) and W_b is the weight of the sample retained on 1.70 mm sieve. To find out impact value,

$$Aggregate\ Impact\ Value = \frac{W_a}{W_b} x100 \quad (2)$$

where, W_a is the weight of the sample passing through 2.36 mm sieve and W_b is the total dry weight of the sample.

3. Results and Discussion

3.1. LAA Test Result

The standard IS 2386: Part IV 1963 set a range of limits for Aggregate Abrasion value is 30% maximum. Figure 1 represents the result of an LAA test in the value of Abrasion Value in percent. In accordance with the predicted earlier, slag has the smallest abrasion value which means better than the nature rock. Surprisingly, the abrasion value of the 25% nature rock and 75% slag has good results also, even not really significantly differ. Ssubmerged slag has almost the same value compare to usual slag. From those four results which have almost the same value, it can be known very clearly that slag has great influence for affecting better result of LAA test.

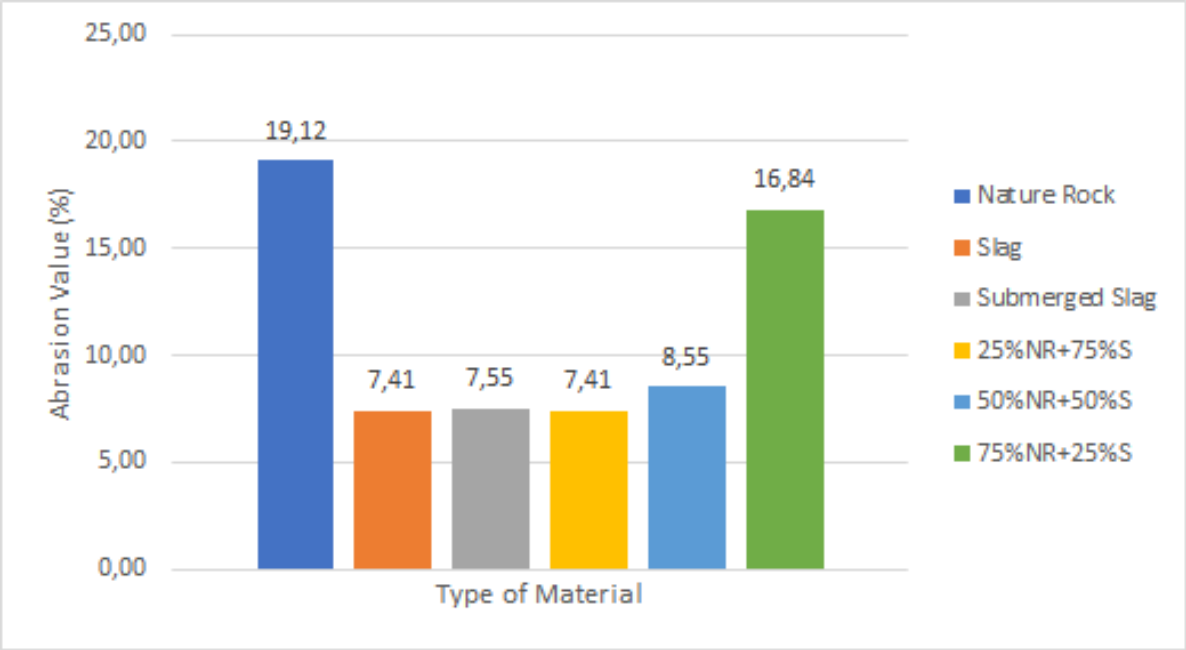

Figure 1. LAA test result of all sample

3.2. AIV Test Result

Figure 2 shows the impact value in percent. The smaller the value of impact value the stronger the material. This indicates that not much material has been destroyed due to applied load. It is clear that slag has the smallest value among all materials. Based on AIV classification, slag is considered to be exceptionally strong while nature rock has higher value comparing with other samples. But it is still considered to be strong according to the standard. The impact value of 1NR+2S is 6,02%. However, this result is still in the range of exceptionally strong. It may prove our assumption is correct. This behaviour indicates possibility the interlocking effect of each material. The standard IS 2386: Part IV 1963 set a range of limits for Aggregate Impact value is 20%maximum

As it can be seen from AIV test result, the slag and submerged slag has much difference in value. This difference is not significant in LAA test. In fact, the submerged slag contained water in the void. LAA test is only for surface degradation. So, it can be assumed that the water did not affect the result that much. But, AIV test pound and try to crush it. Then, it is assumed that the water which take some place in voids and not fully removed will affect the result of AIV test.

