

APPLICATIONS OF INNOVATIVE MATERIALS FOR PERFORMANCE IMPROVEMENT OF FLEXIBLE PAVEMENT OVER EXPANSIVE SUBGRADE

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ABSTRACT: Expansive soils are one of the most problematic materials that are widely encountered in significant land areas in several parts of the world; like Africa, Australia, India, United States and Canada. 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 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 two innovative materials were used namely, CONSOLID and Geotextile for flexible pavement. The CONSOLID application shows the great improvement of CBR values helping the overall stability of the pavement. The Geotextile 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 2 specific boundary conditions are created for observations. The Observations shows about 50 % reduction in shrinkage effect for paved road reinforced with Geotextile subjected to drying and wetting cycles. Both the materials are having its unique advantage in the performance improvement of flexible pavement over expansive subgrade.

Keywords: Expansive Soil, CONSOLID, Geotextile, Pavement Performance

1. 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. 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 (2004) [1] 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. Fig. 1, map of soil deposits in Gujarat

State shows that the majority of South Gujarat area having black cottons soil as top layer.

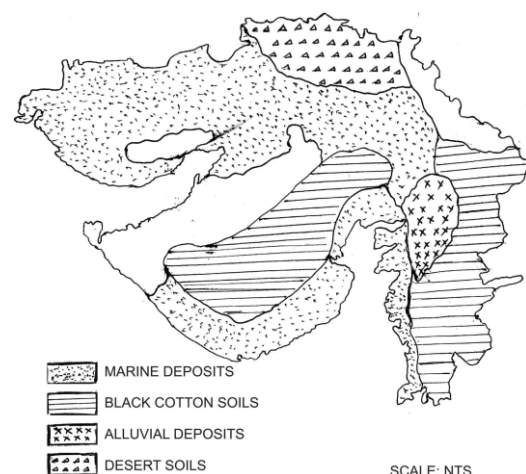


Fig. 1 Map of Soil Deposits in Gujarat State

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 2 specific boundary conditions are created for observations. Observations summarized shows about 50 % reductions in shrinkage effect for paved road reinforced with geotextile compared to road without geotextile.

Also the advanced material called CONSOLID system with two different types of soil were examined for better performance of south Gujarat soil. The samples are collected from SVNIT Campus in South Gujarat region and experimental work carried out for evaluation of CONSOLID system. Two samples are collected and named as, 1) SVNIT Road Side Shoulder Soil, and 2) SVNIT Campus Soil. The soil samples are found of MH and CH type of soil. The Soak CBR for MH type of soil for natural condition is 2.4% which improves about 45% With CONSOLID Treatment. Similarly, the Soak CBR for CH type of soil natural condition is 2% which improves about 27% with CONSOLID Treatment.

2. EXPANSIVE SOIL

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 trafficability 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 [2] 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 (He-Ping Yang et al, 2007) [3]. 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 (Snethen, 1980) [4]. In addition, expansive soils have high degree of shrink-swell reversibility with change in moisture content. Petry and Little (2002) [5] 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 (Smith R, 2004) [6]. Road subgrades can be viewed as the footings/ foundations for road pavements, and if these footings are not adequate, structural damage can occur.

3. 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. Fig. 2 shows the aerial view of the site as observed in Google web page.

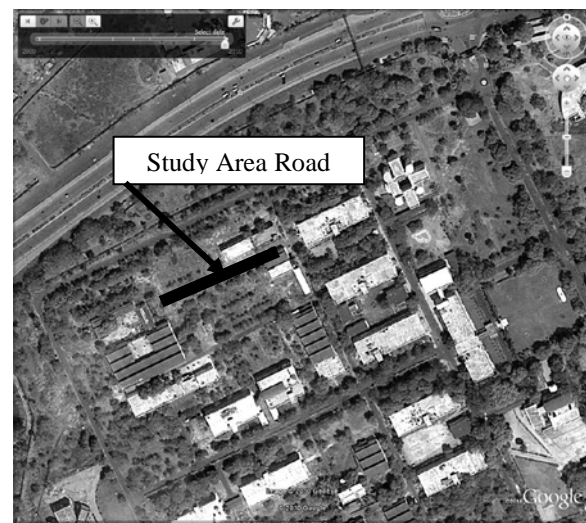


Fig. 2 Location of Road Joining Transportation Engineering Lab to Workshop, at SVNIT Campus, South Gujarat, India

The study by Jigisha (2008) [7] shows the average soaked CBR for typical South Gujarat undisturbed or compacted soil as 2.0 %.

