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Performance Improvement of Flexible Pavement on Swelling Subgrade Using Geotextile

Ravin M. Tailor
Civil Engineering Department, S.V. National Institute of Technology, Surat, India
Email: ravin@ced.svnit.ac.in

Navin. C. Shah
Chhotubhai Gopalbhai Patel Institute of Technology, Bardoli, Gujarat, India

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 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 2 specific boundary conditions are created for observations. Observations shows about 50 % reduction in shrinkage effect for paved road reinforced with Geotextile subjected to drying and wetting cycles.**

Index Terms—**expansive soil, subgrade improvement methods, geotextile, pavement performance**

I. 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 in spite 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 (2004) [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. Fig. 1 map of soil deposits in Gujarat State shows that the majority of South Gujarat area having black cottons soil as top layer.

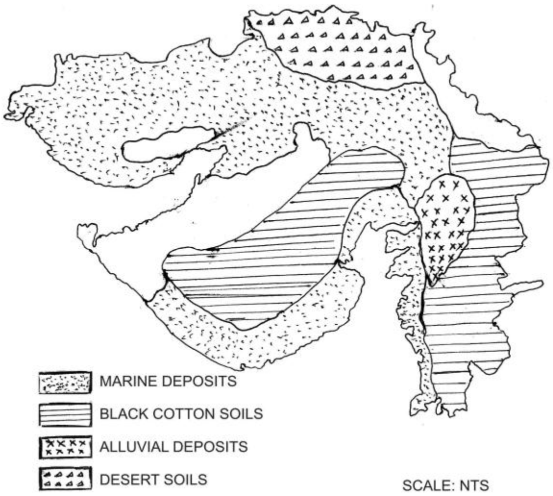

Figure 1. Map of soil deposits in gujarat state

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

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in shrinkage effect for paved road reinforced with geotextile compared to road without geotextile.

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 traffic ability when welled. 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.

II. EXPANSIVE SOILS

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) [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, posses a net negative electrical charge imbalance that attracts the positive pole of dipolar water molecules and cations (Snethen, 1980) [5]. In addition, expansive soils have high degree of shrink-swell reversibility with change in moisture content. Petry and Little (2002) [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 (Smith R, 2004) [7]. Road subgrades can be viewed as the footings/ foundations for road pavements, and if these footings are not adequate, structural damage can occur.

A. *Factors Govering Pavemet Performance 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 (Main Roads, 2008) [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).

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.

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 (Crilly and Chandler, 1993) [9]. Fig. 2 indicates the potential active zone of a reactive soil.

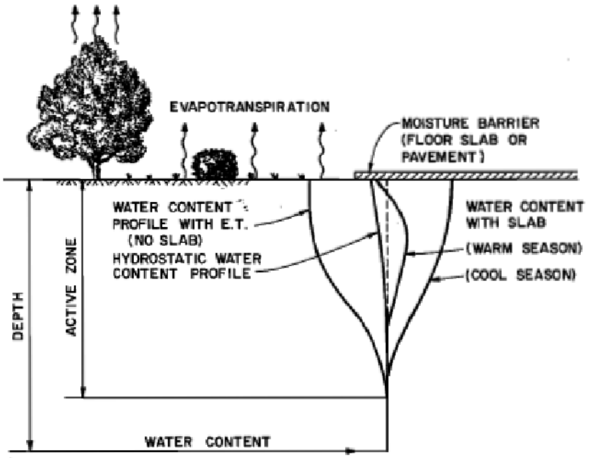


Figure 2. Active depth for reactive soil (Nelson and Miller, 1992) [10]

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. (Smith et al, 2004) [7].

III. SUBGRADE TREATMENT METHODS

Petry and Little (2002) [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 methods are few of the popular treatments.

B. *Replacement*

Das (2006) [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 insitu Lime - Flyash stabilized soil layer has been prepared as subgrade.

C. *Compaction*

Das (2006) [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.

D. *Chemical Stabilization*

Generally, there are three types of chemical stabilisers – traditional, by-product (kiln dust) and non-traditional (such as sulphonated oils, polymers, enzymes etc). Petry and Little (2002) [6] make the comment that lime and Portland Cement are the most commonly used chemical stabilisers, however, moisture stabilisation is still the most widely used method.

