EXPERIMENTAL STUDY OF USE OF GEOGRIDS AS HORIZONTAL REINFORCING ELEMENT IN SWELLING SUBGRADES

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Abstract: The expansive soils of India, colloquially known as Black Cotton soils, are very poor material for foundations as well as for constructions. Black cotton soils are essentially clay deposits possessing high plasticity and compressibility, small shear strength when saturated and exhibiting very high volumetric changes during drying-wetting. Black cotton soils cover nearly 20% of Indian subcontinent.

Out of the numerous construction activities in the black cotton soil areas, the construction of highways and roadways constitutes a major activity. It has been the common observation and experience that the pavements of highways and roadways constructed either on insitu soil formations or on compacted black cotton soil embankment show several types of damages to pavement structures, and in many instances the pavements may even become unserviceable because of highly deteriorated conditions of the whole pavements system.

Many efforts since past many years are being made in pavement construction practice to prevent such damage and to ensure stability and effective performance of the pavement structure. The degree of effectiveness in improving the conditions of swelling soil at subgrade thereby providing a damage free environment to the pavement structure varies from individual method to method.

Keeping this in view, a laboratory investigational study is under taken to evolve an integrated soil subgrade system using geogrids as horizontal reinforcing element. Firstly to keep the vertical heave within the permissible magnitude. Secondly, the soft black cotton soils subgrade can safely withstand and sustain the traffic loads. Thirdly, to minimize the rut depths for the designed traffic loading.

Keywords: Expansive soil, Geogrid, Swelling, Settlement, Cyclic load, Prediction.

INTRODUCTION

Well built and maintained roads play a major role in the development of the nation. Construction of a road involves substantial investment and therefore proper planning, construction and maintenance of these national assets is of paramount importance.

Black cotton soil is an expansive soil, which swells or shrinks excessively due to change in moisture content. When black cotton soil is associated with an engineering structure, it experiences either settlement or heave depending on the stress level and the soil swelling pressure. Design and construction of civil engineering structures on and with expansive soils is a challenging task for geotechnical engineers. Subgrade soil is an integral part of the road pavement structure as it provides the support to the pavement above. The subgrade soil and its properties are important in the design of pavement structure. The main function of the subgrade is to give adequate support to the pavement and for this the subgrade should possess sufficient stability under adverse climatic and loading condition. If the weak subgrade is stabilized or reinforced, the crust thickness required will be less. The rutting is also restricted resulting in less repairs and overall economy.

The recent design and construction changes brought about primarily by heavier wheel load and heavier traffic level have led to the introduction and increased use of stabilized subgrade, sub-base and base courses in flexible pavements. For last several years, concentrated efforts have been made to develop a more fundamental based design analysis and evaluation of benefits of using stabilizer in different layers of a flexible pavement. One of the major challenges in pavement design is to investigate the innovative methods to improve the mechanical properties of subgrade soils

The concept of reinforcing soils with tension resisting elements has been widely accepted in engineering practice. Soil reinforcement is an effective and reliable technique for improving the strength and stability of the soil. In conventional method of reinforced soil construction, the inclusion of strip, fabric, bar, geo-grid and geotextile are used and normally oriented in a predefined direction and are introduced sequentially in alternate layers (Rao 1995, Kulkarni *et al.* 1997, Rao *et al.* 1989).

The technique of reinforcing the soil increases the stiffness and load carrying capacity of the soil through frictional interaction between the soil and the reinforcement. Hence, reinforcing black cotton soil with geotextiles is of great importance in the field of road construction. The normal stress membrane support has been explicitly recognized by a number of previous investigators (Barenberg 1980, Giroud and Noiray 1981, Bourdeau *et al.* 1982, Sellmeijer *et al.* 1982). Similarly, the subgrade bearing capacity improvement has also been recognized by the other investigators (Love *et al.* 1987, Jewell 1988, Houlsby *et al.* 1989, Barksdale *et al.* 1989). Study on strength characteristics of soil reinforced by used polythene fabrics was conducted by Pradipkumar and Sathyamurthy (1993).

