



A laboratory study of thickness design of flexible pavement by the CONSOLID system in black cotton soil

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Abstract—With rapid growth of population, fast urbanization and more construction of buildings and other structures has resulted in reduction of good quality available land. There is no choice for People except to use soft and weak soils around for construction activities. Such soil possesses poor shear strength and high swelling & shrinkage. 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. A laboratory investigation is carried out to study the effect of CONSOLID SYSTEM on index and engineering properties of the Black Cotton Soils. The properties of stabilized soil such as compaction characteristics and California bearing ratio were evaluated and their variations with content of consolid444 and Solidry are evaluated and also to evaluate the improvement in properties by the addition of consolid444 and Solidry to be used in pavement design for economy. A CONSOLID system also reduces thickness of the pavement and save resources and construction time. A comparative study of pavement thickness design by IRC METHOD is also done.

Keywords— Black cotton soil, soil stabilization, consolid444, Solidry, increase CBR, IRC pavement design

I. INTRODUCTION

Several types of advanced materials are tried to establish the efficiency of new materials in road construction. However, the use of new materials and technologies is not becoming popular owing to certain procedural constraints as well as lack of awareness and therefore appropriate steps may have to be taken for popularizing the new technologies for building better roads with less cost. Adoption of such technique may also result in the conservation of natural resources, energy and environment. Roads are having different layers which provide strength for sustaining the heavy loads due to vehicle movement. If sub grade soil has poor properties, it needs modification or stabilization with stabilizers to improve its properties. Along with improvement in engineering properties of soil, stabilization is also used to achieve economy in terms of cost by reducing thickness of layers of pavement by CONSOLID system.

II. MATERIALS USED FOR STUDY

SOIL: The study area is selected is of GJ SH 181 i.e. Dharampur Taluka, Dist. VALSAD , south Gujarat and obtained at a depth of 0.5 to 1.0 mt. from 4 different location at a chain-age of 200,350,600,850 mt. respectively. Approximate 25 – 30 kg soil per location was collected. The visual examination indicates that the soil is having black colour and possesses the quality under moisture changes to expand soil and swell. Such soil causes distresses in road pavement.

The CONSOLID system: It is a Swiss Technology for Permanent soil stabilization. The CONSOLID system is a dual system, where two additives are used. i.e. Consolid444 (Liquid) & Solidry (Powder) and is commercially available. It is procured from competent authority of company Mr. Manish Shah, Ahmadabad for study purpose. Consolid444 is controlling the capillary rise of water and Solidry controlling the influence of surface water. The two components are mixed with the soil and afterwards the soil is completely compacted. The CONSOLID system is an environment friendly, due to the very small quantities of the additive required. The CONSOLID treatment proves to be one of the best available stabilizers for various soils. Black cotton soil is highly plastic soil and bearing strength is very less compared to other soil. By adopting consolid444 and Solidry in required doses, bearing strength can be improved.

CONSOLID 444: It is a chemical liquid white substance having the property to lower water absorption through reducing the capillary activity, reduces permeability, lowers OMC and increases density of treated soil.

Solidry: It is a dry, grey colored chemical powder substance and it prevents the treated soil from water soaking in by closing the capillary.

Applied at rate of:

1. **Solidry** : 1.0 to 2.0 % by wt. of soil
2. **Consolid444** : 0.4 to 0.8 L/m³ (1.0 to 2.0 % by wt. of soil)
 Mixed with water in ratio of 1: 20 to 50 part of water

Advantages of CONSOLID system:

1. Reduces free swell index.
2. Reduces Plasticity Index & Optimum Moisture Content.
3. Increases California Bearing Ratio value.
4. Increases maximum dry density

III. PROBLEM DEFINITION & OBJECTIVES OF STUDY

• **Problem definition:**

In this case study area region is of Black cotton soil that creates:

1. Swelling of soil in sub-grade in expansive type of soil
2. Shrinkage creates crakes in sub-grade in dry season.
3. Low bearing capacity of sub-grade in wet season.
4. Consolidation creates uneven pavement in dry season.
5. Design Problems in Black Cotton Soil.

