Characterization of soil mixed with garnet waste for road shoulder

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Abstract. This paper presents the findings on the characterization of soil mixed with garnet waste for road shoulder. Road shoulder at local road nowadays has insufficient compaction due to local settlement and further compaction by parked vehicles. Garnet waste is one of the industrial wastes that is getting bulkier, and thus create opportunity to reduce and reuse the waste. The research aims to determine the properties of soil and garnet waste, to determine the moisture content of materials, degree of compaction, and to propose the maximum percentage of mix proportion under California Bearing Ratio (CBR) test for road shoulder. Material properties testing involved sieve analysis and chemical composition. Compaction test in the mixed proportion of 100% soil (10S), 100% garnet waste (10G), 20% soil and 80% garnet waste (2S8G), 40% soil and 60% garnet waste (4S6G), 60% soil and 40% garnet waste (6S4G), and 80% soil and 20% garnet waste (8S2G) obtained the Optimum Moisture Content (OMC) between 8–20% and Maximum Dry Density (MDD) between 1.74–2.56 mg/m³. From the OMC desired, CBR test was conducted and the optimum value of 40% added percentage of garnet waste can be used as the mix proportion for road shoulder construction. The addition of garnet waste content tends to increase MDD and the fineness modulus also influence the degree of compaction. The results showed that garnet waste has good potential as road shoulder in the percentage of 40% and above for mixed proportion with soil. The regression value (R²) of 0.86 and 0.96 for CBR and MDD, respectively was derived to predict the real CBR and MDD during real road construction using the garnet waste content.

1. Introduction
Public Work Department, Malaysia recently issued news on the damaged happened on local roads, especially road shoulder at the rural area caused by layers of strength and thickness, mixture design, change in traffic load, and a few more factors [1]. Road shoulders must function effectively and be sufficiently stable to support vehicle loads. However, road shoulders at local road are suffering from insufficient compaction due to local settlement and further compaction by parked vehicles. This creates the need to build a stronger road shoulder by blending the main materials with other waste materials. As demand for increase load bearing capacity materials to be used in road shoulder is high
but sand as its source are limited, the cost of sand is now increasing. Alternatively, garnet waste has been proven as potential materials to stabilize the road shoulder. 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 properties of road shoulder in the local area, and took the opportunity to introduce garnet waste to be partially added into soil. By doing so, the waste can be reused and reduced without compromising the environmental issue.

Soil improvement is one of the most trustable, practical, and cheapest ways in soil stabilization to enhance its resistance, strength, and permeability [2]. A lot of studies have been done by previous researchers to determine soils behavior [2-5]. Three main agendas in the soil strength are to increase load bearing capacity, stiffness and resistance to weathering on the development and to reduce swelling potential as the modification of soil or aggregate layers by incorporating stabilizing materials. Ozdemir [6] found that addition of 7% or more fly ash (FA) can improve the bearing capacity of soil in the area of Elmadag, Turkey. Their findings showed that maximum dry density (MDD) decreased slightly as addition percentage of FA while the optimum moisture content (OMC) increase gradually. Gupta and Sharma [7] studied on the influence of waste materials on geotechnical characteristics of expansive soil along Beas River, where the soil chosen was black cotton soil in India. The soil had cyclic swelling and shrinkage behavior that encounter many problems during construction. They found that 15% of fly ash added with 63% black cotton soil and 27% sand composite can stabilize black cotton soil as a subbase.

Evaluation of lateritic soil stabilized with Arecanut coir for low volume pavement was done by Lekha [8]. They found that Arecanut coir mixed with 0.6% OMC by weight of soil can improve the soil properties in terms of stabilization. Addition of fly ash, lime, and sugarcane straw also increased OMC and California Bearing Ratio (CBR) value [9-10]. A study by Aravind and Das [11] in Malaysia found that industrial waste products such as fly ash, blast furnace slag, waste tire, glass waste, china clay, marble dust, and demolition waste can be used in highway construction.

