Improvement of CBR value in soil subgrade using garnet waste

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Improvement of CBR value in soil subgrade using garnet waste

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Abstract. This paper presents the findings on the improvement of California Bearing Ratio (CBR) value of soil subgrade using garnet waste. Soil subgrade are very important in construction of roadways and need more attention in strength. Many researchers found that soil subgrade in Malaysia need an improvement technique for the road constructions. One of the techniques is using garnet waste which is an industrial waste that is getting bulkier, and thus create opportunity to reduce and reuse the waste. The research aims to determine the properties of soil subgrade and garnet waste, to determine the CBR value of soil subgrade and to determine CBR value of soil subgrade mixed with garnet waste. Material properties testing for soil subgrade are sieve analysis and Atterberg limit; and garnet waste used sieve analysis and chemical composition. Compaction test in the mixed proportion are used to obtain the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) and CBR test was done using CBR-Marshall Tester. In this study, the result obtained from garnet waste have been used to observed their effect on CBR value of soil subgrade by varying the amount of garnet waste contain 20%, 40%, 60%, 80% and 100%. 100% garnet waste content showed the best result for the highest 43% CBR value. The CBR value of the soil showed judicious improvement after mixing with above 40% garnet waste in the soil subgrade. As a conclusion, the improvement of CBR value in soil subgrade using garnet waste is applicable.

1. Introduction

Researchers nowadays had done different tests on soil subgrade to improve and to evaluate the strength so that soil subgrade can be used in road construction. The characteristic of soil subgrade depends on load bearing capacity and volume degree [1]. Poor soil subgrade needs several methods to improve pavement performance. Soil subgrade should have a sufficient strength to support the structure that is constructed over it [2]. The most important test to determine the strength of soil is California Bearing Ratio (CBR) test. The test is used to calculate the strength of the soil to be used as subgrade for road pavement in terms of CBR value. Study from Naveen *et al.* [3] found that soil subgrade voids are going to reduce by cohesive attraction between soil subgrade particles. To get more strength for pavement, adding the admixture to soil subgrade are necessary.

Subgrade is the foundation layer for road construction which must eventually support all the loads derived on to be pavement. The performance of the pavement is affected by the characteristics of the subgrade. The strength of subgrade is increased by soil compaction or by soil stabilization. In this

study the soil with lower CBR value is improved upon adding garnet waste [2]. Soil improvement is one of the most trustable, practical, and cheapest ways in soil stabilization to enhance its resistance, strength, and permeability [4]. A lot of studies have been done by previous researchers to determine soils behaviour [4-7]. L. Singh *et al*. [1] study about concrete fines stabilized with soil and the results show that concrete fines can be used to strengthen the subgrade and subbase in road construction.

The addition of 9% bottom ash to the road sub-base aggregate were improved the CBR value for unsoaked condition and slightly decrease of CBR value for soaked condition [8]. However, the result of CBR value for both conditions were fulfilled the requirement for road sub-base aggregate from Public Work Department Malaysia (JKR) for Standard Specification for Road Works whereas the CBR value for subgrade is more than 20% [9]. The study shows, bottom ash more effectively used as additives to the road sub-base aggregate to enhance the CBR value. Study from B.K. Sahu [10] found that CBR value for silty sand is maximum while very minimum for black cotton soil. The study proved that addition of fly ash can increased value of CBR.

Cement stabilization is one of the most common techniques for stabilizing recycled road base material and offers a longer pavement life [11-12]. A pavement section of 100m in length on the Southbound Carriageway of the North-South Expressway (West Malaysia) has been rehabilitated by strengthening the existing granular road base using cement stabilization.

Alternatively, garnet waste has been proven as potential materials to stabilize the soil [2]. Acknowledging the potential of reusing and the need to reduce garnet waste, Metallic Polymer Coating and Services Sdn. Bhd. is encouraging outsiders to take garnet waste because the amount of the waste is getting bulkier. Thus, this research was conducted to identify soil subgrade properties and took the opportunity to introduce garnet waste to be fully and partially added into soil subgrade. By doing so, the waste can be reused and reduced without compromising the environmental issue. Study from Aravind *et al*. [13] found that many waste products that could be the possible usage for road construction. From their findings, the use of garnet waste is still not being highlighted because maybe India doesn't have a large amount of garnet waste yet.