• **Objectives of study :**

1. To determine changes in properties of natural soil by the addition of stabilizers i.e., C444 & SD.
2. To design of flexible pavement by CONSOLID system.
3. To do comparative analysis between Conventional Pavement design and the CONSOLID system pavement design.

IV. METHODOLOGY

Methodology adopted for this study was initially the problem will be identified such as identifying causes of sub grade failure in Black cotton soil and design problems in black cotton soil , then objectives would be set as per the requirement that minimize the problems and lastly data would be collected such as Soil sample and Volume of vehicles. Then soil sample would be analyzed with laboratory test i.e., Sieve analysis test, Liquid and Plastic limit test , Modified Proctor test, Free Swell Index and California Bearing Ratio test as per the IS code and after that flexible pavement design as per IRC:37-2012 would be done.

V. ANALYSIS OF DATA AND RESULTS

Experimental Investigations:

Laboratory tests are conducted for determining the properties of the natural soil and soil treated with CONSOLID system are Grain size analysis, Liquid and Plastic limit tests, Modified proctor test, Free Swell Index & California Bearing Ratio test.

RESULT OF UNTREATED SOIL SAMPLE:

Table 1: Result of Untreated soil sample

SR. NO	TEST PARAMETERS		UNITS	CHAIN-AGE (METER)				TEST METHOD
				1.SOIL @ 200	2. SOIL @ 350	3. SOIL @ 600	4. SOIL @ 850	
1	PARTICLE SIZE ANALYSIS	GRAVEL	%	1.5	1.7	1.3	1.6	IS – 2720 (PART – 4)
		SAND	%	11.6	12.2	13.6	14.8	
		SILT	%	86.9	86.1	85.1	83.4	
		CLAY	%					
2	CONSISTENCY PROPERTIES	LL	%	52.75	51.32	52.68	52.97	IS – 2720 (PART – 5)
		PL	%	25.58	23.12	24.34	24.67	
		PI	%	27.17	28.20	28.34	28.30	
3	IS CLASSIFICATION	-	-	CH	CH	CH	CH	IS-1498-1970
4	MODIFIED COMPACTION	MDD	GM / CC	1.731	1.512	1.612	1.721	IS – 2720 (PART – 8)
		OMC	%	14.21	12.01	13.11	14.32	
5	CALIFORNIA BEARING RATIO	UNSOAKED	%	3.22	3.56	3.46	4.13	IS – 2720 (PART – 16)
		SOAKED	%	2.64	3.15	2.80	3.23	
6.	FREE SWELL INDEX		%	43	47	41	45	IS – 2720 (PART – 40)

RESULT OF TREATED SOIL SAMPLE:

Table 2: Result of Treated soil sample

SR. No	BLACK COTTON SOIL + STABILIZERS	CONSISTENCY PROPERTIES			FREE SWELL INDEX	MODIFIED COMPACTION		CALIFORNIA BEARING RATIO	
		LL	PL	PI		MDD	OMC	UNSOAKED	SOAKED
		%	%	%		GM / CC	%	%	%
A.	LIQUID (CONSOLID444)								
5.	SOIL (100%) + C-444(1.0%)	55.71	23.88	31.83	38	1.631	18.98	3.48	6.73
6.	SOIL (100%) + C-444(1.25%)	52.54	24.24	28.30	33	1.683	16.87	4.03	7.01
7.	SOIL (100%) + C-444(1.50%)	51.174	23.851	27.32	30	1.716	14.38	3.92	8.53
8.	SOIL (100%) + C-444(1.75%)	50.861	25.376	25.49	24	1.733	12.67	3.53	9.53
9.	SOIL (100%) + C-444(2.0%)	49.25	28.14	21.11	22	1.691	11.04	4.16	8.90
B.	POWDER (SOLIDRY)								
10.	SOIL (100%) + SD (1.0%)	55.75	26.51	29.24	41	1.731	17.68	6.25	14.368
11.	SOIL (100%) + SD (1.25%)	53.83	30.719	23.111	36	1.743	16.08	6.58	15.983
12.	SOIL (100%) + SD (1.50%)	52.00	31.79	20.21	32	1.782	13.93	7.02	17.056
13.	SOIL (100%) + SD (1.75%)	50.984	30.19	20.794	25	1.853	11.95	8.86	19.986
14.	SOIL (100%) + SD (2.0%)	49.11	29.408	18.702	21	1.713	10.52	7.518	18.256

RESULT: From the laboratory test it has been observed that the soil treated with 1.75% of Consolid-444 (liquid) and 1.75% of Solidry (Powder) having highest CBR value.

