STUDY ON THE POSSIBLE IMPROVEMENTS OF ICTAD SPECIFICATIONS FOR COHESIONLESS SOIL TO BE USED 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 the roads will optimize the cost and reduce the adverse environmental impact. Recently cracks, settlement and outward movements have been observed in the pavements 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 personel. 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, CBR value, plasticity index, and liquid limit by mixing different types of clays with pure coarse sand. Laboratory test results and data collected from road construction project were analysed. Final results were reviewed by the senior consultant at RDA and NBRO.

Keywords: Cohesionless soil, Subbase, Plasticity Index, CBR, Sieve Analysis

1. Introduction

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. Since highway construction is an expensive task, locally available materials have been widely used in the recent past for the upgrading of existing roads to optimize the cost. 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, uneven settlements and outward movements have been observed in the road pavements. Such failures can occur due to poor material selection, poor construction practices or poor design. In this research we suspected that the quality of the construction material, specially the cohesionless soil found in the vicinity could be the main contributory factor for the above failures.

2. Problem Identification

Subbase is a secondary load spreading layer in the pavement structure and it 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.

ICTAD specification suggests following limiting values for material selection of subbase:

* Maximum Dry Density (MDD) > 1750 kg/m^3
* LL and PI should be less than 40 & 15 respectively
* 4 Day Soaked CBR > 30 (for low volume road)
* Particle Size Distribution (PSD) shown in Table 1

Table 1: Specification Requirement for Particle Size Distribution

Sieve Size	Maximum Finer %	Minimum Finer %
50	100	100
37.5	100	80
20	100	60
5	100	30
1.18	75	19
0.3	50	9
0.075	25	5

Cohesionless soil may not be a suitable material for a highway construction since stability of cohesionless soils are lost when it is; at or near saturation, compacted to low density, subjected to large vibration, or very dry condition. Further, it has temporary densification until the capillary action is introduced to the sand particles due to source of water. (Bergeson, 1999)

It was observed that, during the compaction process, maintaining moisture content is a difficult task due to the absence of adsorption effect and plasticity of the soil being compacted. Although the cohesionless soil has the above issues, it has been selected as a subbase material due to the following reasons:

1) ICTAD specification (Sri Lanka) allows Cohesionless soil to be used as subbase construction material.
   - Specification recommends limiting values for PSD.
     Limiting value is mentioned up to 0.075 mm finer size. Here it can be silt or clay. It does not emphasize presence of clay
   - PI shall not be greater than 15, but a lower limit is not specified. So, this might lead to the selection of pure cohesionless soil as well.

2) Common practice and belief in industry. When the soil satisfies the MDD, PI, LL and PSD requirements according to the ICTAD specification, it will satisfy the CBR requirement as well.

Therefore, it is necessary to assess the quality of the cohesionless soil, and improve the ICTAD specification requirement in order to ensure the presences of clay particles and proper gradation.

3. Objective and Methodology

After identifying the problem, objective of the research was defined as follows:

* To identify the behavior of cohesionless soil at different liquid limit and plasticity index value
* Identify the behavior of cohesionless soil at different grading pattern and the importance of grading requirement for highway construction material
* Define a lower limit for 'plastic limit' and 'narrow the grading requirement' for cohessionless soil to ensure the CBR requirement.

Initial field visits were made to several projects in progress, and laboratory test results of subbase material was collected, especially from road projects in Hambantota and Colombo – Katunayaka expressway. Test results of borrow-pit samples were also collected from NBRO. Series of laboratory tests were conducted by mixing varying proportions of pure bentonite, dolomite, kaolin and red clay with coarse sand. The percentage of clay in the blended soil was varied from 5 to 20 in 5% intervals since ICTAD specification allows 5% to 20% passing through 0.075 mm sieve (Sieve no 200).

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4. Results and Discussions

Initially the authenticity of common industry's belief was assessed for cohesionless soil. Fig: 1 shows scatter plot of CBR Vs PI, plotted for selected sample, under controlled MDD, LL and PSD.