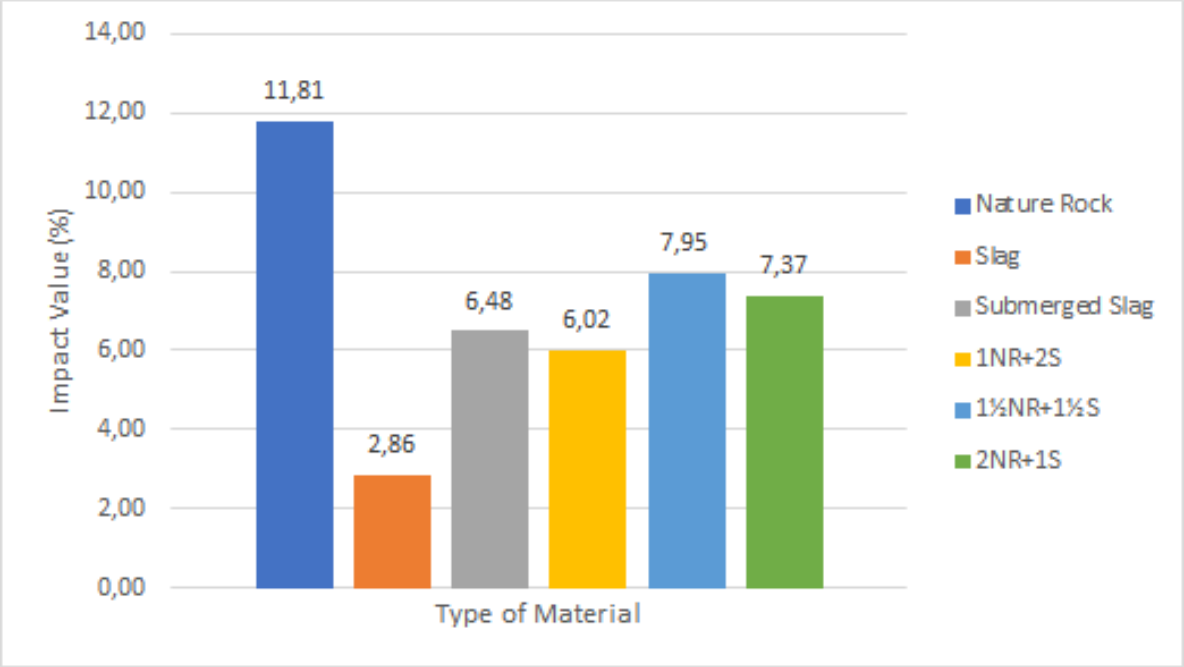

Figure 2. AIV test result of all sample

4. Conclusion

The LAA and AIV test result of slag is 7.41% and 2.86%, respectively. It proves that slag is better materials among the others. Submerged slag also showed good result for both test, again this shows that the quality of slag is good. The test result of slag and natural rock combination surprisingly has good result also, especially for 25%NR+75% (LAA test) and 1NR+2S (AIV test). The result is 7,41% and 6,02%, respectively. However, future research about the combination of slag and nature rock, for ballast railway still need to be developed. From the test, it is also noticed that that size of particle also affects the strength. Medium size particle between 30mm to 12mm size give better result. It is possible that different results will be obtained if large particles are tested in the LAA test. Whether that result still be reliable or not. So, for further research, it is recommended to examine large-sized particles as well. From our result it can be seen that besides slag, the combination of nature rock and slag also give good result, but it is suggested doing more experiment on this and also find which one is more economical to use as railway ballast.

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