Suitability of Cohesionless soil as a Highway Construction material

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Abstract

Major parts of the Eastern and Northern provinces of Sri Lanka are covered with cohesionless soil. Utilization of locally available soil for the construction of the subbase of these roads will optimize the cost and reduce the environmental impact. Recently cracks, settlement and outward movement have been observed in the pavement constructed using the locally available sandy soil. It is suspected that the usage of locally available soil would have caused this failure. Objective of this study is to assess the quality of the cohesionless soil as a highway construction material. Further, the applicability and validity of the currently used specifications for use of cohesionless soil as a highway construction material are also evaluated. To accomplish the above tasks, the experience of the construction industry in this regard was gathered through site visits, case studies, interviews with relevant personals. Based on the collected information a comprehensive laboratory test program was formulated to investigate the interrelationships between the soil properties such as grading, maximum dry density, California Bearing Ratio(CBR) value, plasticity index(PI), and liquid limit by mixing different type of clays with pure coarse sand. Laboratory test results and field data collected from road construction projects were analyzed. Final results were reviewed by the senior consultants at Road Development Authority (RDA) and National Building and Research Organization (NBRO).

1. Introduction[1]

Large number of infrastructure development projects is currently underway in Sri Lanka and major portion of that development drive is in the highway sector. The infrastructure development projects related to highway sector can be categorized into two: construction of new expressways and upgrading of existing roads to highways. Since highway construction is an expensive task, locally available materials have been widely used in the recent past for the upgrading of existing roads. In addition to the economical benefits, use of locally available material reduces the adverse environmental impacts. Roads in the Northern and Eastern regions of Sri Lanka have been upgraded using locally available cohesionless soils, but problems such as: cracks, settlement and outward movement have been observed in the road pavement. It is suspected that the poor quality of the

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construction material, specially the cohesionless soil found in the vicinity could be the main contributory factor for the above failures. In this paper, improvements for parameters given in specification of Road Development Authority (RDA), Sri Lanka and utilization of locally available cohesionless soil as a highway construction material have been discussed.

Sub base is a secondary load spreading layer in the pavement structure and acts as a working platform as well. Sub base should be free from excessive settlement, cracks, and outward movements and should have adequate bearing strength for smooth functioning of the road surface. RDA (Sri Lanka) specification allows cohesionless material to be used as subbase construction material. However, it is found that when cohesionless soil is used as a subbase material, it is difficult to achieve the required compaction and bearing strength. It was observed that during the compaction process, maintaining moisture content is a very difficult task due to the absence of adsorption effect and plasticity of the soil being compacted. Therefore, sub bases constructed using cohesionless soil found to be vulnerable and selection of cohesionless soil as subbase material should be limited.

2.0 Objective and Methodology

RDA specification does not specify a lower bound for the Plasticity Index (PI) of soil to be used for subbase in the construction of highways. This research focuses on finding an acceptable lower bound for the PI for soil used for subbase. Soil samples with varying plasticity were prepared, while maintaining the particle size distribution, Maximum Dry Density (MDD), Liquid Limit (LL) values within the RDA specification requirements. Atterberg limits, California Bearing Ratio (CBR) and Proctor compaction tests were conducted on prepared soil samples and the results were compared with the specification to find out a lower limit for the PI.

Plasticity of the soil was changed by mixing varying proportions of pure bentonite, dolamite, kaoline and red clay with coarse sand. The percentage of clay in the blended soil was varied at 5, 10, 15, and 20. According to the RDA specification 0.075 mm particle fraction (Sieve no 200) should be maintained within limit of 5% to 25%. So that selection of clay percentage was limited to 5% – 20 %.

3.0 Results and Discussion

Figure 1 shows typical Particle size distribution of coarse sand with clay mixture, which strictly maintained within bounds as RDA specified for sub-base.

In order to obtain the worst condition for the prepared samples in terms of sub-base material, coarse particle size and its percentage were maintained at finer.

