Variability in index properties of a lateritic gravel deposit for subbase construction

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ABSTRACT: Even though naturally occurring road construction material abound in the tropics, only certain specific conditions of climate, topography and geomorphology combine to create weathering profiles that yield natural material suitable for the construction of the upper layers of road pavements. Practitioners in the tropics therefore have developed procedures to explore the landscape for suitable road construction material. In these methods the suitability of the deposit is assessed based on the index and compaction properties as well as the CBR. However, these methods for exploration of potential gravel deposits are time consuming, tedious and expensive. A good understanding of the variability of the material properties in the deposit is required in order to be able to optimize the gravel exploration effort. A potential gravel deposit was identified and six samples were recovered for laboratory. Subsequently, a bull dozer was used to stockpile the material and bulk samples were also recovered for testing. The variability in the properties of the material from the trial pits is analyzed in terms of the mean, standard deviation and coefficient of variation and compared with the bulk samples. The possibility of reduction in the number of exploration holes is discussed.

1 INTRODUCTION

Under the tropical conditions of high temperature and high rainfall, chemical weathering of the parent rock predominate in the weathering process. Due to the high rainfall, when the topography is also favourable, the weathering product of silica is dissolved leaving behind higher concentrations of the oxides of iron and aluminium which crystallize out into various forms. The weathered products with relatively high concentrations of oxides of aluminium and iron but with low concentrations of silica and the bases constitute what is referred to as laterites and lateritic soils. The subsequent leaching out of silica leading to the concentration of oxides of iron and aluminium, is facilitated by the topography. In the bulk majority of cases, it has been confirmed by various researchers such as Maignen 1966, Clare 1960 and Ahn (1970), that the lateritic soils are located at the summit, upper and middle slopes of the topography, while the lower slopes and valley bottoms will be made up of colluvium and alluvial transported soils. For these upper slopes, the processes of the formation, erosion and reworking of material moving down the slope can create layers of differing uniformity. The laterite and lateritic soils tend to have generally good engineering properties and are therefore frequently used for the construction of roads and other transport infrastructure in the tropics since they are readily available. It had generally been noted that most of the borrow areas of good base and subbase gravel were located either on high grounds as primary residual laterite that is rich in sesquioxides of iron and aluminum or on midslopes as secondary laterite that had sesquioxides of iron and aluminum transported into the profile and deposited by groundwater movements. It is, therefore, inferred that laterites formed over high slopes have relatively fewer fines and, therefore, are more suitable for road pavements than gravels found on lower slopes and in valleys.

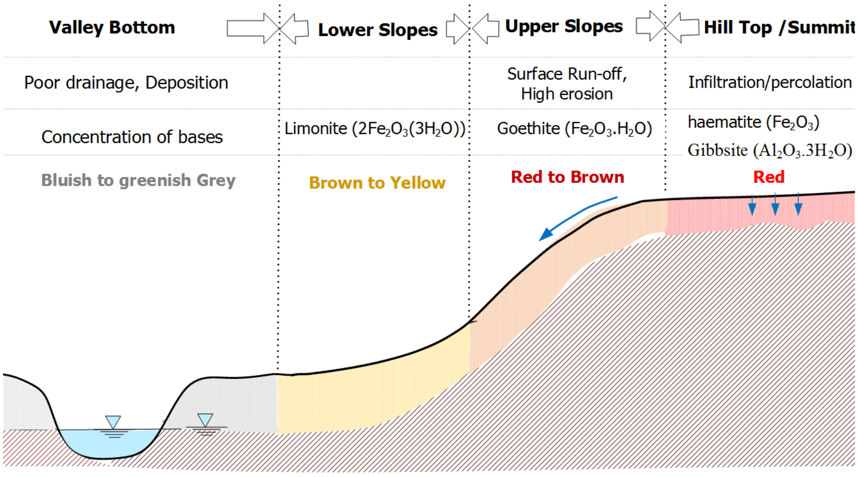

Figure 1 Topography and Laterite Formation (Ampadu SIK, 2015)

Practitioners in the tropics therefore have developed procedures to identify and explore the landscape for potentially suitable road construction material. The procedures involve the use of trial pits spaced evenly throughout the deposit to obtain samples for laboratory testing. The suitability of the deposit is assessed based on the index and compaction properties as well as the CBR of the samples tested. It is only when the exploration judges the deposit to be suitable that it is exploited for road construction. The exploration and exploitation of borrow pits are essential components of road construction activities that have high impacts on project costs and delivery. However, the current methods for exploration of potential gravel deposits are not only time consuming, but also tedious and expensive. A good understanding of the variability of the material properties in the gravel deposit is required in order to be able to optimize the gravel exploration. This study seeks to investigate the material variability in a borrow area and compare the results with those of bulk samples from exploited gravel to determine the potential for reducing the amount of testing during the gravel deposit exploration.