So keeping in view the above object, information related to black cotton soil / soft soil was studied with respect to the stabilization materials, various methods and their performance, the effect of various un-reinforced and reinforced materials on the engineering properties of soil, and various tests on black cotton and reinforced soil. Similarly papers related to control of heave, swelling – shrinkage behavior of black cotton soil with remedial measures were also referred.

The main domain of this study is to search information related to control of heave and improvement of pavement subgrade with respect to vertical soil movement and to increase overall stiffness for traffic load transmission.

A laboratory investigational study is undertaken to evolve an integrated soil subgrade system using geogrids as horizontal reinforcing element. Firstly to keep the vertical heave within the permissible magnitude. Secondly, the soft black cotton soils subgrade can safely withstand and sustain the traffic loads. Thirdly, to minimize the rut depths for the designed traffic loading.

MATERIALS

Soil

The swelling type of subgrade material used in the investigation was black cotton soil collected from locality Punjabrao Deshmukh Agriculture University, farmland, near Sitabuldi, and Murrum soil (red soil) used as the cushioning layer was collected from Ring road (Katol road to Wadi), Nagpur, Maharashtra, India. Their physical properties has been determined in the laboratory investigations and are shown in the Table 1 ;

Table 1. Physical properties of swelling soil and Murrum soil.

Physical property	Clay	Murrum
Water content (%)	8.1	3
Specific gravity	2.52	2.64
Liquid limit (w_L)	56.2%	23.6 %
Plastic limit (w_P)	40.4%	18.4%
Shrinkage limit (w_S)	10.66%	17.6%
Plasticity index (I_P)	15.8%	6.0 %
OMC (%)	20.6	7.3
MDD (kN/m^3)	18.2	19.9
CBR	1.80%	14%
Angle of internal friction	6^o	36
Cohesion (kN/m^2)	3.6	12
Free Swell Index	35%	--
Swelling pressure (kN/m^2)	23.25	--

Granulometric composition

- Silt & clay percent …… 90.855%
- Coarse particles content …… 9.145%

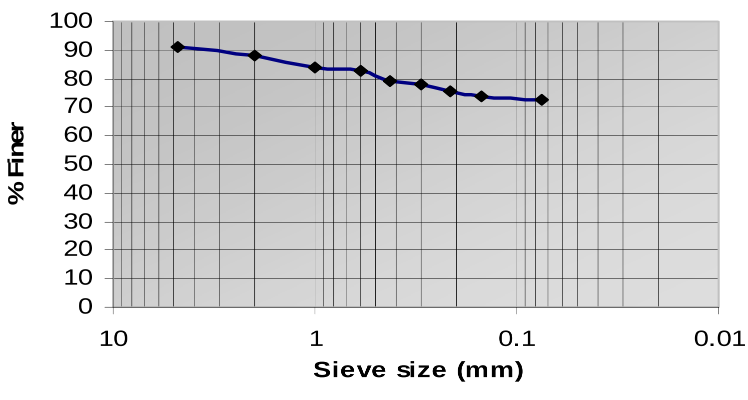

Figure 1. Grain size analysis

Aggregate

The aggregate used in the swell studies was procured from the crushing plant, located in Panchgaon, Nagpur. The gradation characteristics and engineering properties of aggregate used in the study are given in the Table 2 and Table 3.

Table 2. Gradation of aggregates

S.No.	Sieve size (mm)	Percent passing by weight
1.	90	100
2.	63	100
3.	53	57
4.	45	6
5	22.4	2

Table 3. Engineering properties of aggregate

1.	Specific Gravity	2.75
2.	Impact value (%)	18.5
3.	Crushing value (%)	21.6
4.	Abrasion value (%)	25.6

Geogrid

Two punched and drawn polypropylene (pp) biaxial geogrids I and II were evaluated. The physical properties obtained from the manufacturer are listed in the Table 2.

