Characterization of Soil Mixed with Garnet Waste for Road Shoulder

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ABSTRACT
Road shoulder at local road nowadays has insufficient compaction due to local settlement and further compaction by parked vehicles. Garnet waste is one the industrial waste that getting bulkier and it is the idea to reduce and reuse the waste. The research aims to determine the materials properties for soil and garnet waste, to determine the moisture content of materials and degree of compaction for road shoulder and also to determine the optimum mix proportion under California Bearing Ratio (CBR) test. Material properties testing are sieve analysis, Atterberg limit and chemical composition. Compaction test in the mixed proportion of 100% soil, 100% garnet waste, 2S8G, 4S6G, 6S4G and 8S2G were got the Optimum Moisture Content (OMC) between 8-20% and Maximum Dry Density (MDD) between 1.74-2.56 Mg/m$^3$. From OMC desired, CBR test was conducted and the optimum value gave 40% of 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 obtained that garnet waste has a good potential as road shoulder in the percentage of 40% and above for mixed proportion with soil. The regression value of $R^2$ was 0.86 and 0.96 for CBR and MDD, respectively derived to predict the real CBR and MDD during real road construction using the garnet waste content.

1. Introduction

Nowadays, Public Work Department, Malaysia had been issuing news on the damaged on local roads especially road shoulder at the rural area. The reasons behind can be observed by layers of strength and thickness, mixture design, change in traffic load, and etc. [2]. In addition, disposal problems from industrial are increasing with the vast quantity of the waste material made.

**Problem 1**: Road shoulders must function effectively and be sufficiently stable to support vehicle loads. However, road shoulders at local road nowadays have insufficient compaction due to local settlement and further compaction by parked vehicles. Thus, this research was conducted to identify soil properties of road shoulder in the local area.

**Problem 2**: Sources of sand is limited nowadays so the cost are increased as well as the demand to search for new materials as stabilizer for road shoulder. Therefore, garnet waste was introduced in this research for partially or fully mixed with soil as replacement of sand. Metallic Polymer Coating and Services Sdn Bhd is encouraging outsider to use garnet waste because the waste is getting bulkier and there are no proper to keep it except to pay Kualiti Alam for disposal. This type of disposal is expensive, thus the ideas to reuse, recycle and reduce the garnet waste without jeopardizing the environmental.

The overall objective of this research is to determine the percentage content of garnet waste as an agent of stabilize to be mixed with laterite soil in the road shoulder. The specific 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 mix proportion under California Bearing Ratio (CBR) test for road shoulder

Soil improvement is one of the most trustable, practical, and cheapest ways in soil stabilization to enhancing the resistance, strength and permeability of soil [7]. A lot of studies have been done by previous researchers to determined behavior of soils [18][9][7][11].

Two main agendas in the soil stabilization are to increase load bearing capacity stiffness and
resistance to weathering on the development and reduce swell potential as the modification of soil or aggregate layers by incorporating stabilizing materials.

Study by researchers found that addition of 7% or more fly ash can improve the bearing capacity of soil in the area of Elmadag, Turkey [13]. MDD is decreased slightly as addition % of FA while the OMC increase gradually. Study on the influence of waste materials on geotechnical characteristics of expansive soil along Beas river [6] had been done for black cotton soil in India. The soil had cyclic swelling and shrinkage behaviour that encounter many problems during construction. They found that 15% of fly ash added with 63% black cotton soil and 27% sand composite can be stabilized black cotton soil as a subbase.

Study on evaluation of lateritic soil stabilized with Areca nut coir for low volume pavement [8] found that Areca nut coir mixed with OMC 0.6% by weight of soil can improve the soil properties stabilization. Addition of fly ash, lime and sugarcane straw also increased OMC and CBR value [16] [12].

Study in Malaysia found the possible usage of industrial waste products, for example fly ash, blast furnace slag, waste tire, glass waste, china clay, marble dust and demolition waste [1]. Findings of their study conclude waste product can be used in highway construction.

Stabilization of subbase layer materials with waste pumice in flexible pavements showed Pumice can increase the strength and can be used as subbase [15]. A research on the use of recycled glass for the construction of pavements, where light infill material used is recycled glass [5]. The researcher finds that recycled glass can be best mixed with asphalt and concrete.

A big volume of cutting waste sand found at Lawrence Livermore National Laboratory (LLNL) [10]. Study found that waste cutting sand for two cases, mixed with concrete and application as trench backfilled. The finding result showed that garnet waste can be used for concrete poured to form a walkways and patio at the laboratory.

2. Methodology

A sample of soil was taken from the road shoulder along the local road in front of POLISAS. The soil was collected and the experiment was carried out at Geotechnical Laboratory, JKA, POLISAS using BS Standard as a guideline. Experiment involved are sieve analysis and Atterberg limit; plastic limit and liquid limit, Compaction test and CBR Test.

Garnet waste sample (Figure 1) were taken at Metallic Polymer Coating and Services Sdn Bhd. Chemical composition was carried out to characterized the encountered properties. After blasting process, the garnet waste was tested for mercury present by using mercury survey meter (Figure 2) and the result showed value of 0.002mg/m³. The requirement of mercury value is below 0.01mg/m³. It can be concluded that this garnet waste is safe to be used in the mix proportion with soil.

![Figure 1: Garnet Waste](image1.png)

![Figure 2: Mercury Survey Meter](image2.png)

Atterberg limit which consists of two experiment that is a plastic limit and liquid limit were done according to BS 1377 Part 2, 1990 [3]. Sieve analysis is to determine the percentage of different grain sizes contained in the soil and garnet waste was done according to BS 1377 Part 2, 1990.

