Original Article

Effect of Quarry Dust in Compaction Characteristics of Loose Sandy Soil from a Local Paddy Field

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ABSTRACT

Loose Soils found in locations such as paddy fields deemed as unsuitable for construction works in general. Loose sandy soil is characterized by its granular and non-cohesive structure, which results in a high porosity and low bulk density. In construction, achieving adequate compaction is essential for enhancing the load-bearing capacity and stability of the soil. Therefore, if the geotechnical properties of these soils can be improved using a waste material such as quarry dust, which is a byproduct of the construction aggregate crushing process, it can offer a significant advantage. This study aims to assess the effect of quarry dust in maximum dry density and optimum moisture content of sandy soils from a local paddy field. Quarry dust is mixed with the soil in proportions of 10%, 20%, 30%, 40% & 50% by weight. Laboratory tests such as sieve analysis, specific gravity, Atterberg limit and proctor compaction tests were conducted on soil and soil – quarry dust. The results indicated that maximum dry density continues to increase with the addition of quarry dust while optimum water content reduces up to the addition of 30% quarry dust. The findings support that compaction characteristics can be improved using quarry dust which increases the suitability of the soil for construction purposes.

Index Terms- Sandy Soil, Quarry Dust, Paddy Soil, Soil Compaction, Maximum Dry Density, Optimum Water Content

INTRODUCTION

As the construction industry experiences rapid growth, the effective and optimum use of available resources becomes paramount. Currently, weak soils from paddy fields are rarely employed for meaningful purposes in construction. Loose sandy soil found in local paddy fields is one such example. If the geotechnical properties of such soils can be improved using waste materials such as quarry dust, it certainly can contribute to the sustainable use of resources.

Paddy soils play a crucial role in supporting agricultural practices, but often present challenges when it comes to construction activities. Loose sandy soil within paddy fields presents a unique set of considerations for civil engineers and construction professionals due to its unstable nature [1].

Quarry dust is a solid waste material generated during the process of crushed aggregate production. Quarry dust shows significantly high shear strength which is extremely advantageous in improvement of geotechnical properties of soil [2]. There are a number of useful geotechnical applications available for quarry dust such as embankment backfills and as road sub-base material in large quantities.

In a soil –quarry dust mix, the optimum moister content tends to decrease while maximum dry density tends to increase as the quarry dust percentage increases. This is mainly attributed to the presence of coarser solid particles and high specific gravity of quarry dust. In addition, particles size distribution curves may exhibit more well graded behavior with the addition of quarry dust, depending on the soil type. This could also lead to aforementioned characteristics in optimum moister content and maximum dry density [2] [3].

In addition to compaction characteristics, there are several soil properties soil that can be enhanced with the usage of quarry dust. When quarry dust is mixed with expansive soil it influences swelling behavior and reduces free swell strain. Also the addition of quarry dust results in the reduction of Plastic limit, Liquid limit and Plasticity index. [4]

Increased quarry dust content results in increment of shear strength in soil. Quarry dust possess a relatively higher Friction angle and hence tend to increase the overall friction angle of soil quarry dust mix. However the opposite can be observed when it comes to cohesion, due to lack of cohesion among quarry dust particles. [5][6]

Addition of Quarry dust content also enhances the California bearing ratio (CBR) of soil. Higher CBR values can be observed when quarry dust percentage is increased up to 60 % of the soil-quarry dust mix. No significant improvement in CBR can be detected beyond 60%. [2][6].

As the literature suggest, several geotechnical properties of range of soils can be improved with the addition of quarry dust. This paper mainly focuses on the compaction properties and hence aims to identify the effect of quarry dust in maximum dry density and optimum moisture content, when mixed with loose sandy soils obtained from a local paddy field.

RESEARCH METHODOLOGY

In the beginning, the quarry dust and sandy soil were tested separately to identify their properties. The tests conducted were liquid limit tests, specific gravity tests, particle size distribution tests and compaction tests. All the tests were done following the BS standards.