Table 4 . Physical property of geogrids**.**

S.No.	Physical property	Units	Geogrids	
			I	II
1.	Unit weight	g/m^2	315	220
2.	Average aperture size	mm x mm	25.7 x 33	21 x 25
3.	Rib dimension	mm	3.1	3.0
4.	Ultimate tensile strength (MD)	kN/m	20.1	13.5
5.	Ultimate tensile strength (XD)	kN/m	30.7	20.5
6.	Tensile Modulus @ 2% (MD)	kN/m	70	205
7.	Tensile Modulus @ 2% (XD)	kN/m	110	300

EXPERIMENTAL PROCEDURE

Swelling Tests

Swelling tests were carried out on specimens prepared in CBR moulds to assess the swelling of subgrade soil (clayey material). Subgrade soil is reinforced with geogrids I and II, separately at the surface of subgrade soil and nominal layer of 20 mm Murrum is laid over the geogrid for fixity of geogrid. Where in Murrum has no contribution in the free swell.

A WBM of 300mm thickness (half the thickness of base/sub-base thickness as per design code IRC 37 – 2001) is laid over the reinforced subgrade soil with geogrids. Free swelling (heave) observed on the following combinations with subgrade material:

a) Only subgrade soil ---- Unreinforced subgrade (US).
b) Reinforced Subgrade with Geogrid – I ---- (RS – I)
c) Reinforced Subgrade with Geogrid – II ---- (RS – II)
d) Reinforced Subgrade with Geogrid – I and WBM --- (RS – I + WBM)
e) Reinforced Subgrade with Geogrid – II and WBM --- (RS – II + WBM)

Table 5. Free swell observations

Free swell (mm)				
US	**RS- I**	**RS- II**	**RS - I + WBM**	**RS - II + WBM**
34.5	25.5	24.3	16.5	15.6

EXPERIMENTAL PROGRAMME

A model Steel Tank (800mmx800mmx1200mm) represents a pavement model. The model pavement was prepared by filling subgrade and WBM in layers (Fig 2). Each layer was compacted uniformly to the required density. Necessary precautions were taken to reduce the friction from the sides of the steel tank.