2 METHODOLOGY

2.1 *Fieldwork*

The fieldwork consisted of the exploration of the borrow pit followed by its exploitation. The borrow pit identified was located at Pepenti-Darko in the Ashanti region of Ghana.

2.1.1 *Exploration of Borrow Pit*

In order to determine whether the borrow pit was suitable for the project, six trial pits (TP1-TP6) were evenly distributed over the borrow area and manually sunk to penetrate the gravel layer. The trial pits were randomly distributed across the borrow area at approximately 30m centres. Each pit was logged and samples were collected and sent to the laboratory for further testing.

2.2 *Exploitation of Borrow Pit*

The guidelines for the sustainable exploitation of the borrow pit are specified in the Ministry of Roads Specifications, (MoT 2007). It involves both the Contractor and the Engineer working collaboratively to obtain legal permit for the exploitation. After that, first the topsoil and unsuitable overburden was stripped off using a bulldozer to an approximate depth of about 0.3m and piled separately for later reuse for replanting the exhausted borrow area. Then the borrow area was grubbed of roots. After that the material was excavated to the depth of the gravel layer which in this case study was between 0.7 and 1.0m and then stockpiled on site. Bulk samples of the stockpiled material were then sent to the laboratory for further testing to determine the material properties for the design and construction of the subbase layer.

2.3 *Laboratory work*

In the laboratory both the trial pit samples (from the exploration) and the bulk samples (from exploitation), were air dried, repackaged into sacks and stored for the different tests. They were subjected to the Atterberg limits tests in accordance with BS 1377-2 1990 Clause 4 for the cone penetrometer method and BS 1377-2-1990 clause 5 for the plastic limit test. The grading test by wet sieving was performed in accordance with BS 1377-2. Then the bulk samples were compacted in accordance with ASTM D1557 and then subjected to the four-day soaked CBR test in accordance with ASTM 1883-99.

3 DISCUSSION OF RESULTS

3.1 *Topography of Borrow Area*

The location of the borrow area on Google Earth is shown in Figure 2(a). It covered an area 110mx110m. A topographical section through the borrow area in the approximate E-W direction is shown in Figure 2(b).

(a)

(b)

Figure 2 (a) location of borrow area on google earth and (b) topographical section through borrow area (c) Profile of the gravel borrow area

The topographical section shows that the borrow area is located in the middle slopes at an elevation of about 247m above sea level. Figure 2(c) is a profile through the gravel pit showing the top soil and the gravel layer.

3.2 *Exploration and Exploitation Test Results*

The results of the index properties and AASHTO classification of the lateritic gravel from all the trial pits during the exploration survey are summarized in Table 1 and compared with the MRH 2007 standard for G60 subbase material. The grading curves for each trial pit sample is also plotted in Figure 3. The results show that apart from TP2 and TP3 which had borderline values of the Liquid Limits (LL) and Plasticity Index (PI) for G60 material, all the individual values were within the specification threshold. According to the AASHTO classification system, the soil is classified as A-1-a which is described as an excellent to good soil, expected of a subgrade material. The material from TP6 soil was classified as A-1-b on account of the higher fines contents. On the average the mean values all show parameters within the G60 thresholds.

Table 1 Summary of Test Results for Exploration compared to Standard

	Depth(m)	LL(%)	PL(%)	PI	Gravel(%)	Fines(%)
TP1	0.8	29.1	18.4	10.7	37.8	14.5
TP2	0.7	31.6	19.4	12.2	37	11.4
TP3	0.8	30.6	18.5	12.1	37	13.7
TP4	0.9	29.7	19.3	10.4	37.2	14.9
TP5	1	29.2	18.2	11	35.4	13.6
TP6	0.7	30.4	18.6	11.8	37.8	16
Mean	0.82	30.1	18.7	11.4	37.0	14.0
STD	0.12	0.95	0.50	0.77	0.88	1.55
Range	0.7-1.0	29.1-31.6	18.2-19.4	10.4-12.2	35.4-37.8	11.4-16
Covariance	14.3%	3.2%	2.7%	6.7%	2.4%	11.1%
Standard G60	----	30	----	12	20-50	5-22

The test results of the material from the bulk samples are summarized in Table 2. Again it can be seen that the LL, PI and grading are all within the threshold of G60. The grading curve in Figure 3 also falls within the grading band for G60. The bulk material classifies as A-1-a

Table 2 Summary of Test Results from Exploitation

LL(%)	PL (%)	PI	Gravel (%)	Fines (%)	MDD Mg/m^3	OMC(%)	AASHTO Class
28.3	17.8	10.5	38.1	13.5	2.179	9.5	A-1-a