This study focuses on the alternatives for utilization of garnet waste and their potential as additives to the road subgrade. This study was limited to the uses of garnet waste in order to enhance the CBR value of road subgrade mixed with garnet waste. Specifically, the objectives of this research are to determine properties of soil subgrade and garnet waste, to determine the CBR value of soil subgrade and to determine the CBR value of soil subgrade mixed with garnet waste.

2. Materials and method

2.1. Materials

The soil subgrade (Figure 1) used in this study was collected in front of Politeknik Sultan Haji Ahmad Shah (POLISAS), Pahang. The experiment was carried out at the Geotechnical Laboratory, Civil Engineering Department, POLISAS using BS as a guideline.

Figure 1. Soil subgrade sample.

Garnet waste (Figure 2) was collected at Metallic Polymer Coating and Services Sdn. Bhd., Kemaman, Terengganu. Garnet waste used for this research came from blasting pipe activity. Here at workshop, the size used for pipe blasting is 30 to 60 mesh and produced a 2 to 3 mil profile on steel surface and considered to be an overall workhorse grade for a new steel and maintenance for coating up to 20 mils.

Figure 2. Garnet waste sample.

2.2. Method

The following tests were performed to conduct study:

- Determination of chemical composition of garnet waste using mercury survey meter.
- Sieve analysis of soil subgrade and garnet waste.
- Determination of Atterberg Limits of soil subgrade (plastic limit and liquid limit).
- Determination of the Optimum moisture content and maximum dry density of soil subgrade by conducting the Standard proctor test.
- Determination of CBR value of soil subgrade.
- Determination of CBR value of soil subgrade mixed with 20%, 40%, 60%, 80% and 100% garnet waste.

All samples were analysed using BS 1377 [14] and verified by third party laboratory**.** Chemical composition of garnet waste was determined at the Central Laboratory, University Malaysia Pahang (UMP) and other tests were conducted at Geotechnical Laboratory, Civil Engineering Department, POLISAS.

Table 1. The Notation of mixed proportion.

Sample Type	Description
10S	Fully soil
10G	Fully garnet waste
2S8G	20% soil with 80% garnet waste
4S6G	40% soil with 60% garnet waste
6S4G	60% soil with 40% garnet waste
8S2G	80% soil with 20% garnet waste

3. Results and Discussion

This study is designed according to British Standard Testing (BS1377) and Malaysian Public Work Department Specification (JKR/SPJ/1998) and discusses the results from the study conducted.

3.1. Properties of soil subgrade and garnet waste

Table 2. Result of soil subgrade properties.

No.	Properties	Results
1	Liquid Limit (%)	47
2	Plastic Limit (%)	23.1
3	Plasticity Index (%)	23.9
4	Optimum Moisture Content (%)	20
5	Maximum Dry Density (kN/m^3)	1.74
6	CBR Value (%)	19.0

Table 2 shows result of soil subgrade properties which include six (6) properties appearance a lower CBR value of 19%. The soil category is brown clayey sand and the fineness modulus is 2.81mm. Garnet waste is categorized as single graded size reddish pink sand with fineness modulus of 1.96mm. Chemical composition was carried out to characterize the encountered properties. After blasting process, the garnet waste was tested for mercury presence by using mercury survey meter and the result shows value of 0.002mg/m^3 which is below than 0.01mg/m^3 [15]. Figure 3 shows chemical composition differences between soil subgrade and garnet waste. The highest value of composition for soil is SiO_2 while for garnet waste is Fe_2O_3. This silica content helps in strengthening the compressive strength mixture of soil due to pozzolanic process [16]. Two chemicals are higher from the original, SiO_2 and Al_2O_3 but after blasting process, it was reduced for almost 50% except for Fe_2O_3. The reaction due from blasting process made percentage of ferum in Fe_2O_3 increased.

