GEOTEXTILE AS REINFORCEMENT IN FLEXIBLE PAVEMENT FOR SWELLING SUBGRADE

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ABSTRACT: The South Gujarat region in India have majority of top soil as black cotton soil. The black cotton soil has characteristics of shrinking on drying and heaving on wetting. This soil being expansive creates several types of damages to pavement structures, and in some cases the pavement may even become unserviceable. The compacted black cotton subgrade undergo volumetric changes due to seasonal variation. The normal climate condition of study area shows short wet and long dry period which aggravate the problem of swelling and shrinkage. The IRC: 37 – 2001, Annexure – 4 suggest 0.6 to 1.0 m thick non-cohesive soil cushion on the expansive soil for road construction which led to higher cost for road construction. Also for new urban areas it is difficult to raise the embankment or to excavate the subgrade upto such a depth due to existing structures and under laying service lines. To provide economical solution along with feasible application Geotextile used as reinforcement material for flexible pavement. It is provided below the pavement components to act against the heaving of the swelling soil at the same time it helps as drainage layer also. Field study is undertaken to observe the effect of Geotextile in flexible pavement performance and about 2 to 3 boundary conditions are created for observations. Observations are in progress for positive results of performance of paved road reinforced with Geotextile subjected to drying and wetting cycles.

INTRODUCTION
Roads are vital to link our communities and sustain the economy and quality of life in society. Roads constructed over the expansive soil observed with high maintenance expenditure inspite of high capital cost. As per Austroads - 2002 [1] construction and maintenance works on pavements in Australia and New Zealand cost three billion per year, or approximately half of the total annual road expenditure. These are because many roads in this region are failing prematurely due to the expansion of reactive soils underneath the roadway, causing safety issues and increases road maintenance costs.

Frost, Fleming and Rogers [2] outline the primary roles that a subgrade or pavement foundation must play in pavement design. The volume change at subgrade creates variety of failure in flexible pavement like cracking, rutting, potholes etc. Expansive soils are one of the most problematic materials that are widely encountered in significant Land areas in several parts of the world e.g. parts of Africa, Australia, India, United States and Canada. In these countries expansive soil is having great impact on the construction and maintenance costs of highways.

The South West region of India is covered by top soil as black cotton soil. Figure 1 shows the top soil layer for India. The map shows that the majority of South Gujarat area having black cottons soil as top layer.

To understand the phenomenon of expansion of swelling soil and to provide economical solution along with feasible application utilising various strength of Geotextiles study started at the SVNIT campus, South Gujarat region of India. Geotextile is provided below the pavement components to act against the heaving of the swelling soil at the same time it helps as drainage layer also. Field study is undertaken to observe the effect of geotextile in flexible pavement performance and about 2 to 3 boundary conditions are created for observations. Observations are in progress for positive results of performance of paved road reinforced with geotextile subjected to drying and wetting cycles.

EXPANSIVE SOILS
Expansive soils are clayey soils, mudstones or shales that are characterized by their potential for volume change on drying and/or wetting. Usually the clay content is relatively high and the clay mineral montmorillonite dominates. They are characterized by their high strength when dry; very low strength when wet; wide and deep shrinkage cracks in the dry season; high plasticity and very poor traffiicability when
wetted. Whenever insufficient attention is given to the deleterious properties of expansive soils, the results will be premature pavement failure evidenced by undulations, cracks, potholes and heave. Methods were developed for the identification and classification of expansive soils both locally and worldwide. In India IS: 1498-1970 [3] describe the methods to identify the expansive soil.

There are three basic particle size components of naturally occurring soil: sand, silt and clay. Plastic clays termed as expansive soils or active soils exhibit volume change when subjected to moisture variations [4]. Swelling or expansive clay soils are those that contain swelling clay minerals (such as montmorillonite and smectite) and can often be scientifically referred to as Vertosols. Vertosols are soils that contain clay minerals which, because of their natural physiochemical properties, possess a net negative electrical charge imbalance that attracts the positive pole of dipolar water molecules and cations [5]. In addition, expansive soils have high degree of shrink-swell reversibility with change in moisture content. Petry and Little [6] discuss the history of clays and their engineering significance, dating back to papers written in the early 1930’s.

