Soil characterization of lateritic soils used for bunds in Goa

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ABSTRACT

Bunds are the traditional embankments mainly used for roads in Goa-India. Soil characterization is an important step in determining the constants needed for geotechnical analysis. These are commonly called as red lateritic soils because it is the predominant color of the soils that is found in Goa. Soils were collected from various depths at various excavation sites and tested. Natural moisture content, Atterberg limit, particle size analysis, specific gravity, shear and standard proctor compaction tests were carried out on each sample. The properties were found to vary with depth and with color. Based on these investigations, the soils used for bunds and other embankments in Goa were characterized. As the predominant component of soils analyzed was sandy, the bunds need to be tested for seepage and slope stability and liquefaction while designing embankments. Embankment design should make allowances for wide variation in properties.

Keywords: Lateritic soil of Goa; Bunds, Soil characterization; traditional Goan Saraswat Bund, Index Properties.

1 INTRODUCTION

Traditional Goan Saraswat Bunds (Fig. 1) are the embankments used for centuries for various purposes in Goa, India, including mainly transportation, but also river training, flood mitigation, hill-side stabilization etc. In any civil engineering projects, suitability of soil is justified if it meets existing local requirement for index properties in addition to certain strength criteria. Typical limits of these properties are project specific. Soil characterization is an important step in determining the constants needed for Geotechnical analysis.

Fig. 1. Photo showing Traditional Goan Saraswat Bunds in Goa.

The combination and interaction of five major factors, igneous parent material, time, tropical climate, relief topography and local organisms lead to lateritic soils formation. Traditionally, lime-ash-stabilized riverside silty-sand was used in their construction, but due to excessive demand for sand in construction today, deep hill cutting is taking place leading to placement of different types of lateritic soils in same embankment and also frequent landslides in the monsoons at the cuts.

1.1 Lateritic soils of Goa

Lateritic soils are widely found in most of the tropical countries. They are widely used as embankment fill material in most of the constructions.

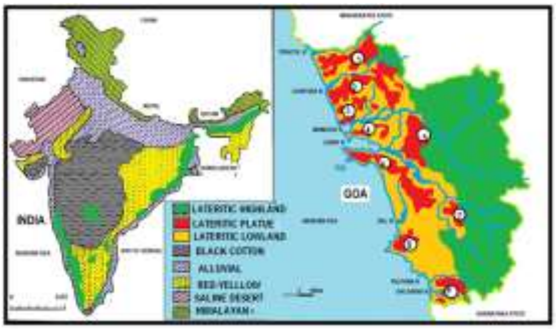

Fig. 2. Map showing location of lateritic soils in India and plateaus of Goa where soil samples were taken-1-Pernem 2-Mapusa 3-Aguada 4-Bambolim 5-Ponda 6-Salcete 7-Canacona 8-Quepem 9-Galgibag.

These soils are products of weathering under condition of high temperatures and humidity with defined alternating wet and dry season. They dot the coasts of India (Fig. 2). In Goa, they are dispersed in lateritic lowlands, lateritic–plateaus and lateritic highlands. In Goa, they are found up to about 30 meter in depth. The soil is basaltic in origin. (Raychaudhuri 1980). The laterites of Goa State form an important component of this Late Cenozoic Konkan – Kanara laterite belt (Mascarenhas 2009 and Widdowson 2009).

1.2 Variations in lateritic soils of Goa

In the Fig. 3 shown below, the wide variation in lateritic soil with depth and location (photos are placed at the approximate depth at which they are taken). This phenomenon is due to the replacement in Gibbsite with aluminum, iron and manganese, thus leading to formation of complex different lateritic soils. It is also observed that geotechnical failures especially landslides occur at the interface of such different colored soils, within the same depth. Usually, a trial pit of 2-3 m depth is taken and soil is analyzed for most engineering projects. This invariably gives results of red lateritic soils which are then inappropriately applied for all other lateritic soils used in embankments (Fig. 4). These soils are commonly called as red lateritic soil because of its predominant color found in Goa. In this paper, they were classified and analyzed as per their color: white (W), pink (P), brown (Br), black (Bl) and yellow(Y). The properties of common red (R) soil and the soils used traditionally in bunds (B) are also given for comparison.

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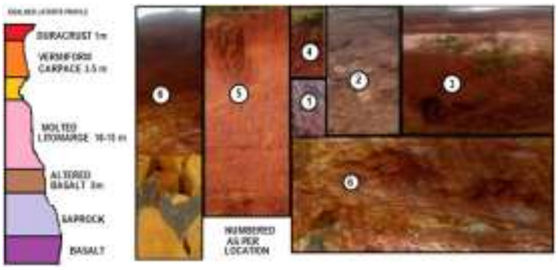

Figure 3 Lateritic profile and different colored lateritic soils in Goa (Widdowson, 2009).