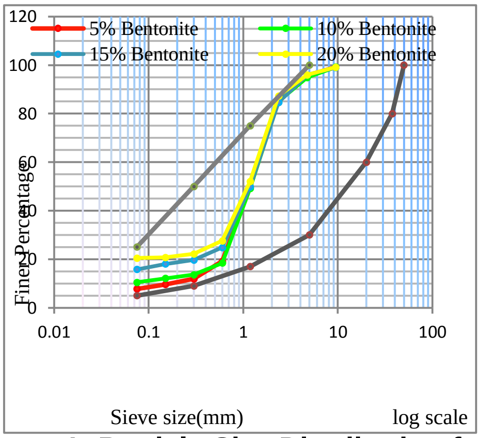

Figure1: Particle Size Distribution for Bentonite clay at all percentages

Table 1 shows summary of Atterberg limit test results for the prepared samples. It shows that the LL, PL (Plastic Limit) and PI values increase with increment of clay percentage. In order to check the validity of above findings, activity diagram was plotted. Figure 2 shows a plot of PI against clay percentage from the above data. Extension of each line goes through the origin, this shows the accuracy of the tests, and from the gradient of each line it can be observed that, bentonite and dolomite are having consecutively higher and lower plasticity indexes. Kaoline is having PI little higher than dolamite, and PI of red clay is in between bentonite and kaoline.

Table 1: Summary of Atterberg Limit test

Clay type	% of Clay	Liquid limit	Plastic Limit	Plastic Index
Red Clay	5%	28.40	23.40	5.00
Red Clay	10%	40.25	27.69	12.56
Red Clay	15%	50.98	29.90	21.08
Red Clay	20%	57.15	30.45	26.71
Kaoline	5%	15.50	11.35	4.16
Kaoline	10%	21.94	14.66	7.28
Kaoline	15%	29.98	17.67	12.31
Kaoline	20%	31.40	18.09	13.31
Bentonite	5%	29.80	21.90	7.90
Bentonite	10%	42.25	26.64	15.61
Bentonite	15%	52.12	29.00	23.12
Bentonite	20%	59.15	30.25	28.91
Dolamite	5%	12.80	10.38	2.42
Dolamite	10%	19.40	3.51	5.89
Dolamite	15%	23.50	16.40	7.10
Dolamite	20%	27.32	17.00	10.32

Typical plot of the proctor compaction test for soil prepared by mixing bentonite is shown in figure 3. It shows that optimum moisture content is increasing with clay percentage. Similar behaviour is observed for other clay types as well. Further, it can also be observed that the MDD of soil is increasing with clay percentage and after 10% of clay mixture it starts to reduce.

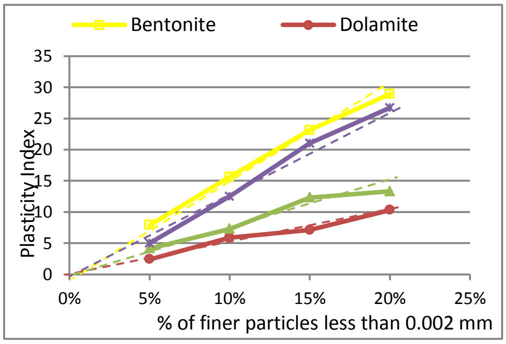

Figure 2: Activity Diagram for prepared samples

For dolamite and kaoline clay maximum dry density value is increasing with clay percentage. Red clay achieved the maximum dry density at 15% of clay mixture

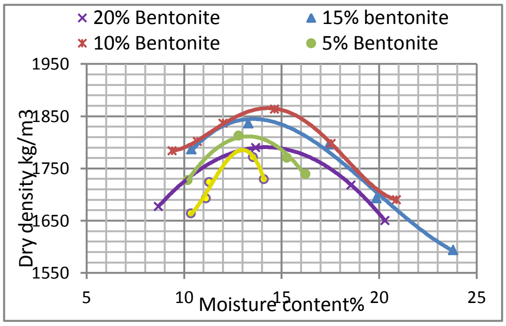

Figure 3: Proctor compaction curve for Bentonite at all percentage

In order to check the variation of maximum dry density with relevant PI, a typical plot has been drawn between these two parameters. Figure 4 shows a plot of maximum dry density against PI. In order to increase the accuracy of the plot, compaction data for natural soil were also included to the graph. It can be observed that, maximum dry density value is increasing up to certain PI value and it starts to reduce with increment of PI and almost all the maximum dry density values are greater than 1750kg/m3. It means that all the samples are satisfying the maximum dry density requirement given in the RDA specification.

