Effect of Alternate Wetting and Drying on Laterite and Their Engineering Behaviour

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ABSTRACT

Laterite is well known in Asian countries as a building material for more than 1000 years. It is a highly weathered material, rich in secondary oxides of iron and aluminum or both and hence its colour is reddish brown. In India, it occurs in Andhra Pradesh, Kerala, Tamil Nadu, Maharashtra, Karnataka, Goa. It is observed during the field investigation that the hard layer of laterites are under laid by loose material of different nature with a change in colour and considerable reduction in strength. The unique nature of laterite of changing strength and the presence of Lithomargic clay extending to considerable depth, alternate and wetting and drying make the behavior, properties and analysis of laterite imperative. The heavy rains in the recent past has given a wake up call to all engineers to analysis and prevent damages to cutting, slopes and foundations on lateritic soil. The laterite core and soil samples were taken from Verna Industrial Estate, which is located in Konkan belt of Goa. During the feasibility and preliminary design stages of the project when very little detailed information is available about laterite rock and soil its engineering properties can be determined by generating relationship between these properties. In the present work, an attempt is made to evaluate the shear strength parameters of lateritic soils and the effect of alternate wetting and drying on these parameters is studied. The soil sample is dried for twenty four hours and saturated for 1, 2, 5, 10, 15 and 21days, and the shear parameters are evaluated. Also, the effect of alternate wetting and drying on Atterberg limits is studied. From the experimental study it is found that after a number of alternate wetting and drying cycles, the lateritic soil starts loosing its strength as compared to the initial strength.

1. INTRODUCTION

Generally, it is expected that deeper the excavation, harder the ground met with but in lateritic formation, this situation is reversed as seen in the geoprofile. Hard stratum is met at top followed by soft stratum of weathering zone for considerable depth and the parent rock at the deepest level. According to strength criteria, it goes reducing from top to deeper level due to varying engineering properties. Lateritic soil has good shear strength in dry condition but negligible shear strength in saturated condition. (Narayanan G. 2006)

Lateritic soils constitute an important group of residual soils of India, covering an area of about 10,000 sq. km. They are found mainly on the Western and Eastern coasts over large areas and in small quantities in the Southern and Eastern States of India. (Shreekatian H. R. (1987)

Laterites are formed by the decomposition of the rock, removal in solution of silica and bases and accumulation of Aluminum of iron sesquioxides, titanium, magnesium, clay and other amorphous products generally a course grained concretionary material with ninety percent or more of these Laterite constituents is termed Laterites. While relatively fine-grained material with lower concentrations of oxides are referred to as Lateritic soils. The type of Laterite found all along the coast is known as the “low level laterite”. Low-level laterite generally belongs to the residual type of soils. They are the residue, resulting from in situ weathering of the parent rock, granites gneiss, under intense condition of tropical climate, high temperature and rainfall.

As the warm rainwater soaked constantly through the rocks, it broke down mineral grains forming the rock and dissolved away many of the chemical elements making them up. Some were easier to remove than others, such as sodium, potassium, calcium, magnesium and silicon. However, the iron and aluminum tended to remain behind as their hydrated oxides, such as goethite and gibbsite.
On 27th July 2005 there was an unpredictable torrential rainfall in Mumbai, Konkan and other parts of Maharashtra and Goa. An all time record of 944 mm rainfall occurred in 24 of hours, swapping the earlier highest rainfall of 838.2 mm in 24 hours at Cherapunji. These heavy rains caused the heavy destruction of life and property due to landslides and sinking of buildings in the ground due to reduction in bearing capacity of soil. Thus this has given a wake up call to all engineers to analyze and prevent damages to cutting, slopes and foundations on Lateritic soil.

2. LATERITES AND LATERITIC SOILS

Laterite is derived from Greek word ‘later’ meaning brick. From the geological point of view laterite can be defined as, “Laterite is a kind of vesicular rock composed essentially of mixture of hydrated oxides of aluminum and iron with small percentage of other oxides such as manganese or Titanium”. (Gidigasu M. D. 1976)

It is defined as soil layer that is rich in iron oxide and derived from a wide variety of rocks weathers under strongly oxidizing and leaching conditions. It forms in tropical and subtropical regions where the climate is humid. Lateritic soils may contain clay minerals; but they tend to be silica-poor, for silica is leached out by waters passing through the soil. Typical laterite is porous and claylike. The term laterite is often substituted for ferricrete but technically refers to a soil rich in iron oxides and aluminum. In areas of extensive leaching, many plant nutrients are lost, leaving quartz and hydroxides of iron, manganese, and aluminum. This remainder forms a distinctive type of soil, called laterite or latosol. Laterite beds/deposits forms on the top mainly due to chemical weathering of rocks laterisation with high content of iron hydroxides. (Nagadath R. 2005)

Laterization takes place in Tropical climatic regions having district dry and wet periods. Laterites are formed by the process by which parent rocks undergo upper facial decomposition, with removal in solution of combined silica, lime, magnesia, potash and with residual accumulation assisted by capillary changes of hydrated mixture of oxides of iron, alumina and manganese.