A. Materials

Sandy soil collected from a paddy field in the vicinity of Borelasgamuwa area (Colombo district). This particular location has been selected due to the soil's high content of medium to fine sand, as depicted in fig. 1. Quarry dust is produced from aggregate crushing process (size range 0mm-10mm) used as the material to be mixed with the sandy soil.

B. Test Procedure

1) Sieve analysis

BS sieves with varying mesh sizes (10mm, 5mm, 2.36mm, 0.6mm, 0.3mm, 0.15mm) were systematically arranged for the test. Figure 1 shows a graph on a semi-log sheet. It displays the sieve sizes and percentage mass passing data. Sieve analysis test was done quarry dust and paddy sand separately.

2) Specific gravity test

The specific gravity test was carried out for both sandy soil and quarry dust. The tests were conducted adhering to the ASTM D854 standard. The results are shown in table 2.

3) Atterberg Limit test

The liquid limit test and plastic limit tests were conducted separately for sandy soil and quarry dust, according to the standard ASTM D4318.

4) Proctor compaction test of the quarry dust and sandy soil

The proctor compaction tests were conducted according to the BS 1377 standard for following mixtures of quarry dust and sandy soils as given in Table 1.

Table 1 Mixtures of quarry dust and sandy soils

Mixture No	Percentages of Quarry Dust (%)	Sandy soil (%)
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60
6	50	50

RESULTS AND DISCUSSION

Below shows the results of the tests conducted on sandy soil, quarry dust and their respective mixtures.

1. Particle size distribution

Fig. 1 demonstrates the particle size distributions of the sandy soil and quarry dust. In the soil, fine content is calculated as less than 5% while rest is determined as sand. Only around 2% soil is consist of coarse sand (>2mm). Around 50% of the soil consist of medium sand (0.425mm-2mm) while the fine sand (0.075mm -0.425mm) content is observed to be around 40%. Also Uniformity Coefficient (Cu) and Coefficient of Curvature (Cc) values of sandy soil are calculated as 5 and 1.12 respectively. Therefore the soil can be considered as well graded sand. For quarry dust, Cu & Cc values were calculated as 20 and 1.08 respectively. It is clear that quarry dust exhibit more well graded qualities compared to the sand soil, as indicated by the Cu value.

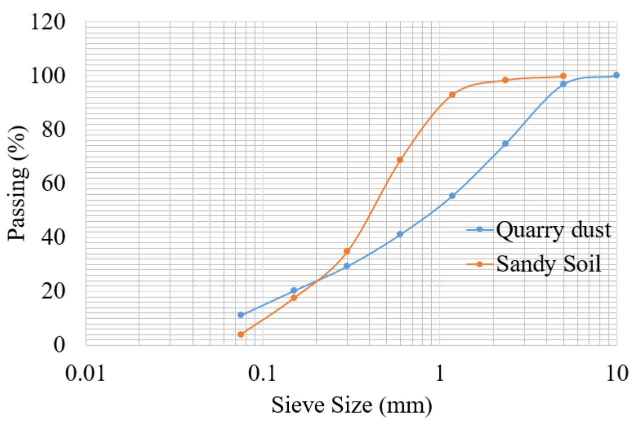

Figure 1 Particle size distribution of sandy soil & quarry dust

2. Specific gravity

The results of the specific gravity tests shown in Table 2 . It is evident that average specific gravity (at 20^0C) of quarry dust is significantly higher than that of the sandy soil

Table 2 average specific gravity at 20 ^{0}C

Test	**Specific gravity at 22^0C**
Sandy Soil	2.404
Quarry dust	2.678

2. Liquid Limit & plastic limit

Liquid limit of quarry dust was determined as 13% while for sandy soil, it was determined as 28.5%. No plastic limit reading was possible for both sandy soil and quarry dust.

3. Proctor compaction

Proctor compaction results of the sandy soil in fig. 2. The maximum dry density is shown to be less than 1.5g/cm^3 while the optimum water content is observed at a relatively higher value of 21 %. Fig. 3 details the Proctor compaction results of all mixtures of quarry dust and sandy soils. The typical maximum dry density - optimum moisture content relationship is being observed more or less in all the mixtures.