1.3 Necessity for color based characterization

The formation process results in poor engineering properties such as poor workability, high plasticity, tendency to retain moisture high natural moisture content low strength and high permeability. This is the main reason why single test or few soil test results carried out on a soil in a trial pit at the beginning of excavation are misleading. They are not mindful of the composite and complex nature of the lateritic materials and the variation in the engineering properties of the materials with depth of the profile and the color of the soil (which indicates the composition of the soil). Therefore to neglect the changes in the index properties of soil leads to misleading result and consequently could result in serious failure of geotechnical engineering structure. It is therefore necessary to study the soils with respect to their depth and color.

Fig. 4. Photo showing the usage of different colored lateritic soils in embankments in Goa

2 METHODOLOGY

Disturbed Soil samples and cores were collected from various location and various sites in Goa as shown in the map, in polyethylene bags and sealed (Fig. 5). During the excavation, the soil profile was visually inspected. Disturbed samples of the soil, used for the bunds, were tested in the Civil engineering Laboratory of Goa Engineering College for their engineering properties and index values as per relevant Indian and other Standards (EM 1100-2-1913, EM 1100-1-1906, EM 1100-1-1902, IS: SP- 36 Part 1 and 2).

Fig. 5. Photo showing disturbed samples in bags and cores of different colored lateritic soils taken for testing

3 RESULTS AND DISCUSSIONS

After testing similar soils from various sites, it was found that the properties remained relatively constant within same color but varied from color to color. This is due to the mineralogical compositions of the soils. The properties also varied with depth. The average values are shown in (Tables 1 to 6) below.

3.1 Visual inspection

The profile of the hill-cuttings in Goa (Fig. 3) showed that they are organic-brown for top 1 m, reddish for next 3 to 5 meters, and varied in color for the next 10 to 25 meters till they approach the base rock at about 30 meter depth. The soils beneath the red lateritic soils were found in uneven layers and lenses. This makes it vital to ascertain the origin of the fill for engineering investigation.

3.2 Variations in Specific Gravity

The typical values of specific gravity (G_s), relative density (D_r) in % and void ratio (e) in % of different soils are show in Table 1 below

Table 1 Specific gravity, relative density and voids ratio

Soil Type	B	R	Br	Y	P	W	Bl
G_s	2.53	2.44	2.41	1.95	2.01	1.60	1.78
D_r (%)	69	85	65	56	48	42	45
e (%)	49	55	56	45	48	42	46

3.3 Variations in Natural Moisture Content

The result of natural moisture content (w) in % of samples and densities (γ) in kN/m^3 of different soils are shown in Table 2 below. Moisture varies with the depth at which sample is collected from while density depends on the mineralogical composition of soil.

Table 2 Natural moisture content and density.

Soil Type	B	R	Br	Y	P	W	Bl
W (%)	18	15	19	21	24	25	23
γ (kN/m^3)	15.8	17.6	18.7	13.2	13.8	11.7	11.9

3.4 Variations in Particle Size Distribution

The particle size distribution (Table3, Figure 6) is based on % of particle faction passing the standard sieves.

Table 3 Particle size distributions of various lateritic soils. (Fractions :-- C-clay, M-silt, FS-fine sand, MS-medium sand, CS-coarse sand, G-gravel)

Soil Type	B	R	Br	Y	P	W	Bl
C	22	11	5	20	15	28	25
M	14	6	4	22	30	30	35
FS	16	9	12	23	15	21	18
MS	12	12	22	12	28	9	7
CS	25	24	29	9	10	10	5
G	11	38	28	14	12	2	10

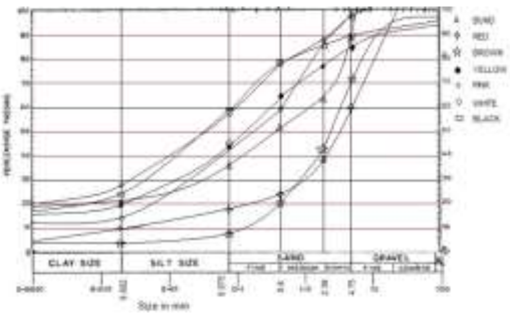

Fig. 6. Particle size distribution curves of different lateritic soils.

They varied from Sandy-loam to sandy-clayey-loam as per triangular textural classification (Fig. 7) and SC to SM - clean sand to Sand with organic fines as per Unified Soil Classification System-USCS.

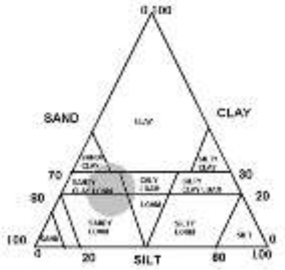

Fig. 7. Triangular classifications of lateritic soils.

3.5 Variations in Atterberg Limit

Atterberg limits (Table 4) are particularly useful for controlling engineered fills. The liquid limit (LL) and plastic limit (PL) of surface soils is higher. The plasticity index (PI) of lower soils is higher. This is a major cause of landslides and embankment failure when rain falls.

Table 4 Atterbergs limits of various lateritic soils.