Stabilization of subbase layer materials with waste pumice in flexible pavements showed that pumice can increase the strength and can be used as subbase [12]. Emersleben and Meyer [13] conducted a research on the use of recycled glass as light infill material for the construction of pavements. They found that recycled glass can be best mixed with asphalt and concrete. A big volume of cutting waste sand was found at Lawrence Livermore National Laboratory (LLNL) [14]. A study found waste cutting sand for two cases: to be mixed with concrete and application as trench backfilled.

The overall objective of this research is to determine the percentage content of garnet waste as particle waste addition materials to be mixed with laterite soil in the road shoulder. Specifically, the objectives of this research are:

i. To determine properties of soil and garnet waste

ii. To determine the optimum moisture content of materials and degree of compaction for road shoulder

iii. To propose the maximum percentage of mix proportion under CBR test for road shoulder

2. Materials and Methods
The soil sample was taken from the road shoulder along the local road in front of Politeknik Sultan Haji Ahmad Shah (POLISAS). Analysis was carried out at Geotechnical Laboratory, Civil Engineering Department, POLISAS using BS Standard as a guideline.

2.1 Materials
The soil was subjected to sieve analysis, compaction test and CBR Test. Garnet waste sample as shown in Figure 1 was taken at Metallic Polymer Coating and Services Sdn. Bhd. Chemical composition was carried out to characterize the encountered properties. After blasting process, the garnet waste was checked for the presence of mercury by using mercury survey meter as in Figure 2
and the result showed a value of 0.002 mg/m$^3$. The requirement of mercury value is below 0.01 mg/m$^3$ [17]. Thus, it can be concluded that this garnet waste is safe to be used in the mix proportion with soil.

2.2 Methods
Sieve analysis to determine the percentage of different grain sizes contained in the soil and garnet waste was performed according to BS 1377 [15]. Chemical composition of garnet waste was determined at the Central Laboratory, University Malaysia Pahang (UMP). XRF Tiger S8 machine was used to determine the parameter for chemical composition of garnet waste. Compaction test and CBR test were done for six (6) types of mixed proportion: 100% soil (10S), 100% garnet waste (10G), 80% soil and 20% garnet waste (8S2G), 60% soil and 40% garnet waste (6S4G), 40% soil and 60% garnet waste (4S6G), and 20% soil and 80% garnet waste (2S8G). All samples were analyzed using BS 1377 [16] and verified by third party laboratory.

3. Results and Discussion
This section discusses the results from the study conducted.

3.1 Properties of Soil and Garnet Waste
Figure 3 shows the particle size distribution curve for soil. The maximum value of particle size retained for soil was at sieve 1.18 mm size which contained 41% retained. According to Unified soil classification system (USCS), the finding on soil size classified the soil as Brown Clayey Sand. From the sieve analysis result shown in Figure 4 the result showed that garnet waste was classified as Reddish Pink Sandy Clay, according to USCS. The pattern of garnet waste was categorized as a single size graded, where very few sizes retained thru the sieve. The physical properties of garnet from materials safety data sheet (MSDS) showed that it is a solid particle, reddish pink color, and odorless. The hardness from 7.50 to 8 indicates it as friable to tough.
Figure 3. Sieve analysis for soil.

Figure 4. Sieve analysis for garnet waste.

The differences of fineness modulus for soil and garnet waste are in the average value of 2.81 and 1.97, respectively (Table 1 and Table 2). The standard deviation for soil were 0.09 and garnet waste was 0.04. It also means that the fine value is finer than the sand and thus both samples are suitable as a mixed proportion for mix design in this study. The properties of garnet waste from blasting pipe process showed potential to be mixed with soil as a road shoulder.

| Sample No. | Fineness Modulus | Average | Standard deviation (SD) |
|------------|------------------|---------|-------------------------|
| 1          | 2.86             |         |                         |
| 2          | 2.85             |         |                         |
| 3          | 2.85             | 2.81    | 0.09                    |
| 4          | 2.65             |         |                         |
| 5          | 2.84             |         |                         |

Table 1. Fineness modulus for soil.

| Sample No. | Fineness Modulus | Average | Standard deviation (SD) |
|------------|------------------|---------|-------------------------|
| 1          | 1.97             |         |                         |
| 2          | 1.94             |         |                         |
| 3          | 1.94             | 1.97    | 0.04                    |
| 4          | 1.98             |         |                         |
| 5          | 2.05             |         |                         |

Table 2. Fineness modulus for garnet waste.