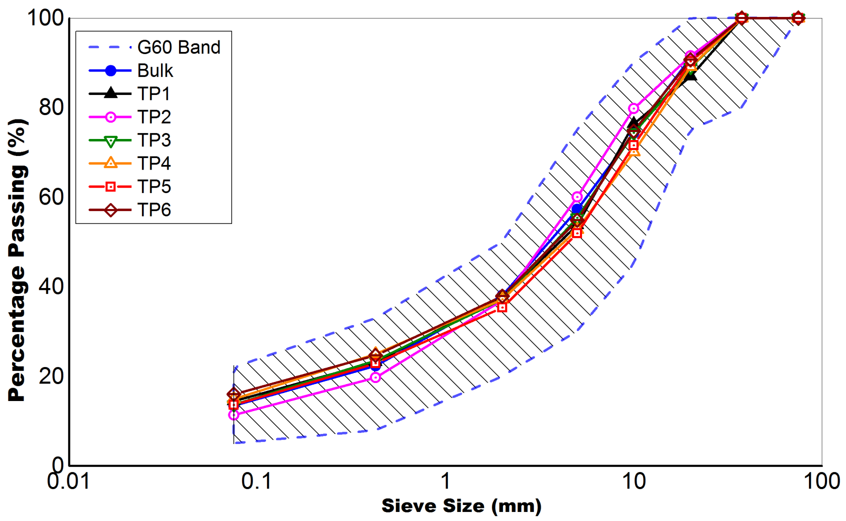

Figure 3 Grading curves from exploration and bulk samples superimposed on G60 band

3.3 *Compaction and CBR Values*

The compaction characteristics of the bulk sample is shown in Figure 4(a) while Figure 4(b) shows the variation of the soaked CBR with the level of compaction (LC). It can be seen that the soaked CBR value of 57 for 98% level of compaction is slightly lower than the 60 required for G60 material for a sub-base.

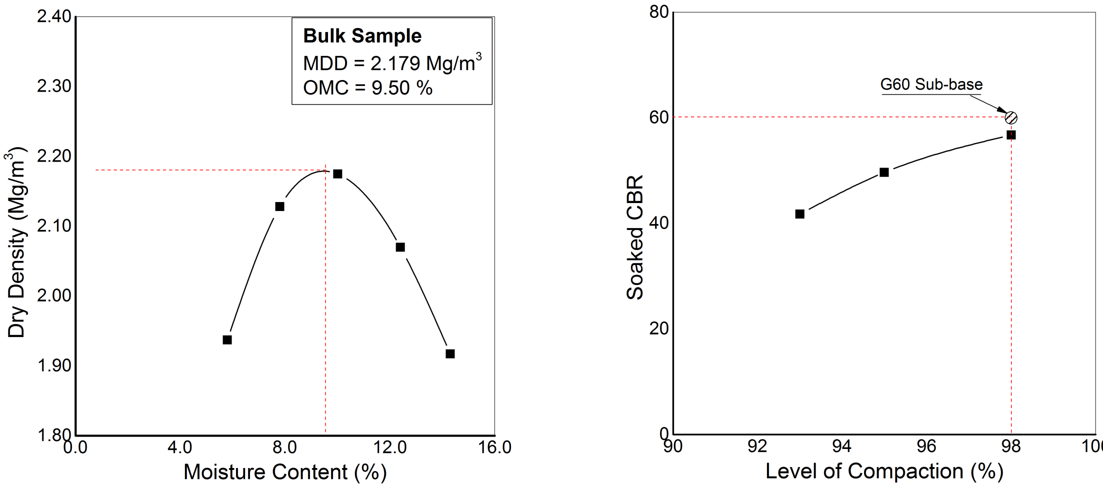

Figure 4(a) Modified AASHTO compaction (b) Variation of CBR with level of compaction of bulk sample

3.4 *Variability in Index Properties*

The variability in the Atterberg limits is shown in Figure 5(a) and (b) for the LL and the PI values respectively. The mean LL value of 30.1% from the boreholes is effectively at the maximum value allowed for G60 material. The very low covariance of 3.2% and 6.7% of the LL and PI suggests that the material in the gravel pit has fairly uniform values for the LL and PI. The bulk sample, however, was significantly well within the maximum threshold for LL and PI.