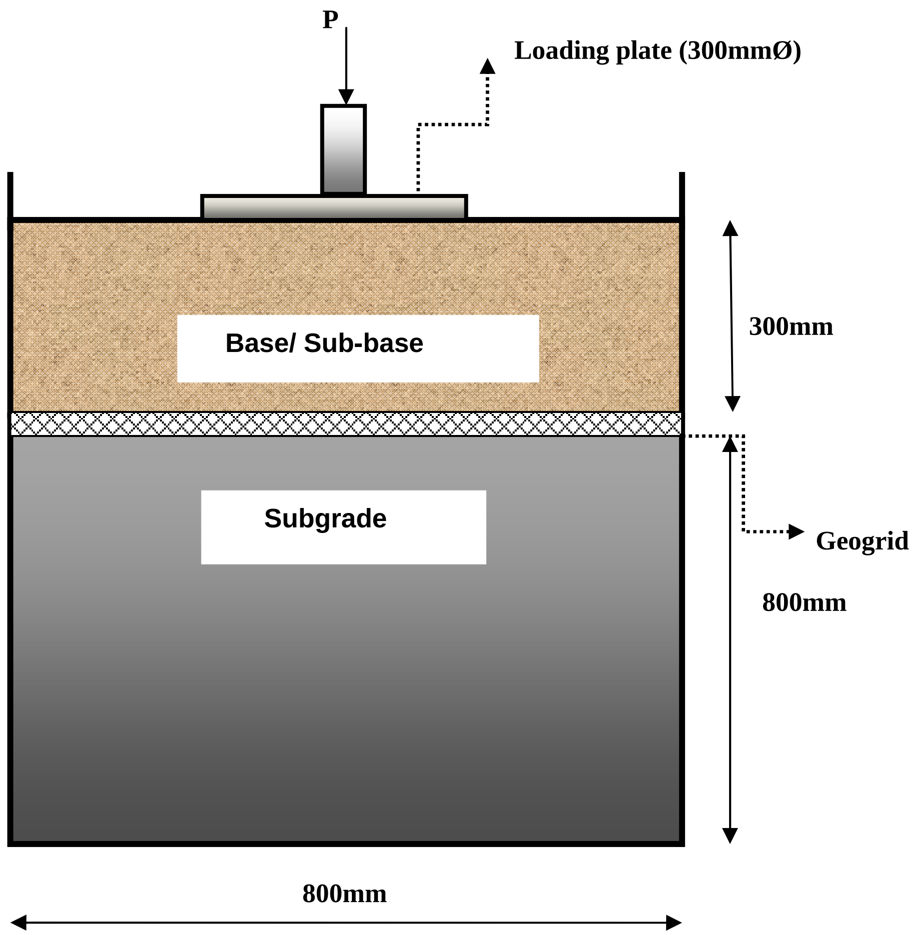

Figure 2. Steel tank (800mmx800mmx1200mm)

The model steel tank was placed, axially centered on the frame of MTS machine (250 kN capacity, servo-controlled, with a cross head travel of 200mm). The loading ram of the machine was lowered in such manner that loading plate just touched the prepared finished surface of the model pavement.

Up to 10000 sinusoidal loading cycles have been applied through a circular loading plate having 300 mm diameter. The tests have been performed at a frequency of either 5 or 10 Hz. With an equivalent applied pressure of 700 kPa. The vertical settlements (ruts) have been recorded as function of number of cycles together with the permanent deformation in the road section. Due to limitation, only 10000 loading cycles were applied. The model pavements were not loaded till the failure. The settlements were measured only under the loading plate and recorded.

Table 6. Cyclic load test (cycles vs vertical settlement)

	Vertical settlement (mm)				
Cycles	**US**	**RS-I**	**RS-II**	**RS -I + WBM**	**RS -II + WBM**
10	10.0	6.0	5.5	4.0	4.0
50	24.0	8.0	7.0	6.0	6.0
100	33.4	10.0	8.2	7.0	6.0
200	42.8	12.0	10.0	8.5	6.4
400	53.8	15.5	12.6	10.0	8.0
600	60.5	17.2	14.0	11.5	8.8
1000	69.3	20.2	15.8	12.5	10.1
2000	81.2	24.0	18.4	14.8	11.7
3000	90.7	26.3	20.2	16.5	12.9
5000	103.1	28.9	22.8	18.1	14.3
10000	122.6	32.7	26.6	21.0	16.7
		Predicted values			
100000	--	43.5	36.0	29.5	23.0
1000000	--	54.0	46.0	38.0	28.0