The effects on buildings constructed on reactive soils with inadequate footings can be dramatic [7]. Road subgrades can be viewed as the footings/ foundations for road pavements, and if these footings are not adequate, structural damage can occur.

FACTORS INFLUENCING PERFORMANCE OF PAVEMENTS ON EXPANSIVE CLAYS

Expansiveness is a property of soil influenced by seasonal climatic conditions, which describes a soil’s propensity to change in volume with moisture variation. There is no direct measure of this property due to difficulties in simulating atmospheric climatic factors, and so it is necessary to use comparative values of swell measured under known conditions to assess expansiveness [8]. Damage caused by soil movement is normally restricted to light structures, such as house slabs, low embankments and drainage structures. Expansiveness is controlled by three elements: the type of clay minerals, the change in moisture content (active depth), and the applied stresses (embankment loading).

a) Type of Clay Mineral

The type of clay mineral is largely responsible for determining the intrinsic expansiveness of the soil. Kaolinitic clays are relatively non-expansive whilst the more expansive clays are smectite clays, also known as montmorillonite clays.

b) Active Depth:

Expansive soils will only react if there is a change in moisture content, to cause either shrinking or swelling. The change in moisture content (or suction) controls the actual amount of swell that a particular soil will exhibit under a particular applied stress. This change in moisture content is brought about by climatic extremes. The active depth is the depth over which seasonal moisture changes are observed. Below this depth, the soil moisture is relatively stable and therefore volumetrically stable. The active depth can be estimated by the measurement of soil suction with depth over time. Pore water suction in soil samples is a more fundamental and reliable indicator of the degree of desiccation in an expansive clay profile than the measurement of moisture content [9]. Figure 2 indicates the potential active zone of a reactive soil.

Fig. 2 Active Depth for expansive soil [10]

Active depth can be influenced by external factors that are unrelated to rainfall and runoff. Influential objects such as trees and urban drainage can cause changes in the active depth profile, and consequently result in pavement deformation. Trees cause deep drying of the clay profile by suction, well beyond the design depth. In addition, trees produce increased soil moisture changes throughout the clay profile. This drying often causes significant clay shrinkage and cracking of road pavements. This is exacerbated by drought as the tree roots seek moisture from the clay soils. Climatic variations cause natural variations in ground moisture. Other factors such as water, sewer or storm water pipes which leak, cause wetting of soil and swelling (heave). This is often localized and can distort the shoulders causing settlement and failures [7].

SUBGRADE TREATMENT METHODS

Petry and Little [6] believe that the majority of treatment methods currently employed in the field have been around since 1960; including various forms of chemical or mechanical modification. The following six methods are but a few of the popular treatments.

Replacement

Das [11] lists the first precaution of foundation construction on swelling clays as replacement of the expansive soil with a less expansive material.

For Indian scenario the IRC: 37-2001 [12] Annexure – 4 suggest 0.6 to 1.0 m thick non-expansive cohesive soil cushion on the expansive soil for road construction.
Alternatively in situ Lime - Flyash stabilized soil layer has been prepared as subgrade.

**Compaction**
Das [11] states that if clay is compacted at less than OMC, inter-particle repulsion is minimized and the double layer surrounding the particle will be suppressed, leading to a random particle orientation. This means that the soil tends to swell as there is space for water molecules to occupy, however, a greater strength is achieved than those soils compacted greater than OMC. When the soil is on the “wet” side of OMC, the particles align producing less voids but a slight reduction in strength.

**Chemical Stabilization**
Generally, there are three types of chemical stabilizers – traditional, by-product (kiln dust) and non-traditional (such as sulphonated oils, polymers, enzymes etc). Petry and Little [6] make the comment that lime and Portland Cement are the most commonly used chemical stabilizers, however, moisture stabilisation is still the most widely used method.

Desai M.D. et al [13, 14] conducted research on application if lime-flyash stabilisation for expansive subgrade at south Gujarat of India. Results are excellent with reduction in maintenance cost of the flexible pavement roads within Surat Municipal Corporation limit.

**STUDY AREA OBSERVATIONS**
The research started based on the theme to provide effective solution against the moisture variation and differential swelling / shrinking of expansive soil in the area. There was planning of road construction at SVNIT campus near the observed site. The flexible road was proposed connecting transportation lab to workshop building on the back side of Civil Engineering Department. This site was selected for the further research work. Figure 3 shows the aerial view of the site as observed in Google web page.