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

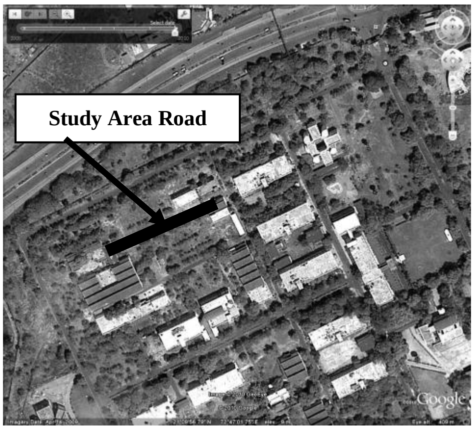


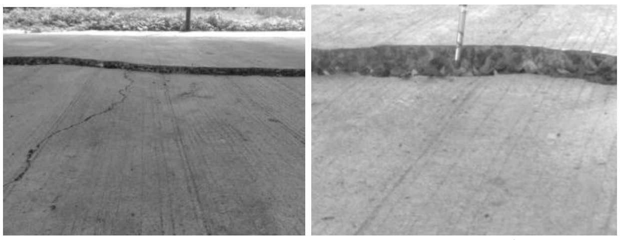
Figure 3. Location of road joining Transportation Engineering Lab to Workshop, at SVNIT Campus, South Gujarat

The study by Jigisha (2008) [13] shows the average soaked CBR for typical South Gujarat undisturbed or compacted soil as 2.0 %. The study also describes some ambiguity in results due to uneven moisture distribution within the soaked test specimen. Also study carried out by Yogendra (2008) [14] shows the similar type of observation for the South Gujarat region soil. Table I shows the Geotechnical Properties of Black cotton soil as observed by Yogendra (2008) [14].

TABLE I. 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}

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 Fig. 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 (1992) [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.



a) Crack at Mid way b) Enlarge view of crack

Figure 4. Photo showing enlarge view of crack at mid way of the parking shed.

V. GEOTEXTILE FOR FOUNDING FLEXIBLE PAVEMENT ON EXPANSIVE SUBGRADE

Fig. 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 Fig. 7 indicates the geotextile layer as provided in the road construction.

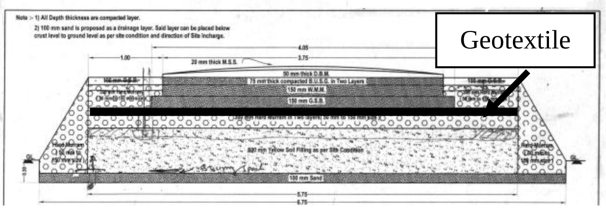


Figure 5. Crust composition along with laid geotextile at site, SVNIT Campus

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).

Fig. 6 shows various stages of the road construction at site.

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

Figure 6. Road construction work in progress at site.

VI. OBSERVATIONS

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.

A. Ground Profile Survey

The levelling 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 change in ground level from December 2010 to December 2011 are summarised in Table II below.

TABLE II. SUMMARY OF DIFFERENCE IN GROUND LEVEL FROM DECEMBER 2010 TO DECEMBER 2011 AT GEOTEXTILE REINFORCED FLEXIBLE PAVEMENT BEHIND CED, SVNIT, SURAT