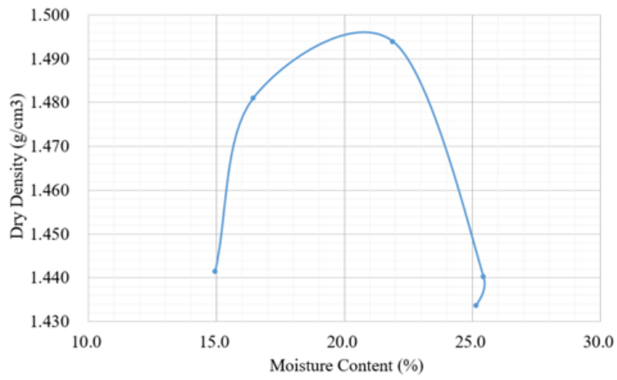

Figure 2 Proctor compaction results for the sandy soil

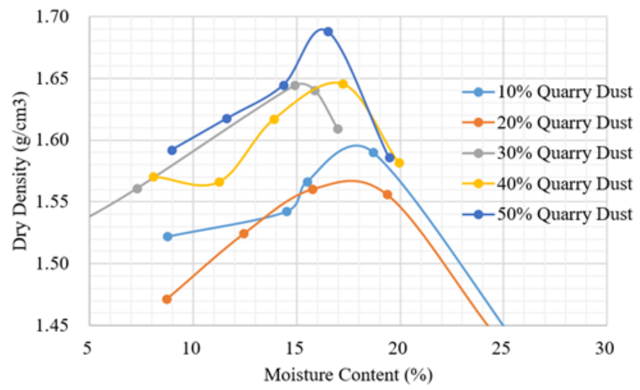

Figure 3 Proctor compaction results after mixing paddy soil with quarry dust.