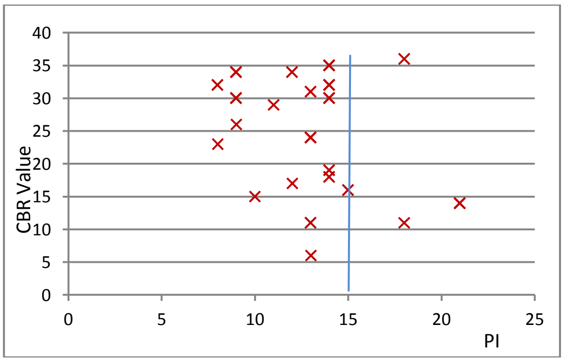

Figure 1: Scatter plot of CBR Vs PI for collected sample

In Fig: 1, samples are satisfying MDD, LL and PSD values according to the ICTAD specification. When PI value is less than 15, samples do not have CBR greater than 20. So, the common belief in industry about soil indices is not valid for cohesionless soil.

Then the quality of cohesionless soil was assessed. In order to identify the behavior of cohesionless soil among CBR, PI and PSD, Fig: 2 has been plotted between CBR values against PI values for laboratory test result, road projects in Hambantota and borrow-pit sample. Results presented in Fig: 2 indicate that, CBR increases as the plasticity index increases up to a certain value and starts to decline with further increase in the plasticity index. All the samples which were collected from different locations show the same polynomial behaviour.

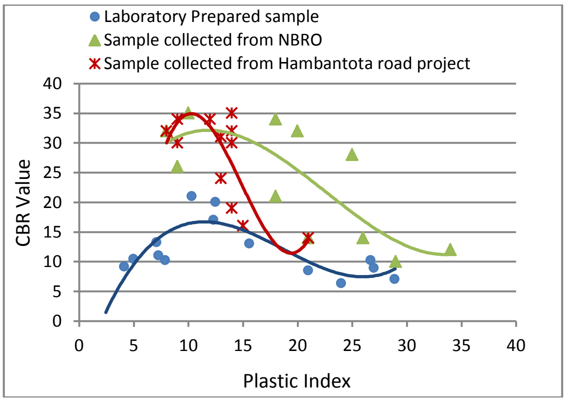

Figure 2: Scatter plot of CBR Vs PI for collected sample and laboratory sample

It can be observed from Fig: 2 that, CBR value increases for each type of soil used in the industry and sample tested in the laboratory. This is because of the particle size distribution. Well distributed curve has a higher CBR than poorly distributed curve. Particle size distribution of the soil tested in the laboratory and collected from the industry has been shown in Figs: 3, 4 and 5.

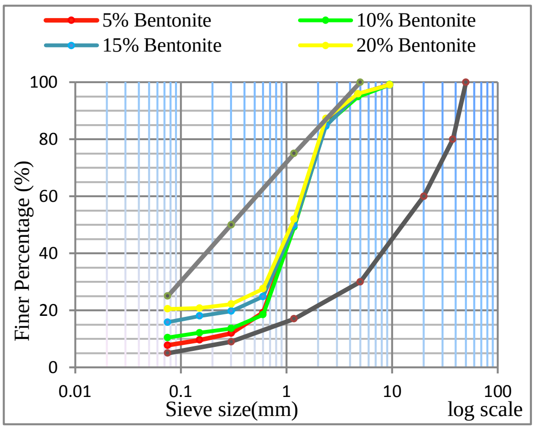

Figure 3: Particle Size Distribution for laboratory sample at different clay percentages