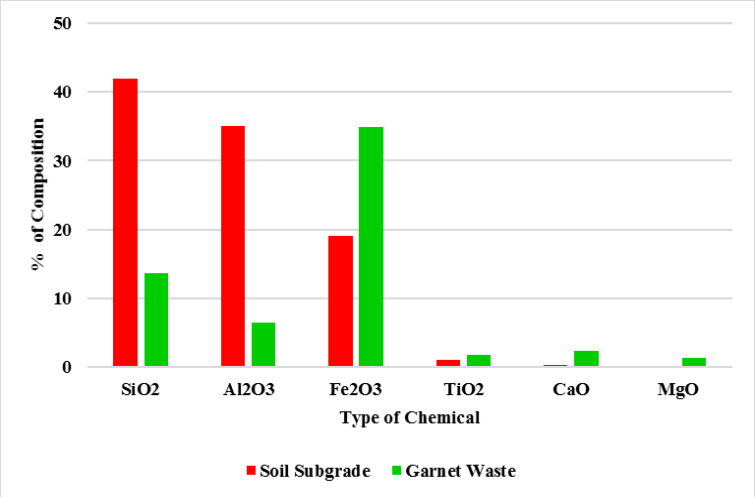

Figure 3. Chemical compositions between soil subgrade and garnet waste.

3.2. Compaction test

Figure 4 shows the correlation between OMC and MDD. The higher the value of the percentage of garnet waste added, the higher the degree of compaction. It means that the voids are less, resulted in the high and strong density. MDD increased from 1.74 to 2.56 Mg/m^3 with a decreased of OMC from 20% to 8%. The increasing of garnet waste percentage reduced the OMC and obtained a better MDD.

It shows that the particle size of garnet waste with fineness modulus of 1.97 influence the degree of compaction. 100% garnet waste obtained density value of 2.56 Mg/m^3, which is the highest density.

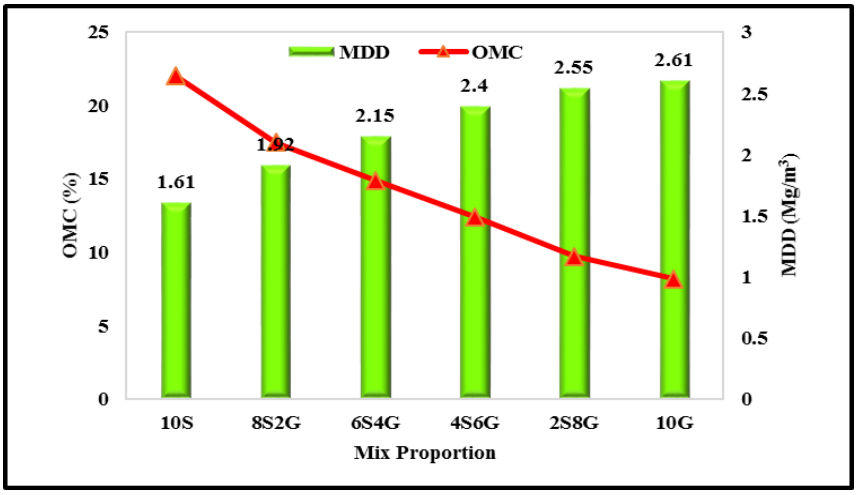

Figure 4. Correlation between OMC and MDD.

3.3. California Bearing Ratio (CBR)

Table 3. CBR values for all samples.

Sample Type	Description	CBR Value (%)
10S	Fully soil subgrade	19
10G	Fully garnet waste	43
2S8G	20% soil with 80% garnet waste	38
4S6G	40% soil with 60% garnet waste	24
6S4G	60% soil with 40% garnet waste	23
8S2G	80% soil with 20% garnet waste	20

Table 3 shows the CBR values for all samples in the mixed proportion. Figure 5 indicates the correlation between CBR values, the percentage of garnet waste content. From the histogram, the value of CBR increased by increasing the percentage of garnet waste content with Standard Deviation (SD) in the range between 0.20–0.48 Mg/m^3. According to JKR/SPJ/1998 [9], the allowable value of CBR for earthwork specification is 20%. From this result, the increasing amount, that start from 40% of garnet waste content indicate that it was suitable for mixed proportion due to the improvement of CBR value.