VI. PAVEMENT DESIGN AND COST ANALYSIS

In order to design a flexible pavement IRC: 37 – 2012 are used in which the evaluation of factors (design traffic, vehicle damage factor, design life, etc.) are considered for state highway. Thickness design for untreated soil and treated soil with Solidry is carried out.

The data for pavement design are assumed for state highway which are given below and from that thickness design of flexible pavement is worked out.

Data:

- P = No. of commercial vehicles as per last count = 277 Nos.
- x = No. of years between the last count and the year of completion of construction = 1 year
- D = Lane distribution factor = 75 % (Two lane single carriage way)
- F = Vehicle damage factor = 3.5 (Plain Terrain)
- n = Design Life in Years = 15
- r = Annual growth rate of commercial vehicles = 7.5 %

Design Calculations:

A = Initial Traffic in the year of completion of completion of construction in term of no. of CVPD

$$= P (1+r)^x = 277(1 + 0.075)^{15} = 298 \text{ CVPD}$$

N = the cumulative no. of standard axles to be catered for in the design in terms of msa.

$$= \{365 \times [(1+r)^n - 1] / r\} \times \{A \times D \times F\} = \{365 \times [(1+0.075)^{15} - 1] / r\} \times \{298 \times 0.75 \times 3.5\} = 7.45 \text{ msa} \quad \text{i.e., } 7 \text{ msa}$$

• **There are two types of Pavement:**

1. Pavement design on untreated Black Cotton soil and the CBR value of Black Cotton soil is 2.64%.
2. Pavement design on treated Black Cotton soil with 1.75 % solidry and the CBR value of Black Cotton soil is 19.986%.

Note: - All the specification taken by IRC: 37-2001, IRC: 37-2012, and latest SSR of R&B Dept, VALSAD.

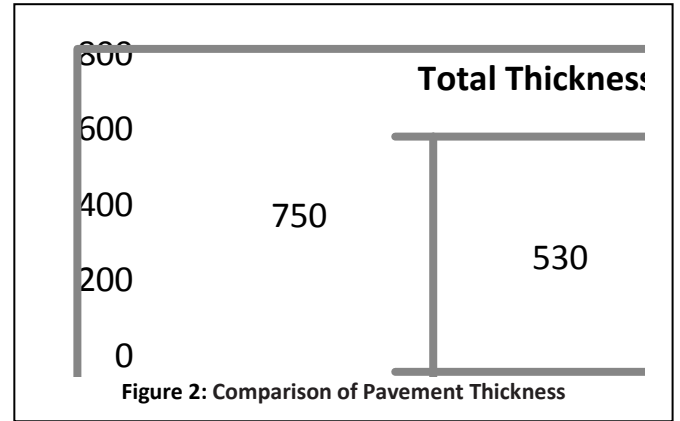
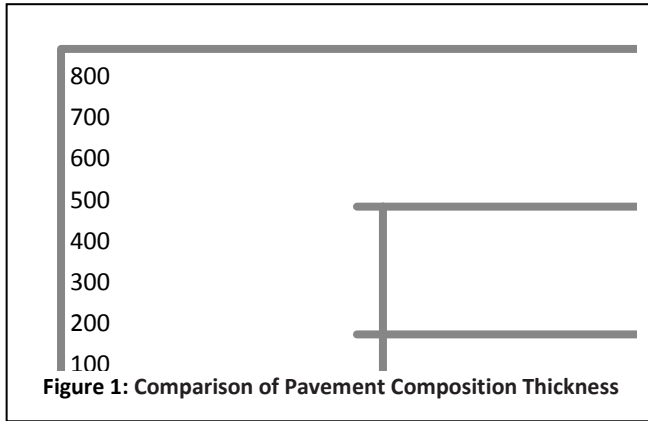