Thus Laterization requires three stages to complete, which are as described below:

(a) The first state (decomposition) is characterized by physico-chemical break down of primary minerals and the release of constituent elements (SiO₂, Al₂O₃, Fe₂O₃, CaO, MgO, K₂O, Na₂O etc.) which appear in simple ionic forms.
(b) The second stage (Laterization) involves the breaching under appropriate of combined silica and bases and the relative accumulation or enrichment from outside sources of oxides and hydroxides of sesquioxides (mainly Al₂O₃, Fe₂O₃ and TiO₂)
(c) The third state (dehydration O₂ desiccation) involves partial or complete dehydration. (Sometimes involving hardening) of the sesquioxide rich materials and secondary minerals.

Types of Laterite

According to stratiography of the area & the composition of the Parent rock, the laterites are mainly categorizes in the following three types:

(a) Type I

This occurs extensively over the Deccan trap. Lava flows & shows evidences of in situ development. The typical profile of this laterite developed over Deccan traps shows –
(i) Course saprolite horizon
(ii) Lithomarge horizon.
(iii) Duricrust

Course Saprolite is course to medium grained with spheroidal shell of light pink in colour. The thickness of course saprolite horizon which is a Transition zone is about 10 cm to 1.5 m. coarse saprolite is regular & sharp texture.

Lithomarge is fine saprolite occurs as unconsolidated slightly Ferruginous formation essentially composed of Kaolinite, occasionally with quartz & accessory goethite & hematite. The thickness of lithomarge varies between 10 cm to 30 cm & this horizon is developed & preserved at or below the level of ground water table.

Overlying the lithomarge, relatively thick reddish brown to black red indurate horizon is present that is known as the duricrust or ferruginous cuirrase, duricrust composed of considerably accumulation of iron as Fe₂O₃.

The thickness deposits ranges from 0.2 cm to 1.5 M. They are solid or nodular or pisolite in texture on the basis of the solid parts of voids present.

(b) Type – II

This Laterite has developed in situ over the Miocene sediments. Obviously these laterites are younger to Miocene & could be lower Pliocene. There show the typical components laterite profile, including the development of occasional bauxite. However on careful examination top most duricrust of these laterites shows well rounded pebbles of laterite & quartzite within a lateritic matrix.

(c) Type-III

This Laterite shows same profile as of Type I in the sense that their laterites are also developed over the Deccan traps. However they also show the presence of laterite pebbles within the upper nearly 1 m of the profile this type of laterite is observed only in the coastal
3. EFFECT OF ALTERNATE WETTING AND DRYING ON GEOTECHNICAL PROPERTIES

As said earlier, alternate wetting and drying of laterites which is commonly seen in cuts due alternate cycles resulting from heavy monsoons and high temperature accompanied by relatively high humidity typical of tropical climates. It is seen that alternate cycles of wetting and drying results in lowering of liquid limit and plasticity limit, which also results in the reduction in the plasticity Index. Permeability of such rocks increases with alternate cycles of similar tests on grain size distribution indicates that the grain tends to be lower from the initial course distribution. Their results corroborate well with the plasticity characteristic.

Consolidation tests on Lateritic soils indicate that both \(C_e\) & \(C_s\) decreases with alternate wetting & drying. These indicate that the compressibility decreases with alternate wetting & drying. Direct shear tests on lateritic soils indicate that the angle of shearing resistance increases & the cohesion decreases with increasing wetting and drying cycles.

4. EXPERIMENTAL WORKS

Direct Shear Test

Test Procedure

The detailed procedure for shear test depends of course, on the type of apparatus used. The following procedure presented is for the hand operated direct shear machine. The lever arm and the loading yoke is balanced so that the loading is applied vertically and when no load is applied the yoke is just touching the top of the loading pad through steel ball and is not exerting any force on the loading pad. The soil container is taken out from the machine and its internal dimensions are measured. Then the parts of the soil container are assembled. A dish along with the dry cohesion less soil, which is to be tested, is weighed. The soil is placed in smooth layers to such a thickness that the shear plane divides the soil sample into two equal halves. The soil is tamped, if the denser sample is to be tested. Then the surface of the soil is levelled. The upper grating and the loading block is put on the top of soil sample. The thickness of the soil specimen is measured. The dish along with the remaining soil sample is reweighed so that the weight of the soil used in the container can be determined. The container with the loading pad is mounted on to the direct shear machine. The steel ball is put on the loading pad and the yoke is entered properly. Then the loading pad is loaded with suitable load say 3 kg 6 kg, 9 kg and 12 kg. The dial gauges are fixed to measure the horizontal displacement of the soil sample. The two parts of the soil container are separated slightly by turning spacing screws.

The loading handle is rotated till the proving ring dial indicates small reading say 5 to 10 divisions, showing that the handle if continued to rotate would cause shearing of the sample. The reading of the proving ring dial was brought back to zero and then the lock screws are removed which prevent shearing of the sample while handling the container. It should be seen that the locking screws are removed before conducting the test. The handle is rotated at the rate of about 12 r.p.m. i.e. about 0.05/ min. The readings of all the dials are taken at intervals of 15 secs. i.e. at 3 rotations of handle. The shearing of the sample is continued till there is well defined drop in the reading of the proving ring dial or the shear displacement is 15% (i.e. 15/100 x 6 = 0.9 cm). The test is repeated for other normal loads. At least 4 sets of readings are obtained.