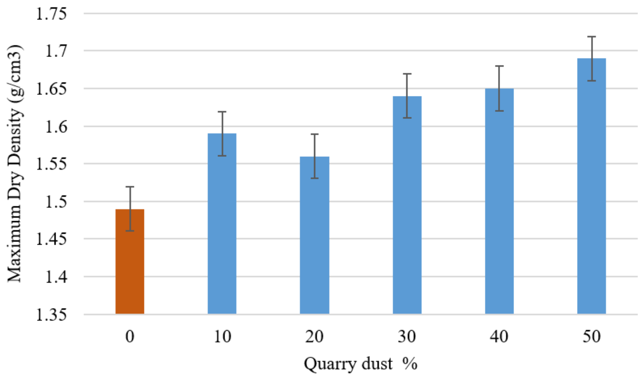

Figure 4 Maximum dry density *vs quarry dust percentage*

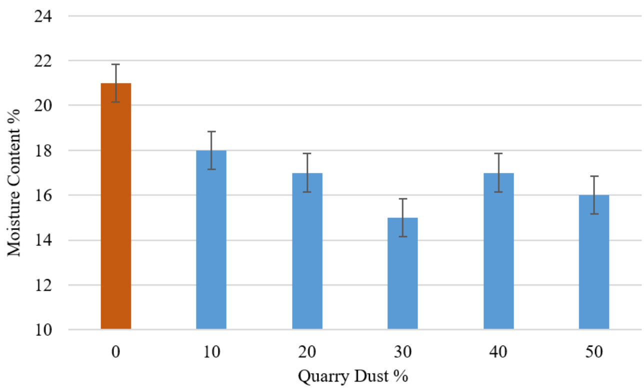

Figure 5 Optimum moisture content vs quarry dust percentage

Quarry dust consists of hgher specific gravty (2.678) compared to the sandy soil (2.404). It is evident that addition of quarry dust should increase the overall density of the mix due to this difference in specific gravities. As shown in the fig. 4 the maximum dry density increased in each 10 % increment of quarry dusts used in the mix except for the 20% quarry dust mix. Even though the 20% quarry dust mix slightly deviates from the increasing trend, the achieved maximum dry density value is higher than that of sandy soil without quarry dust. Also, the error bar (standard error) comparison indicates that all the quarry dust-sandy soil mixtures achieved a significant increase in maximum dry density compared to sandy soil without quarry dust. In the other hand, it is fair to assume that the disparity between particle size distribution curves also may have contributed to this increment of maximum dry density. As we can observe in fig 1 and from the values obtained for Cc and Cu, it is clear that quarry dust exhibits relatively high well graded qualities compared to the sandy soil. When higher percentage of quarry dust get added it may increase well graded qualities of the soil and hence improve the ability to compact. Also, the other noticeable difference is that quarry dust contains significant amount (30%) of coarse particles (>2mm) compared to the sandy soil (2%). As a result of that the soil – quarry dust mix offers a higher range of particle size distribution and along with its well gadded characteristics, a higher degree of compaction can be expected.

As shown in fig. 5, the optimum moisture content tends to decrease with the addition of quarry dust to a certain extent, where the least value is achieved at 30% quarry dust mix. However, this tendency is shown to decline as the quarry dust % increased beyond 30 % and it is obvious that the mix required more water to reach the maximum dry density. The error bar comparison indicates that all the quarry dust- sandy soil mixtures achieved a significant decrease in optimum moisture content compared to sandy soil without quarry dust. The annular shape of quarry dust makes it difficult for the particles to slip past each other when it is subjected to a given compaction effort. Therefore, it may require more water to lubricate the relative movement among particles and hence explain the requirement of additional water content with the increment of quarry dust. Apart from that it can also be observed that the minimum value obtained for 30 % mixture is significant as suggested by the error bar comparison. Therefore this particular mixture can be identified as the one that requires lest amount of water to achieve its maximum dry density.

CONCLUSION

The results indicated that maximum dry density continues to increase with the addition of quarry dust. It was also found that optimum water content reduces up to the addition of 30% quarry dust but starts to deviate from that trend as more quarry dust being added. In overall, it is evident that compaction characteristics can be improved using quarry dust which increases the suitability of the soil for construction purposes. However adding more than 50% of quarry dust can be impractical as well as meaningless. Since quarry dust percentages of 30%,40% shows significant improvements those percentages can be set as upper bounds of practical use.

One limitation of this study is that the sandy soil was collected from a specific location. Therefore, it is imporatant to notice that the soil used in the study may be less representative of general conditions of local paddy fields.

REFERENCES

1. Gajo, A., Piffer, L. and De Polo, F., 2000. Analysis of certain factors affecting the unstable behaviour of saturated loose sand. *Mechanics of Cohesive-frictional Materials: An International Journal on Experiments, Modelling and Computation of Materials and Structures*, *5*(3), pp.215-237.

2. Koustuvee, K., Sridharan, A., Chinmoy, K., Rahul, D. and Malaya, C., 2013. A Study on the influence of particle characteristics on shear strength behavior of quarry dust. In *Proceedings of Indian Geotechnical Conference*, pp. 1-5.

3. Nwaiwu, C., Mshelia, S. and Durkwa, J., 2012. Compactive effort influence on properties of quarry dust-black cotton soil mixtures. *International Journal of Geotechnical Engineering*, *6*(1), pp.91-101.

4. Priyankara, N.H., Wijesooriya, R.M.S.D., Jayasinghe, S.N., Wickramasinghe, W.R.M.B.E. and Yapa, S.T.A.J., 2009. Suitability of quarry dust in geotechnical applications to improve engineering

5. properties. *Engineer: Journal of the Institution of Engineers, Sri Lanka*, *42*(3).

6. Soosan, T.G., Sridharan, A., Jose, B.T. and Abraham, B.M., 2005. Utilization of quarry dust to improve the geotechnical properties of soils in highway construction. *Geotechnical Testing Journal*, *28*(4), pp.391-400.

7. Sridharan, A., Soosan, T.G., Jose, B.T. and Abraham, B.M., 2006. Shear strength studies on soil-quarry dust mixtures. *Geotechnical & Geological Engineering*, *24*, pp.1163-1179