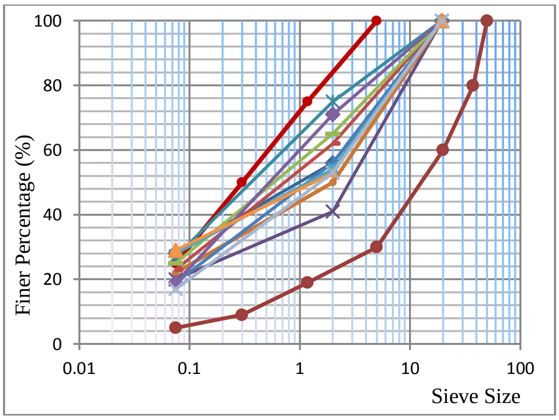

Figure 4: Particle Size Distribution for sample collected from NBRO

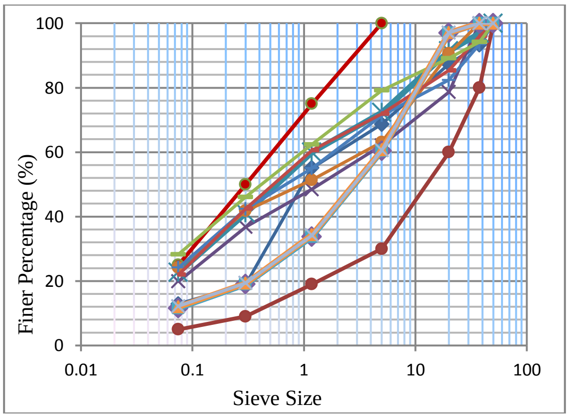

Figure 5: Particle Size Distribution for sample collected from Hambantota road project

Therefore, when cohesionless soil is used as a subbase material it is important to ensure that the presence of clay particles in the sample and PSD shall be well graded. To emphasize these two factors, ICTAD specification shall be improved by improving the limiting values of PI and PSD.

In order to identify the limiting value for PSD, Fig: 6 has been plotted by selecting the sample from all collected data under control PI, LL and MDD of cohesionless soil.

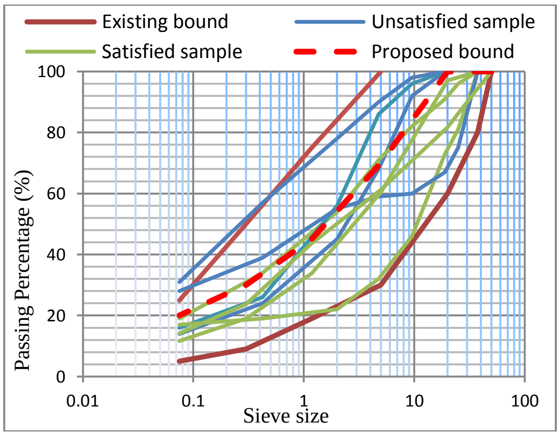

Figure 6: Particle Size Distribution of sample and proposed bound for grading

Although the PI, LL and MDD values are satisfied specification requirement, poorly distributed soil samples do not satisfy the CBR requirement. Samples which are having well distributed curve will satisfy the CBR requirement. So the upper bound of PSD was identified as shown in Table 2 for cohesionless soil.

Table 2: Proposed limiting value for PSD

Sieve Size	Passing Percentage	
	Maximum	Minimum
50	100	100
37.5	100	80
20	100	60
5	70	30
1.18	45	19
0.3	30	9
0.075	20	5

Figure 7 has been plotted to propose lower bound for PI value. According requirements of the ICTAD specification CBR should not be less than 30 for subbase. So, the lower bound of PI was identified as 8.

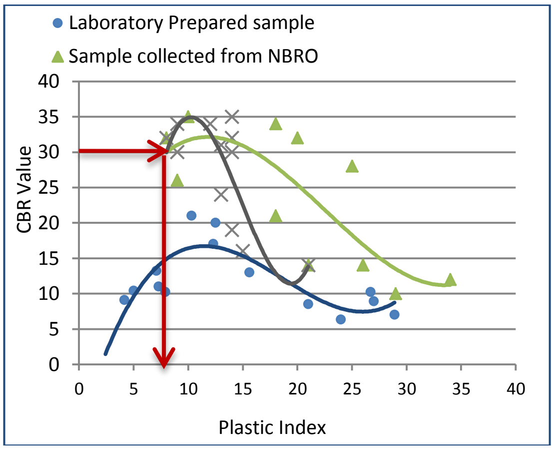

Figure 7: Scatter plot of CBR Vs PI to identify the lower bound of PI

5. Conclusions

From the observations of experimental analysis, following conclusions were developed for cohesionless soil.

- CBR value of soil depends on the Plasticity Index of the soil. For low PI, CBR value is decreasing with reducing plasticity index. It was found that the lower limit of PI is 8 for subbase material
- CBR value of soil depends on grading of particle size distribution. CBR value is very high for the well graded soil than the poorly graded soil. Proposed limiting value for PSD has been shown Table 2.

The research findings were reviewed by the consultants in the industry. Since the results will be very useful for quality control in material selection.

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