5. ANALYSIS OF TEST RESULTS

Angle of internal friction and cohesion before and after alternate wetting and drying cycles for sample 100/5/6 are given below:

Angle of internal friction and cohesion of lateritic soil is obtained by considering the moisture content of soil as 30% and density of soil as 1.3 grams / cubic centimeter.

Table 1: Variation of Cohesion and Angle of Internal Friction with Number of Cycles

<table>
<thead>
<tr>
<th>Sr No</th>
<th>No of Cycles</th>
<th>(q_{uc}) (t/m²)</th>
<th>% Increase(+) or Decrease(-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Insitu condition</td>
<td>62.0</td>
<td>--</td>
</tr>
<tr>
<td>2.</td>
<td>I (^{st}) cycle</td>
<td>62.0</td>
<td>--</td>
</tr>
<tr>
<td>3.</td>
<td>II (^{nd}) cycle</td>
<td>113.7</td>
<td>+83%</td>
</tr>
<tr>
<td>4.</td>
<td>V (^{rd})  cycle</td>
<td>200.32</td>
<td>+222%</td>
</tr>
<tr>
<td>5.</td>
<td>X (^{th}) cycle</td>
<td>117.77</td>
<td>+88.88%</td>
</tr>
<tr>
<td>6.</td>
<td>XV (^{th}) cycle</td>
<td>77.06</td>
<td>+25.45%</td>
</tr>
<tr>
<td>7.</td>
<td>XXI (^{th}) cycle</td>
<td>58.97</td>
<td>-7%</td>
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Bearing Capacity

From the direct shear test, shear parameters i.e. angle of internal friction and cohesion of soil are obtained and using these parameters and using Karl Terzaghi’s equation for ultimate bearing capacity, bearing capacity is found out after the various alternate wetting and drying cycles also percentage increase or decrease in bearing capacity is also tabulated below.

The behaviour and properties of lateritic soils are very challenging and unreliable particularly when it is subjected to alternate cycles of drying & wetting. The lateritic soil behave as hard material during drying season & when it comes in contact with the water it looses its strength and behaves like liquid.

Out of the three samples provided, sample100/5/6 is tested for shear parameters under alternate drying & wetting
cycles. In situ condition of sample shear parameters $c$ & $\phi$ obtained are 15 kN/m$^2$ and 32° respectively. In the succeeding I$^{st}$ cycle of alternate wetting and drying, no significant increase or decrease in the values of $c$ & $\phi$ is observed.

**Table 2:** Bearing Capacity after Various Alternate Wetting and Drying Cycles for Sample 100/5/6

<table>
<thead>
<tr>
<th>Sr No</th>
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For II$^{nd}$ cycle $\phi$ is increased by 12.5% and $c$ value increases by 27% when compared with initial state in situ values. At V$^{th}$ cycle the rate of increase in $\phi$ slows down & increases is around 9% where as $c$ suddenly increases by 93% compared with initial in-situ values.

At X$^{th}$ cycle, the rate of increase becomes very less as compared to V$^{th}$ cycle but still there is % increase of 14 and 40 in $\phi$ and $c$ values respectively when compared with in situ values.

At XV$^{th}$ cycle there is abrupt change in the rate of increase. The % increase of $\phi$ is 3 and that of $c$ is 13 while at XXI$^{st}$ there is total decrease in $c$ and $\phi$ values, $c$ value decreases by 14% and $\phi$ decrease by 3 %.

From $c$ and $\phi$ values bearing capacity is calculated for each alternative wetting and drying cycle and it is observed that up to V$^{th}$ cycle rate of increase of bearing capacity is very high but rate of increase suddenly drop down at X$^{th}$ and XV$^{th}$ cycle which results in reduction in bearing capacity at XXI$^{st}$ cycle up to 7 %.

From the above discussion it can said that after number of alternate wetting and drying cycles (here 15$^{th}$ cycle) the lateritic soil starts loosing its strength as compared to initial strength. Thus pose problem in stability of foundations and slopes. Also it can be seen that alternate wetting and drying results in lowering the liquid limit and plastic limit up to 65 & 31 respectively which also results in reduction of plasticity index.

### 6. CONCLUSIONS

The following conclusions are drawn based on the investigations carried out on Laterite, obtained from Konkan belt of Goa in the present study after experiments in S.P.C.E. laboratory.

- The graph of bearing capacity vs. no of cycles plotted below indicates that bearing capacity increases with increase in alternate wetting and drying cycles but after few no of cycles the rate of increase of bearing capacity reduces drastically and thus there is reduction in the bearing capacity.
- Alternate wetting and cycle also affect the liquid limit and plastic limit of lateritic soil. Both liquid limit and plastic limit decreases with increase in the number of alternate wetting and drying cycles.

### REFERENCES


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**Fig. 1:** Variations of Bearing Capacity Vs Number of Cycles

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