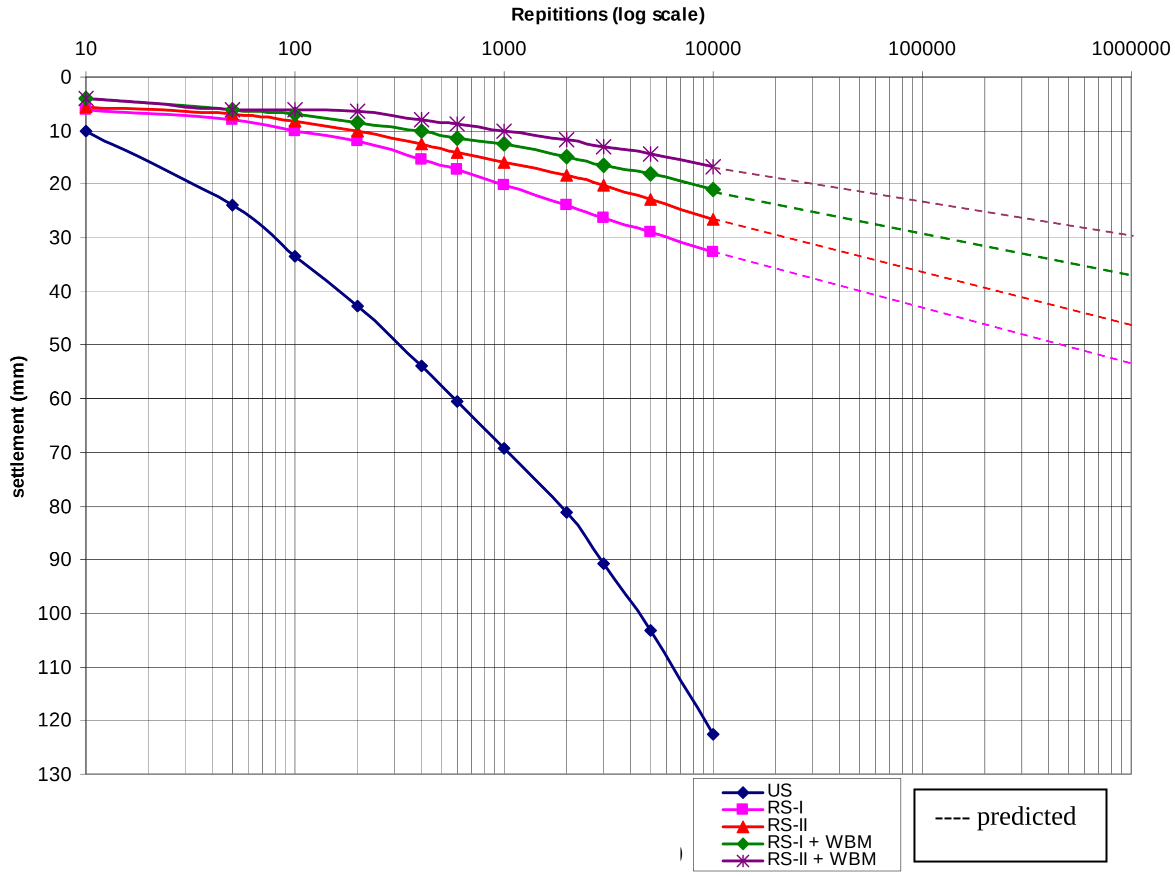

Figure 3. Unreinforced and reinforced (cyclic loading vs. settlement)

TEST RESULTS AND ANALYSIS

The vertical settlements (ruts) are recorded in the Table 6. Fig.3 shows the comparisons of vertical settlement between reinforced and unreinforced section. Ruts geometry for reinforced and unreinforced sections have been analyzed to determine differences in depth and shape of the deformed sections.

Since the load repetitions in the field are not limited to 10000 cycles only, vertical settlements (ruts) are predicted from the Fig. 3, by extending the slope lines of the obtained geometry to 1000000 cycles.

From the Fig. 3, the recorded rut depth of unreinforced soil is 122.6 mm. By reinforcing the subgrade soil with geogrids – I and II, the vertical settlement (ruts) reduced by 73.3% and 78.3% respectively. By reinforcing the subgrade soil with geogrids – I and II and WBM, the vertical settlement (ruts) reduced by 82.87% and 86.37% respectively.

The predicted vertical settlement (ruts) for 100000 cycles for RS – I, RS – II, RS - I + WBM and RS – II + WBM are 43.5mm, 36mm, 29.5mm and 23mm respectively. The reduction in the vertical settlement (ruts) for RS – I, RS – II, RS - I + WBM and RS – II + WBM when compared to unreinforced are 65.5%, 70.64%, 74.09% and 81.34%.

The predicted vertical settlement (ruts) for 1000000 cycles for RS – I, RS – II, RS - I + WBM and RS – II + WBM are 54mm, 46mm, 38mm and 28mm respectively. The reduction in the vertical settlement (ruts) for RS – I, RS – II, RS - I + WBM and RS – II + WBM when compared to unreinforced are 56%, 62.5%, 70% and 77.17%.

CONCLUSIONS

The testing results obtained from the experimental research program demonstrated that:

- There is a considerable reduction in free swell of subgrade soil in the range of 26% to 54% , as recorded in the Table 5.
- The vertical settlement (ruts) of subgrade also reduced drastically in the range of 73.3% to 86.37% with the use of geogrid as a reinforcement element up to 10000 cycles. From the nature of the graphs plotted between 0 and 10000 repetitions, the vertical settlement (ruts) for a higher number of cyclic loading passes can be extrapolated and this can be helpful in the design of pavements.

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