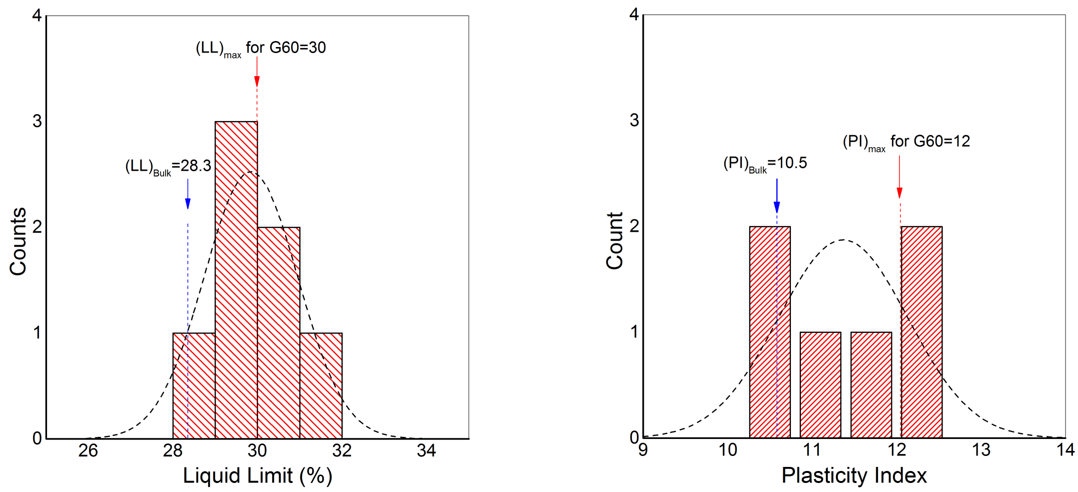

Figure 5 (a) Liquid Limits and (b) Plasticity Index distribution in exploration compared with Bulk sample.

3.5 *Variability in Grading*

The grading curves show variation within a very narrow band. The fines content and the gravel content were used as the parameters for analyzing the variability in the grading. The limitations of using these parameters to analyze the grading curve have been discussed in Ampadu 2020, where it was confirmed that using fractals to characterize the grading curve gave a better account of the different fractions. Figure 6(a) and (b) show the distribution of the fines and gravel contents respectively. Again, the mean fines content almost coincided with the fines content value for the bulk sample, while the mean gravel content was slightly lower than that of the bulk sample. The covariance values of 2.4% for the gravel content and 11.1% for the fines content are both small and again confirms that the material in the gravel deposit is fairly uniform.

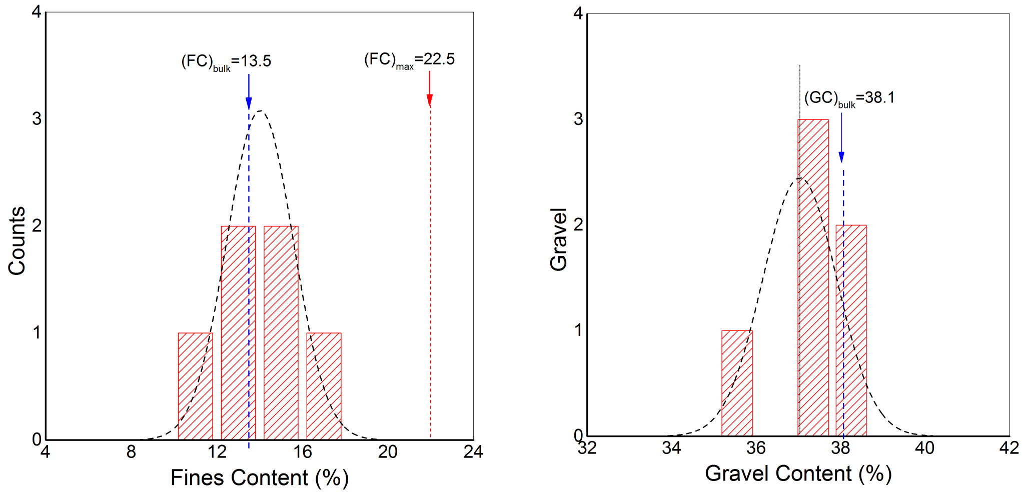

Figure 6 (a) Fines Content and (b) Gravel Content distribution in exploration versus bulk sample

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 *Conclusions*

Based on investigations on a gravel deposit being used as subbase layer in a tropical environment, the following preliminary conclusions may be made concerning the variability:

1. On the average the gravel layer is only about 0.8m deep
2. The mean LL and PI values of 30 and 11 are almost at the threshold of the G60 specification but the covariance of 3.2% and 6.7% indicates the material has very low variability in the Atterberg limits.
3. The grading is well within the G60 grading band and the small covariance values of 2.4% for the gravel content and 11.1% for the fines content indicates low variability in grading.

4.2 *Recommendations*

Though the results are valid for only the gravel deposit investigated, they suggest that the material in the gravel deposit is fairly uniform and therefore the number of boreholes used to explore the suitability of a gravel deposit can be reduced without losing accuracy.

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