Chemical composition of garnet waste was done 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 had been done for six (6) types of mixed proportion, 100% soil, 100% garnet waste, 8S2G, 6S4G, 4S6G and 2S8G. All samples were done using BS 1377 Part 4, 1990 [4], and had been verifying by third party laboratory.
3. Result and Discussion

3.1 Materials properties

Figure 3 shows the particle size distribution curve for soil. The maximum value of particle size retained for soil was at sieve 1.18mm size which contained 41% retained. The result according to Unified soil classification system (USCS) is classified the soil as Brown Clayey Sand.

From the sieve analysis (Figure 4), the result showed that garnet waste according to USCS was classified as Reddish Pink Sandy Clay. The pattern of garnet waste is categorized as a single size graded, where very few sizes had retained thru the sieve. The physical properties of garnet from Materials safety data sheet (MSDS) showed a solid particle, reddish pink colour and odourless. The hardness is between 7.50 to 8 means friable to tough.

The differences of fineness modulus for soil and garnet waste which is the average value of 2.81 and 1.97, respectively. The standard deviation for soil were 0.09 and garnet waste was 0.04. It also means that the fine value is finer than sand and suitable for mix design for both samples as a mixed proportion in this research. The findings materials of garnet waste from blasting pipe process have good properties potential as mixed with soil as a road shoulder.

Table 1 shows the result for Atterberg limit which is the plastic limit and liquid limit. The value of Plasticity Index (PI) is in the range of intermediate plasticity, value of 21.8.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>PL</th>
<th>LL</th>
<th>PI</th>
<th>Cu</th>
<th>Cc</th>
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<td>1</td>
<td>23.1</td>
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<td>21.4</td>
<td>4.86</td>
<td>1.74</td>
</tr>
<tr>
<td>2</td>
<td>22.8</td>
<td>44.0</td>
<td>21.2</td>
<td>4.75</td>
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<tr>
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<td>22.5</td>
<td>43.8</td>
<td>21.2</td>
<td>4.71</td>
<td>1.64</td>
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<td>43.8</td>
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<td>47.0</td>
<td>23.9</td>
<td>5.25</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Figure 5 shows chemical composition differences between laterite soil [17] and garnet waste. The highest value of composition for soil is SiO₂ while for garnet waste is Fe₂O₃. There were two chemical which were higher from the original, SiO₂ and Al₂O₃ but after blasting processed, it was reduced for almost 50% except for Fe₂O₃. Increasing percentage of Fe₂O₃ were due to the process of blasting reacted with the pipe materials which is ferum.

3.2 Moisture Content

Figure 6 shows moisture content for soil range from 17 to 24% while for garnet waste between 4 to 12%. Five samples underwent every moisture content percentage tested. The average moisture content indicates that the value was still in the range of value experimented. The SD were below 0.58% which means the value were consistent and were suitable to proceed with the next CBR test.
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 the voids is less, resulted the density became high and strong. The increase of MDD from 1.74 to 2.56 Mg/m$^3$ with a decrease of OMC from 20% to 8%. The increasing of garnet waste percentage were reduced the OMC and obtain better MDD. It shows that the particle size of garnet waste with fineness modulus is 1.97 influence to the degree of compaction, 100% garnet waste (10G) obtain 2.56 Mg/m$^3$ which is the highest density.

3.4 California Bearing Ratio (CBR)

Figure 8 indicate the correlation between CBR value, the percentage of garnet waste content and error bar of CBR value. From the histogram, the value of CBR was increase by increasing the percentage of garnet waste content with SD I in the range between 0.20Mg/m$^3$ – 0.48Mg/m$^3$. According to JKR/SPJ/1998 [14], CBR value is allowable for earthwork specification is 20%. From this result, the increasing start from 40% of garnet waste content was suitable for mixed proportion due to the improvement of CBR value.

Figure 9 shows the correlation between 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 increment value for both parameters.

Figure 10 shows a prediction equation of CBR and MDD value of the percentage of garnet waste content. The regression value of $R^2$ was 0.86 and 0.96 for CBR and MDD, respectively. These values can be used to predict CBR and MDD during real road construction by using the garnet waste material.
The finding showed that all mixed proportion of percentage garnet waste used in this research can be used as a replacement for road shoulder. CBR value of 80% minimum requirement as road shoulder according to JKR/SPJ/2008. In this case, the design for road shoulder for traffic loading 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 80% minimum requirement by JKR standard.

5.0 Conclusions

5.1 Materials Properties for Soil and Garnet Waste

The soil category is Brown Clayey Sand. Fineness modulus for this soil is 2.81mm. Plastic limit and liquid limit of the soil sample is in the range of 21-23, 43-47 respectively. The value of plasticity index is 21.8 in the condition of well-graded soil.

Physical color of garnet waste was Reddish Pink. It classified as a sandy category with fineness modulus of 1.96. The particle size distribution was a single-graded category. Chemical composition of garnet waste shown that 13.61% of SiO$_2$ and 2.43% of CaO.

5.2 Moisture Content and Degree of Compaction

Increasing of the percentage of garnet waste content gave effect for a better of increment of Maximum Dry Density (MDD) and reducing 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. 100% garnet waste sample resulting for 8% OMC and 2.56Mg/m MDD value.

5.3 Optimum Mix Proportion under California Bearing Ratio (CBR)

Increasing of percentage garnet waste content influence 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 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.

5.4 Recommendations

The following are the recommendation for future research to complement this study:

i. Garnet waste has good potential as a construction material.

ii. To perform flow ability test for garnet waste content in order to prevent any materials penetrate into water easily or flow rate to underneath the road shoulder surface.

iii. Different sources of a garnet waste have to conduct the experiment involve to find the fineness modulus because different sources of garnet waste are prone to have different fineness modulus.

iv. To verify the used of garnet waste content up to 100% in the real construction for road shoulder.

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References