Also study carried out by Yogendra (2008) [8] shows the similar type of observation for the South Gujarat region soil. Table 1 shows the Geotechnical Properties of Black cotton soil as observed by Yogendra (2008) [8].

Table 1 Geotechnical properties of black cotton soil.

Property		Values
Grain Size	Gravel (%)	1
	Sand (%)	12
	Silt + Clay (%)	87
Atterberg's Limit	Liquid Limit (%)	55
	Plasticity Index (%)	27
Compaction Test	MDD (kN/cu.m)	15.50
	OMC (%)	21.75
Swelling Test	Free Swell Index (%)	70
	CBR (%)	1.77
UCS (kN/sq.m)		59
Permeability (m/s)		8.75×10^{-9}

Also the samples are collected from the SVNIT campus to access the suitability with CONSOLID system. Various laboratory tests were carried out for the samples collected and mainly the CBR values are reported for the same. Table-2 shows the results for the same.

Table 2 CBR values of study area soils

Sample I.D.	1 - S.V.N.I.T. Road Side Shoulder Soil	2 - S.V.N.I.T. Campus Soil
Unsoak CBR %	5.7	4.7
Soak CBR %	2.4	2.0

4. GEOTEXTILE FOR FOUNDING FLEXIBLE PAVEMENT ON SWELLING SUBGRADE

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.

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 3 shows various stages of the road construction at site.



a) Geotextile above Murrum,



b) GSB spreading on Geotextile

Fig. 3 Road construction work in progress at site.

4.1 Pavement Observations and Analysis

The following observations were started after finishing of the pavement construction upto grouting layer.

- 1) Visual observation for cracks and other changes
- 2) Ground profile reading to get amount of change in soil thickness with change in moisture content (i.e. change in season).

The visual observation shows that in some of the portion the Top Surface was deteriorated because of non-availability of appropriate Bituminous Layer. In general the area with Geotextile shows less undulation.

4.1.1 Ground profile survey

The leveling exercise carried out after pavement construction in Month of December 2010 to get the initial Ground Level RL. After one year during December 2011 further the ground level are surveyed and another ground level survey was carried out in June 2012.

The detailed observation are summarized and published by Tailor R.M. et. al. in year 2012 [9] and 2014 [10]. The summertime graphs shown in Fig. 4, 5 and 6 represents ground profile for various observations at Right, Centre and Left side.

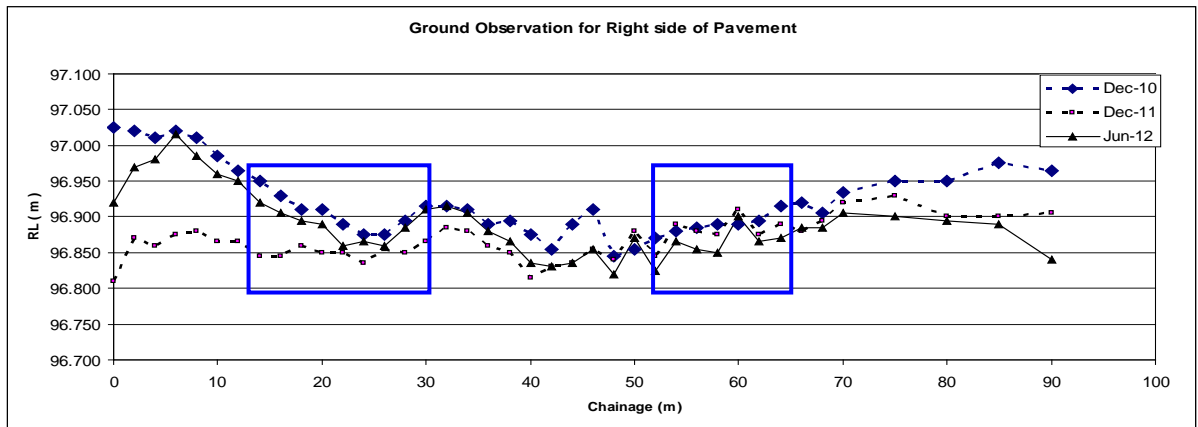


Fig. 4 Ground observation for Right side of Pavement.