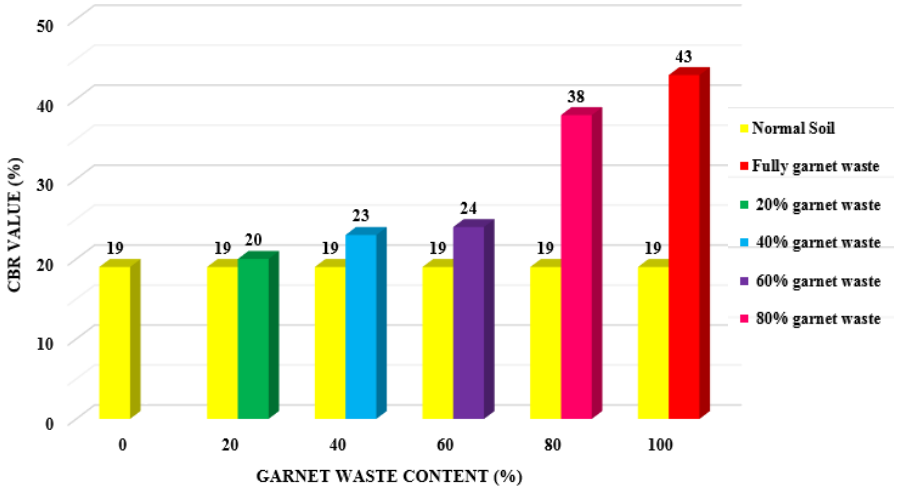

Figure 5. CBR value for all type of mix proportion.

Figure 6 shows the force versus penetration value for all samples used in CBR Test. The CBR value result is taken at 2.50mm and 5.00mm penetration. The finding showed that all mixed proportions of garnet waste percentage used in this study can be used as a replacement for subgrade. CBR value of 20% minimum requirement as subgrade according to JKR/SPJ/1998 [9].

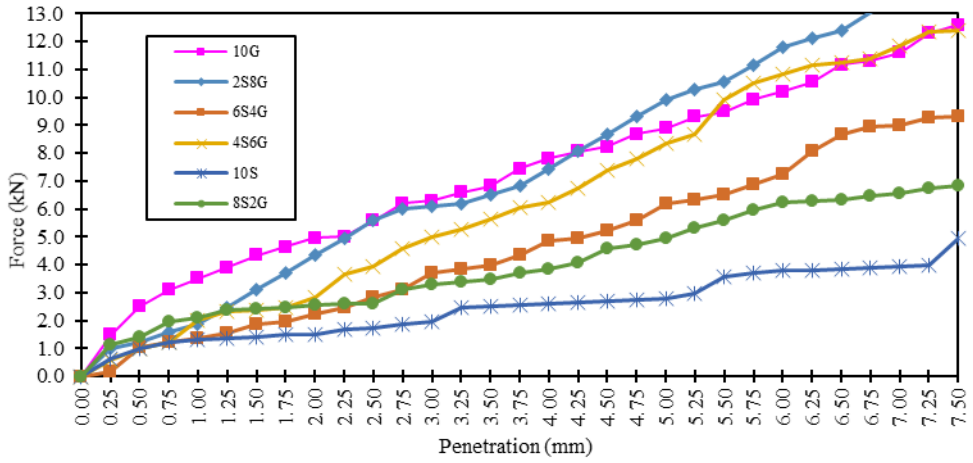

Figure 6. Force versus Penetration value for all samples used in CBR Test.

4. Conclusion

At 20% garnet waste increased in CBR value did not show any significant change. At 40% garnet waste, the CBR value of sample increased from 23% to 24%. The CBR value was improved by 10%. This shows that when garnet waste was mixed at 60% ratio in the soil subgrade, the CBR value was improved by 63%. The significant improvement of soil CBR when garnet waste is added at 80% and fully 100%.CBR result for 100% garnet waste gave CBR value of 43% with the highest density of compaction of 2.56Mg/m^3 compared to other mixed proportion. From the results it is observed that garnet waste can be used to improve the CBR value of soil subgrade with lower CBR value. Garnet waste can be particularly used to strengthen the subgrade in road construction.

The usage of garnet waste materials of more than 40% was recommended for subgrade construction. A higher percentage of garnet waste content influence a better CBR value and degree of compaction. The chemical reaction between the different element presence in soil subgrade and garnet

waste have induced CBR improvement. Ferum reaction from garnet waste and silica content from soil subgrade contributed to CBR improvement for the mixture. The highest percentage added of garnet waste in soil subgrade will not jeopardize the soil subgrade because the result showed there is no mercury present and pollution will not occur. To conclude, garnet waste has the potential to be used as an innovative alternative to replace traditional laterite soil. Garnet waste can be recycled back to the environment and save the environment from pollution. Thus, this will reduce the construction cost and solve disposal problems. Further study will be performed flow ability test for garnet waste content in order to prevent any materials penetrate into water easily.

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