Area Description	Location	Level Diff. (M)	Location	Level Diff. (M)	Location	Level Diff. (M)	Avg. Diff. At Chainage (M)	Avg. Diff. for Area (M)
Without Geotextile Bothside building	Right 0	0.215	Centre 0	0.180	Left 0	0.175	0.190	**0.140**
	Right 2	0.150	Centre 2	0.150	Left 2	0.145	0.148	
	Right 4	0.150	Centre 4	0.135	Left 4	0.150	0.145	
	Right 6	0.145	Centre 6	0.130	Left 6	0.140	0.138	
	Right 8	0.130	Centre 8	0.130	Left 8	0.135	0.132	
	Right 10	0.120	Centre 10	0.115	Left 10	0.115	0.117	
	Right 12	0.100	Centre 12	0.115	Left 12	0.105	0.107	
With Geotextile Bothside building	Right 14	0.105	Centre 14	0.100	Left 14	0.090	0.098	**0.082**
	Right 16	0.085	Centre 16	0.090	Left 16	0.070	0.082	
	Right 18	0.050	Centre 18	0.105	Left 18	0.080	0.078	
	Right 20	0.060	Centre 20	0.075	Left 20	0.075	0.070	
With Geotextile Rightside Building	Right 22	0.040	Centre 22	0.070	Left 22	0.085	0.065	**0.028**
	Right 24	0.040	Centre 24	0.050	Left 24	0.050	0.047	
	Right 26	0.020	Centre 26	0.030	Left 26	-0.060	-0.003	
	Right 28	0.045	Centre 28	0.040	Left 28	0.020	0.035	
	Right 30	0.050	Centre 30	0.010	Left 30	0.000	0.020	
	Right 32	0.030	Centre 32	0.010	Left 32	-0.020	0.007	
Without Geotextile Rightside building	Right 34	0.030	Centre 34	0.000	Left 34	-0.040	-0.003	**0.004**
	Right 36	0.030	Centre 36	0.000	Left 36	-0.045	-0.005	
	Right 38	0.045	Centre 38	-0.025	Left 38	-0.040	-0.007	
	Right 40	0.060	Centre 40	-0.025	Left 40	-0.035	0.000	
	Right 42	0.025	Centre 42	0.005	Left 42	-0.025	0.002	
	Right 44	0.055	Centre 44	0.025	Left 44	-0.030	0.017	
	Right 46	0.055	Centre 46	0.010	Left 46	-0.020	0.015	
	Right 48	0.005	Centre 48	0.000	Left 48	0.010	0.005	
	Right 50	-0.025	Centre 50	0.005	Left 50	0.000	-0.007	
	Right 52	0.025	Centre 52	0.015	Left 52	0.015	0.018	
With Geotextile Rightside building	Right 54	-0.010	Centre 54	0.025	Left 54	0.005	0.007	**0.018**
	Right 56	0.005	Centre 56	0.020	Left 56	0.000	0.008	
	Right 58	0.015	Centre 58	0.035	Left 58	0.025	0.025	
	Right 60	-0.020	Centre 60	0.000	Left 60	0.025	0.002	
	Right 62	0.020	Centre 62	0.030	Left 62	0.030	0.027	
	Right 64	0.025	Centre 64	0.025	Left 64	0.035	0.028	
	Right 66	0.040	Centre 66	0.005	Left 66	0.050	0.032	
Without Geotextile Rightside building	Right 68	0.010	Centre 68	0.045	Left 68	0.045	0.033	**0.063**
	Right 70	0.015	Centre 70	0.045	Left 70	0.055	0.038	
	Right 75	0.020	Centre 75	0.060	Left 75	0.095	0.058	
	Right 80	0.050	Centre 80	0.080	Left 80	0.065	0.065	
	Right 85	0.075	Centre 85	0.120	Left 85	0.130	0.108	
	Right 90	0.060	Centre 90	0.065	Left 90	0.100	0.075	

- x.xxx Shows Heaving

The change in ground level from December 2011 to June 2012 are summarised in Table III below.

TABLE III. SUMMARY OF DIFFERENCE IN GROUND LEVEL FROM DECEMBER 2011 TO JUNE 2012 AT GEOTEXTILE REINFORCED FLEXIBLE PAVEMENT BEHIND CED, SVNIT, SURAT

Area Description	Location	Level Diff. (M)	Location	Level Diff. (M)	Location	Level Diff. (M)	Avg. Diff. At Chainage (M)	Avg. Diff. for Area (M)
Without Geotextile Bothside building	Right 0	-0.110	Centre 0	-0.090	Left 0	-0.105	-0.102	
	Right 2	-0.100	Centre 2	-0.105	Left 2	-0.115	-0.107	