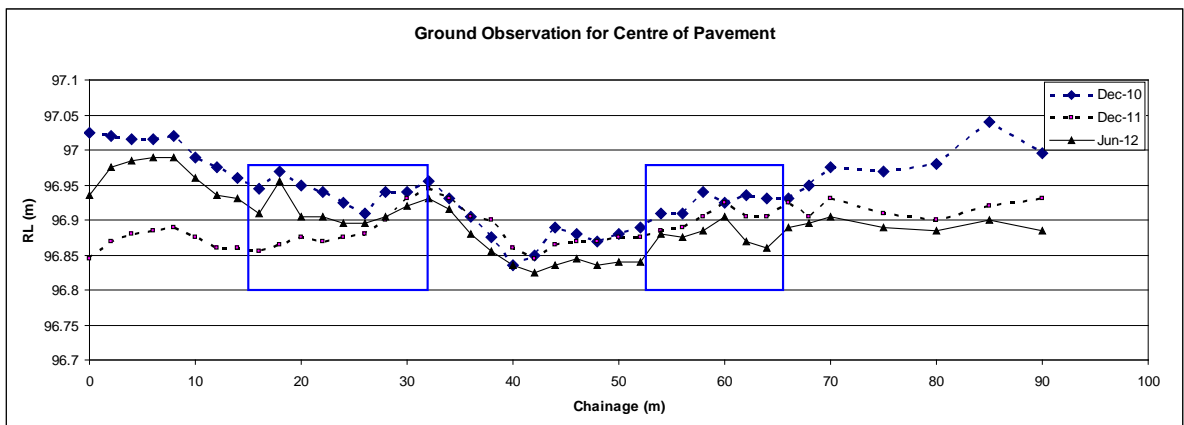


Fig. 5 Ground observation for Centre of Pavement.

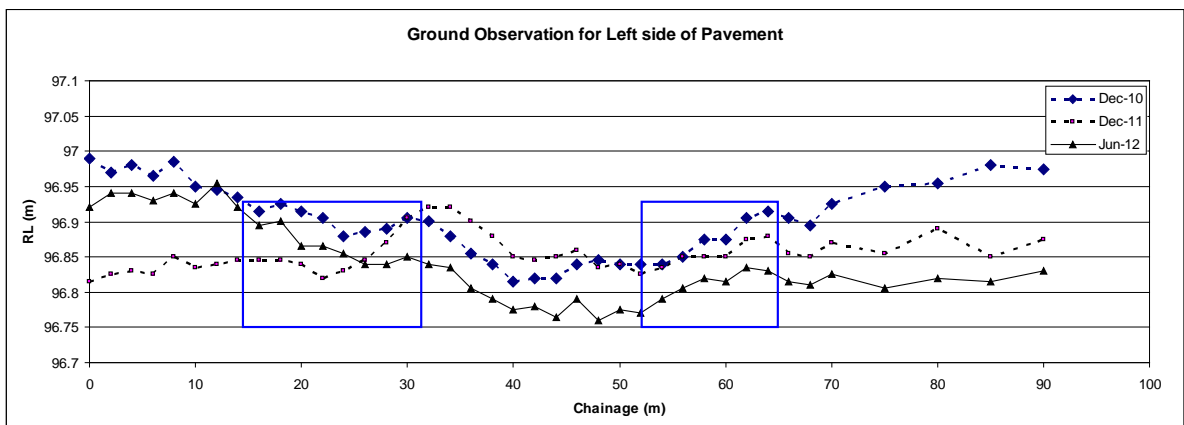


Fig. 6 Ground observation for Left side of Pavement

4.1.2 Observations for WBM unasphalted pavement at Transportation Engineering Laboratory

The subgrade was saturated clay. The typical road construction with structures on both sides and structure on one side were under observation. The other side is water logged and absence of topping

crust was also pervious to some extent. The textile was laid on subgrade in December 2010.