**Table 1- Geotechnical Properties of Black Cotton Soil**

<table>
<thead>
<tr>
<th>Property</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Size</td>
<td>Gravel (%) 1</td>
</tr>
<tr>
<td></td>
<td>Sand (%) 12</td>
</tr>
<tr>
<td></td>
<td>Silt + Clay (%) 87</td>
</tr>
<tr>
<td>Atterberg’s Limit</td>
<td>Liquid Limit (%) 55</td>
</tr>
<tr>
<td></td>
<td>Plasticity Index (%) 27</td>
</tr>
<tr>
<td>Compaction Test</td>
<td>MDD (kN/cu.m) 15.50</td>
</tr>
<tr>
<td></td>
<td>OMC (%) 21.75</td>
</tr>
<tr>
<td>Swelling Test</td>
<td>Free Swell Index (%) 70</td>
</tr>
<tr>
<td>CBR (%)</td>
<td>1.77</td>
</tr>
<tr>
<td>UCS (kN/sq.m)</td>
<td>59</td>
</tr>
<tr>
<td>Permeability (m/s)</td>
<td>8.75 x 10⁻⁹</td>
</tr>
</tbody>
</table>

Expansive soils react with water and because of the change in moisture content the soil have active depth varying from region to region. The study carried out by Desai M.D. (2011) shows the active depth for South Gujarat region as 3 to 4 m. Some observations for study area expansive soil are described as Figure 4. It shows the 3 to 4 cm deep crack at the mid of the parking lot near T.E. Lab which because of the beneath expansive soil at foundation of slab. The phenomenon as described by Nelson and Miller [10] that there will be higher moisture content at inner side of the slab, the higher moisture content had created heaving at mid of the parking lot which finally resulted in severe cracking.

GEOTEXTILE FOR FOUNDING FLEXIBLE PAVEMENT
Figure 5 shows the proposed crust composition for road. The proposed road is studied for its design and planning was done for the observation of the expansive subgrade behaviour. After taking necessary approval from authority it was decided to provide the Geotextile GARWARE made GWF-52-240 PP Grey Multi 240 Twill 5 M, just below the subbase layer for further observation. Thick black line in Figure 5 indicates the geotextile layer as provided in the road construction.

![Fig. 3 Location of road joining Transportation Engineering Lab to Workshop, at SVNIT Campus, South Gujarat.](image)

![Fig. 4 Photo showing enlarge view of crack at mid way of the parking shed.](image)

![Fig. 5 Crust composition along with laid geotextile at site, SVNIT Campus.](image)
The geotextile was laid in such a manner that 2 boundary conditions can be created for the site.
1) Road with both side covered ground (length between Transportation Engineering Lab and Water Resources Engineering Lab)
2) Road with one side covered and one side open ground (length along WRE lab & after WRE lab).
Figure 6 shows various stages of the road construction at site.

(a) Geotextile above Murrum, (b) GSB spreading on Geotextile

Fig. 6 Road construction work in progress at site

OBSERVATIONS
The following observation was started after finishing of the pavement construction up to grouting layer.
a) Visual observation for cracks and other changes
b) Ground profile reading to get amount of change in soil thickness with change in moisture content (i.e. change in season).
The visual ground observations show that there is definite improvement in stability of subgrade below pavement where the Geotextile was laid. The portion with geotextile shows less undulation at top as well as very few cracks are observed. The length without Geotextile showed numbers of cracks and also there was more settlement observed.

CONCLUSION
Pilot initial field observations during execution traffic have established feasibility of use of geotextile reinforcement in pavement to control performance. The observations after 2 monsoons will only confirm its capability to replace cushion of 600 to 1000 mm for expansive subgrades (IRC: 37-2001). Future studies will be assessing minimum tensile strength of fabric and extra embedment over traffic zone.

REFERENCES
5. Snethen Dr D. R (1980), Expansive Soils in Highway Subgrades, U.S Department of transportation, United States of America
12. IRC: 37 – 2001, Guidelines for the Design of Flexible Pavements, Indian Road Congress, New Delhi, India

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