	Right 4	-0.120	Centre 4	-0.105	Left 4	-0.110	-0.112	
	Right 6	-0.140	Centre 6	-0.105	Left 6	-0.105	-0.117	
	Right 8	-0.105	Centre 8	-0.100	Left 8	-0.090	-0.098	
	Right 10	-0.095	Centre 10	-0.085	Left 10	-0.090	-0.090	
	Right 12	-0.085	Centre 12	-0.075	Left 12	-0.115	-0.092	**-0.102**
With Geotextile Bothside building	Right 14	-0.075	Centre 14	-0.070	Left 14	-0.075	-0.073	
	Right 16	-0.060	Centre 16	-0.055	Left 16	-0.050	-0.055	
	Right 18	-0.035	Centre 18	-0.090	Left 18	-0.055	-0.060	
	Right 20	-0.040	Centre 20	-0.030	Left 20	-0.025	-0.032	**-0.055**
With Geotextile Rightside Building	Right 22	-0.010	Centre 22	-0.035	Left 22	-0.045	-0.030	
	Right 24	-0.030	Centre 24	-0.020	Left 24	-0.025	-0.025	
	Right 26	-0.005	Centre 26	-0.015	Left 26	0.005	-0.005	
	Right 28	-0.035	Centre 28	-0.005	Left 28	0.030	-0.003	
	Right 30	-0.045	Centre 30	0.010	Left 30	0.055	0.007	
	Right 32	-0.030	Centre 32	0.015	Left 32	0.080	0.022	**-0.006**
Without Geotextile Rightside building	Right 34	-0.025	Centre 34	0.015	Left 34	0.085	0.025	
	Right 36	-0.020	Centre 36	0.025	Left 36	0.095	0.033	
	Right 38	-0.015	Centre 38	0.045	Left 38	0.090	0.040	
	Right 40	-0.020	Centre 40	0.025	Left 40	0.075	0.027	
	Right 42	0.000	Centre 42	0.020	Left 42	0.065	0.028	
	Right 44	0.000	Centre 44	0.030	Left 44	0.085	0.038	
	Right 46	0.000	Centre 46	0.025	Left 46	0.070	0.032	
	Right 48	0.020	Centre 48	0.035	Left 48	0.075	0.043	
	Right 50	0.010	Centre 50	0.035	Left 50	0.065	0.037	
	Right 52	0.020	Centre 52	0.035	Left 52	0.055	0.037	**0.034**
With Geotextile Rightside building	Right 54	0.025	Centre 54	0.005	Left 54	0.045	0.025	
	Right 56	0.025	Centre 56	0.015	Left 56	0.045	0.028	
	Right 58	0.025	Centre 58	0.020	Left 58	0.030	0.025	
	Right 60	0.010	Centre 60	0.020	Left 60	0.035	0.022	
	Right 62	0.010	Centre 62	0.035	Left 62	0.040	0.028	
	Right 64	0.020	Centre 64	0.045	Left 64	0.050	0.038	
	Right 66	-0.005	Centre 66	0.035	Left 66	0.040	0.023	**0.027**
Without Geotextile Rightside building	Right 68	0.010	Centre 68	0.010	Left 68	0.040	0.020	
	Right 70	0.015	Centre 70	0.025	Left 70	0.045	0.028	
	Right 75	0.030	Centre 75	0.020	Left 75	0.050	0.033	
	Right 80	0.005	Centre 80	0.015	Left 80	0.070	0.030	
	Right 85	0.010	Centre 85	0.020	Left 85	0.035	0.022	
	Right 90	0.065	Centre 90	0.045	Left 90	0.045	0.052	**0.031**

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VII. CONCLUSION

The study area observed with subgrade as saturated clay. The typical road construction with structures on both sides and structure on one side observed during study. The December 2011 & June 2012 observations of elevation on road with nominal traffic shows:

- The introduction of geotextile fabric in sector of walls on both sides shows 40% reduction in shrinkage of fill & subgrade.
- 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)
- 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 (- heave, + settlement) of 37 to 19 mm.
- In general, trend shows shrinkage effect leading to settlement indicates drastic reduction of 50 % or more.

ACKNOWLEDGMENT

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Ravin M. Tailor graduated in Civil Engineering from the S. V. Regional College of Engineering and Technology of Surat, Gujarat, India in 2000. He obtained a Master of Town and Regional Planning degree at S.V. National Institute of Technology of Surat, Gujarat, India in 2003.

From 2003 to 2006 he worked for Unique Engineering Testing and Advisory Services, Udhna, Surat. He had served at S.V.N.I.T. during 2006 – 2007 as Teaching Assistant. In 2007, he joined C.K. Pithawala College of Engineering and Technology, Surat as Lecturer. From 2009 he has been Assistant Professor at Civil Engineering Department of S.V. National Institute of Technology, Surat, Gujarat, India. He is pursuing Ph. D from S.V.N.I.T., Surat. He had guided 9 M Tech dissertation and 3 continued. He has published more than 20 research papers.

Mr. Ravin M. Tailor is life member of the Indian Society For Hydraulics, Indian Society for Technical Education, Indian Road Congress, Institute of Urban Transport (India) and India Geotechnical Society. He awarded 1st Best paper Prize, Mrs. Bhadra M. Desai memorial award at National Workshop on “Utilization Of FlyAsh” during June 10-11, 2011.

Prof. N. C. Shah graduated in 1972 from M.S. University of Baroda in Civil Engineering. Post graduated in 1975 in Transportation Engineering from SVRCET, Surat. Achieved doctorate qualification in 1997 in Transportation Planning from South Gujarat University. He published more than fifty research papers at international and national level. He guided 60 dissertations. At present 8 scholars are perusing their doctoral studies under him.