The December 2011 & June 2012 observations of elevation on road with nominal traffic shows:

- 1) The introduction of geotextile fabric in sector of walls on both sides shows 40% reduction in shrinkage of fill & subgrade.
- 2) Wall on right & free surface on left, Chainage

54 – 90 m. The performance in December 2011 shows 43 mm average reduction of settlement of surface in fabric reinforced zone. (Reduction of about 60 % with reference to no reinforcement zone)

3) In middle sector with wall on right & free water access to left typical ingress of water can be seen to centre of road by December 2011. The left end shows ultimate heave where as right end shows settlement with little movement at centre in zone. In reinforced sector of this road overall performance shows settlement of 37 to 19 mm.

4) In general, trend shows shrinkage effect leading to settlement indicates drastic reduction of 50 % or more.

5. CONSOLIDATE SYSTEM TO IMPROVE CBR

Sustainable production and consumption, leading to increased resource efficiency, is now high on the political agenda. Various alternatives are developed in form of advanced materials and waste utilization for resource intensive activities such as the construction of infrastructure including highways. The range of materials incorporated includes recycled asphalt, recycled concrete, ashes, slags, foundry sand, glass, plastic, rubber and other chemicals. Feasibility studies concerning the potential for the use of these materials are plentiful and some studies exist which have considered the engineering as well as environmental credentials of such practices. This particular study summarizes work conducted to date and investigates the engineering as well performance of CONSOLID system, which is combination of Consolidate444 & Solidry powder to replace conventional materials in non-bituminous layers of flexible pavement. Also same can be used to improve the soil CBR.

To study behavior of CONSOLID system with two different types of soil; samples are collected from Surat city and surrounding area in South Gujarat region and experimental works carried out for evaluation of CONSOLID system. The study for soil characteristics, Free Swell Index, Standard Proctor Test, Specific Gravity, CBR and UCS are conducted for natural and treated soil samples. Two samples are collected from the SVNIT campus and named as, 1) SVNIT Road Side Shoulder Soil, and 2) SVNIT Campus Soil.

The California Bearing Ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement. The CBR value of the specimen reflects on the strength of the specimen in soaked or un-soaked condition

as tested in the laboratory. The soaked CBR values reflect the soil behaviour in saturated condition and hence is very critical for the regions with heavy rainfall and retentive soil types. The soak CBR test is carried out after the submergence of sample in water for 4 days in accordance to IS: 2720 (Part 16) [11]. The test results are presented in Table 3 & 4 below for both samples.

Table 3 CBR values of SVNIT Road Side Shoulder soil with CONSOLID System.

Soil Condition	Natural Soil	Soil with CONSOLID System
Unsoak CBR %	5.7	54
Soak CBR %	2.4	45

Table 4 CBR values of SVNIT Campus soil with CONSOLID System.

Soil Condition	Natural Soil	Soil with CONSOLID System
Unsoak CBR %	4.7	32
Soak CBR %	2.0	27

The 1) SVNIT Road Side Shoulder soil sample found of MH type of soil while the 2) SVNIT Campus soil observed as CH type of soil. The Soak CBR for MH type of soil for natural condition is 2.4% which improves about 45% With CONSOLID Treatment. Similarly, the Soak CBR for CH type of soil in natural condition is 2% which improves about 27% with CONSOLID Treatment.

6. CONCLUSION

The textile was laid on subgrade in December 2010. The December 2011 and June 2012 observations of elevation on road with nominal traffic shows:

1) The area without geotextile bothside building shows uneven change in ground profile while the area with Geotextile bothside building shows about 50 % reduction with uniform change in ground profile.

2) The area without Geotextile Rightside building shows the considerable change of ground in ground profile on lefthand side because of direct entry of rainwater on that side. The area with Geotextile Rightside building shows slight changes in leftside region.

3) Overall the observations show the positive impact of Geotextile laying in flexible pavement over swelling subgrade.

The overall visual observations also indicate considerable reduction in ground profile change for flexible pavement embedded with Geotextile over swelling subgrade.

The CONSOLID system results shows great improvement in soaked CBR values from 2.4% to 45% for MH soil and 2% to 27% for CH soil, which encourage its utilization to improve subgrade condition.

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