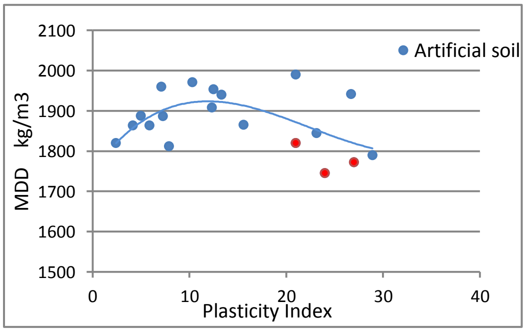

Figure 4: maximum dry density against plastic index for Artificial and Natural soil.

Figure 5 shows the plot of CBR values against PI values. Results presented in figure5 indicate that, CBR increases with the increment of PI up to a certain value and starts to reduce with further increase in the PI. It gives the similar behavior as maximum dry density varies with PI.

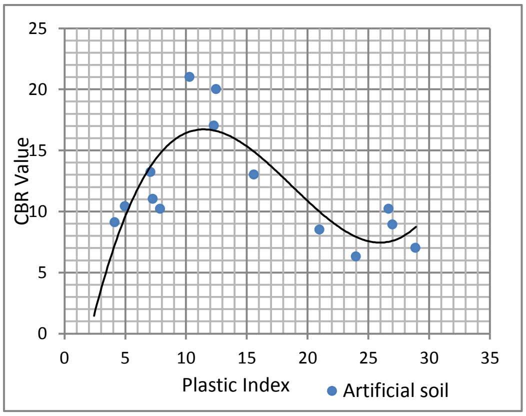

Figure 5: CBR percentage against Plasticity index plot for natural and artificial soil

In order to check the variation of CBR with particle size distribution, laboratory test results were obtained from NBRO for samples which are well distributed and PI value as low. Figure 6 shows the plot of CBR values against PI values for results obtained from NBRO and Laboratory test result with same PI value (Sample No 10, 16). Results presented in Figure 6 indicate that CBR value is high for well distributed sample than the poorly distributed sample. Particle size distribution of above samples are shown in Figure 7.

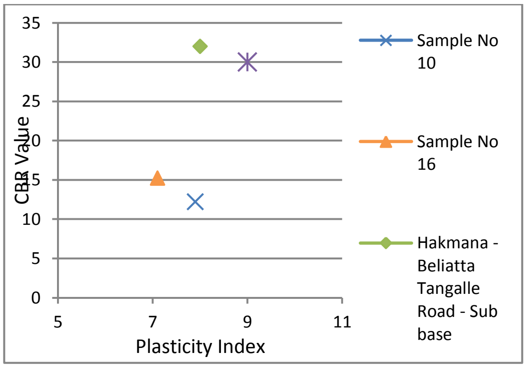

Figure 6: CBR percentage against Plasticity index plot for result got from NBRO and Laboratory test

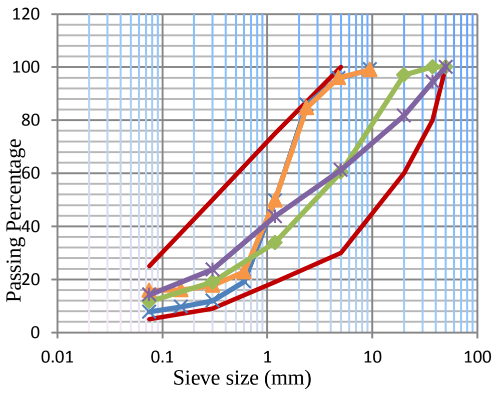

Figure 7: Particle Size Distribution curve for result got from NBRO and Laboratory test

4. Conclusion

According to the RDA Specification selected subbase material should satisfy following criteria.

Liquid limit <40 and Plastic Index<15
Maximum dry density >1750 kg/m3
CBR > 30

According to RDA specification, CBR should be greater than 30 for subbase. Practically it is very hard to obtain CBR value of 30 for natural soil. But, according to Pavement Design Guidelines of RDA (Road Note 31 revised for Sri Lankan context) allows value of CBR>20 for selected material for low volume roads.

The variation of the CBR and the MDD with PI clearly shows that these parameters increase with the increase up to PI of about 12 and then reduce with further increase in the plasticity of the soil. Therefore, cohesionless soil which are having very low PI cannot be used to achieve higher CBR. There should be a limiting value for PI, in-order to avoid the poor material selection.

According laboratory test results, for the limiting value of CBR 15, lower limit of PI should be limited to about 7 (See Figure 5). But to achieve required CBR of 20 for low volume subbase, particle size distribution curve should be improved as 'well graded curve' as mentioned in the section of results and discussion.

Acknowledgements

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