Soil Type	B	R	Br	Y	P	W	Bl
LL (%)	25	50	40	45	48	40	42
PL (%)	15	25	18	13	13	11	12
PI (%)	10	25	22	32	35	29	30

3.6 Variations in Compaction Characteristics

The variation in compaction characteristics (Table 5) giving optimum moisture content (OMC) and maximum dry density (MDD) in kN/m^3, shows a similar relationship to Atterbergs Limits.

Table 5 Compaction characteristics of various lateritic soils.

Soil Type	B	R	Br	Y	P	W	Bl
OMC (%)	9	15	12	9	8	7	7
MDD (kN/m^3)	17.8	19.4	20.4	15.5	16	13	13.5

3.7 Variations in Shear strength Characteristics

There is difference in shear parameters (Table 6) which is another reason that lateritic soils fail when two types are used together (Fig. 4). The variation of shear parameters cohesion (c) and in kg/cm^2 and angle of internal friction (ϕ) show reasonable association to the soil size distribution.

Table 6 Shear strength coefficients of various lateritic soils.

Soil Type	B	R	Br	Y	P	W	Bl
c (kg/cm^2)	18	12	11	17	17	21	20
ϕ	29	38	43	29	33	23	24

3.8 Variations of soil-characteristics with Depth

Samples of red lateritic soil was taken from depths of 0, 5, 10, 15, 20, 25 and 30 meters at Ponda Goa and analysed to find variation in four parameters, viz. moisture content, specific gravity, OMC and MDD. The moisture content rose from almost dry to saturation limit then stabilized. The specific gravity showed a marked increase at great depth. The OMC decreased with depth while MDD increased with depth. The variation and the trend (marked in red) are shown in figures below

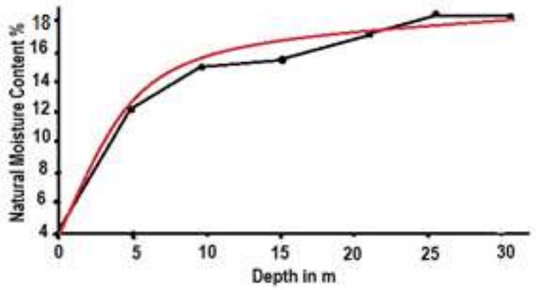

Fig. 7. Variation of natural moisture content with depth.

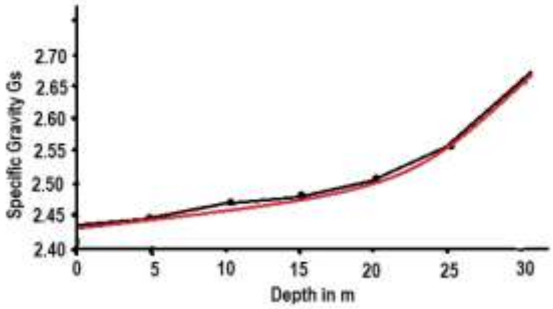

Fig. 8. Variation of specific gravity with depth.

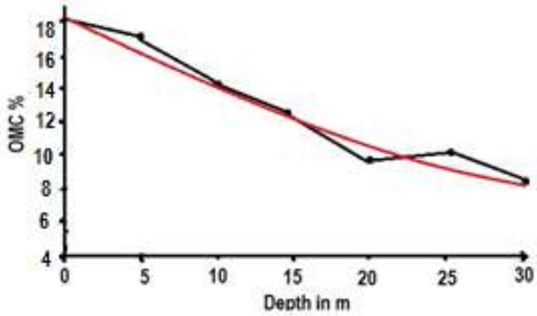

Fig. 9. Variation of OMC with depth

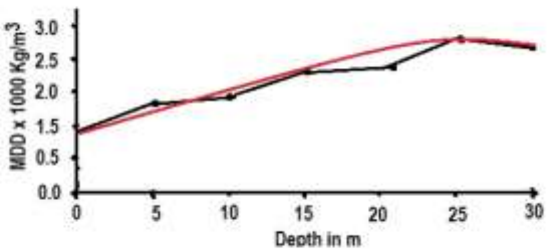

Fig. 10. Variation of MDD with depth

4 CONCLUSION

This study investigated some physical properties of lateritic soil formations used today for Traditional Goan Saraswat Bunds in Goa, India. It was observed that the soil profile consist of reddish lateritic soil having a thickness of about 3 m to 5 m. The soils below this level varied in color and properties to a depth of 25 to 30 m where granitic or basaltic bed rock is found. Properties varied both with color and depth. The particle size distribution generally, showed higher percentage of coarse soil at the reddish lateritic layer and percentage of clay size increased at the layers beneath.

As the predominant component of soils analyzed was sandy, the bunds need to be tested for seepage and slope stability and liquefaction while designing embankments. Embankment design should make suitable allowances for wide variation in properties. There is a need to do further studies and find the co-relationships between different properties for each color lateritic soils. Also, the shear characteristics at the interface of different colored lateritic soils need to be studied.

Based on this investigation, the index proprieties of the residual soils studied showed significant variation with depth and color, therefore investigation at shallow depth should not be used to represent the result of soils at other layers for the avoidance of inaccurate design of soil structures which may lead to its failure on application of the first load.

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