Table 3: Cost calculation for the study stretch without CONSOLID treatment

SR. No	CRUST LAYER	QUANTITY (METER)			TOTAL QUANTITY	RATE (Rs.)	TOTAL COST (Rs.)
		LENGTH	WIDTH	HEIGHT			
1.	GSB-I	1000	7.0	0.230	1610 m3	721.03	11,60,858.00
2.	GSB-II	1000	7.0	0.150	1050 m3	714.77	7,50,509.00
3.	WMM	1000	7.0	0.100	700 m3	783.81	5,48,667.00
4.	WBM-I	1000	7.0	0.150	1050 m3	1218.38	12,79,299.00
5.	DBM	1000	7.0	0.080	560 m3	1957.88	10,96,413.00
6.	SDBC	1000	7.0	0.040	280 m3	2562.21	7,17,418.80
7.	PRIME COAT	1000	7.0	----	7000 m2	31.53	2,20,710.00
8.	QUARRY SPALL	-----			319 m3	387.00	1,23,453.00
					TOTAL COST (Rs.)		58,97,327.00

Table 4: Cost calculation for the study stretch with CONSOLID treatment

SR. No	CRUST LAYER	QUANTITY (METER)			TOTAL QUANTITY	RATE (Rs.)	TOTAL COST (Rs.)
		LENGTH	WIDTH	HEIGHT			
1.	GSB-I	1000	7.0	0.150	1050 m3	721.03	7,57,081.50
2.	GSB-II	1000	7.0	0.050	350 m3	714.77	2,50,169.50
3.	WMM	1000	7.0	0.100	700 m3	783.81	5,48,667.00
4.	WBM-I	1000	7.0	0.150	1050 m3	1218.38	12,79,299.00
5.	DBM	1000	7.0	0.040	280 m3	1957.88	5,48,206.40
6.	SDBC	1000	7.0	0.040	280 m3	2562.21	7,17,418.80
7.	PRIME COAT	1000	7.0	----	7000 m2	31.53	2,20,710.00
8.	1.75% SOLIDRY (KG)	1000	8.0	0.080	640 m3	212.80	1,36,192.00
	1.75% CONSOLID444 (Lt.)	1000	8.0	0.120	960 m3	448.00	4,30,080.00
9.	QUARRY SPALL	-----			319 m3	387.00	1,23,453.00
					TOTAL COST (Rs.)		50,11,277.00

VII. CONCLUSION

1. The Liquid limit of the black cotton soil treated with Consolid444 and Solidry was found decreased by addition of Consolid444 and Solidry but, in case of plastic limit, it's increasing by addition of Consolid444 and Solidry.
2. The Plasticity index and Free Swell Index of the black cotton soil treated with Consolid444 and Solidry was found decreased with the increased percentage of Consolid444 and Solidry.
3. The Moisture content of the black cotton soil treated with Consolid444 and Solidry was found decreased with the increased percentage of Consolid444 and Solidry.
4. The Dry density was found increased by addition of Consolid444 and Solidry @ 1.75 % and further addition of Consolid444 and Solidry does not show any change in Dry density.
5. The soaked CBR value of the Black cotton soil, Consolid444@1.75% and Solidry @ 1.75% are 2.64, 9.53 and 19.986 are respectively. Result also shows that the soaked CBR is about 100% to 150% more than the Unsoaked CBR.
6. Design the road pavement treated with 1.75% of Solidry which having 19.986 % CBR respectively found that reduction in Granular sub-base (GSB) layer by 47.36% and reduction in Dense bituminous macadam (DBM) by 50.00 % on untreated Black cotton soil.
7. Design the road pavement on treated Black cotton soil with CONSOLID system, pavement thickness reduces by 20.89% to the pavement design on untreated Black cotton soil.
8. The cost of the road pavement on treated Black cotton soil with CONSOLID system reduced by 15.03 % to the original cost of untreated black cotton soil.

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