Figure 5 shows chemical composition differences between laterite soil [18] and garnet waste. The highest value of composition for soil is SiO$_2$ while for garnet waste is Fe$_2$O$_3$. Two chemicals are higher from the original, SiO$_2$ and Al$_2$O$_3$ but after blasting processed, it was reduced for almost 50%
except for Fe$_2$O$_3$. The increasing percentage of Fe$_2$O$_3$ are due to the process of blasting reacted with the pipe materials which is ferum.

![Chemical compositions between laterite soil and garnet waste](image)

**Figure 5.** Chemical compositions between laterite soil and garnet waste.

### 3.2 Properties of Soil and Garnet Waste

Figure 6 shows moisture content for soil ranges from 17 to 24% and from 4 to 12% for garnet waste. The average moisture content indicated that the value is still in the range of the value experimented. Standard deviation (SD) below 0.58% means the values are consistent and are suitable to proceed with the next CBR test.

![Moisture content for soil](image)

**Figure 6.** Moisture content for soil.

### 3.3 Compaction Test

Figure 7 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 is 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 (10G) obtained density value of 2.56 Mg/m$^3$, which is the highest density.

![Compaction Test](image)
3.4 California Bearing Ratio (CBR)

Figure 8 indicates the correlation between CBR values and 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 [19], the allowable value of CBR for earthwork specification is 20%. From this result, the increasing that start from 40% of garnet waste content indicate that it was suitable for mixed proportion due to the improvement of CBR value.

Figure 9 shows the correlation between the percentage of garnet waste content for CBR and MDD. The correlation indicates that the added percentage of garnet waste content up every 20% led to the increasing values for both parameters.
Figure 9. Correlation between percentage of garnet waste content for CBR and MDD.

Figure 10 shows predicted equations for CBR and MDD value on the percentage of garnet waste content. The regression value, $R^2$, is 0.86 and 0.96 for CBR and MDD, respectively. These values can be used to predict CBR and MDD during the real road construction by using the garnet waste material.

The finding showed that all mixed proportions of garnet waste percentage used in this study can be used as a replacement for road shoulder. CBR value of 20% minimum requirement as road shoulder according to JKR/SPJ/1998 [19]. In this case, the design for road shoulder for traffic loading is not more than 20% for the emergency case as a stopping lane for the vehicle to maneuver at the roadside. It can be considered until structure level value for 20% minimum requirement by JKR standard.

4. Conclusion
Increasing the percentage of garnet waste content gave effect for a better increment of Maximum Dry Density (MDD) and reduced the percentage of moisture content. Every addition of 20% mixed of garnet waste content will increase 10% degree of compaction from 1.74 Mg/m$^3$ to 2.56 Mg/m$^3$. Optimum Moisture Content (OMC) on the other hand were decreased to about 2% from addition of 20% garnet waste content. Moisture content value also decreases as dry density getting higher. The 100% garnet waste sample gave 8% OMC and 2.56Mg/m MDD value.

Increasing the percentage of garnet waste content influence the CBR values. It increased about 1–10% of CBR value from 0–100% of the garnet waste content. It also influences the increasing of density. The more the value content of garnet waste, it begins to increase the MDD. The usage of
garnet waste materials of more than 40% was recommended for road shoulder construction. A higher percentage of garnet waste content influence a better CBR value and degree of compaction. 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.

5. References
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