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Durability Test of soft soils stabilized with cement and lime waste

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ABSTRACT

Saurashtra is the western part of the Gujarat state. It is linked with the capital city by only national highway-8A. All 11 districts of the Saurashtra are linked by state highways, district roads, and rural or village roads.[1] The major soft soils of this region are black cotton soils, red soils, and saline sands. The existence of expansive soils, red soils, and saline soils are causing big issues for the sub-grades of these roads. With the increase in vehicles on the roads, repeated wheel loads are also increasing. If sub-grades are not stabilized perfectly, the cyclic loading will harmful to both pavements and sub-grades. Indian Roads Congress recommends using the locally available materials including sub-grade soils and the stabilizing materials.[2] This paper is focused on the durability test of stabilized soils of the Saurashtra area using locally available stabilizing agents like cement waste and lime waste. Twelve cycles of wetting and drying process on samples of stabilized soils were performed. Also, the percentage of weight losses of the stabilized soil samples was determined after every cycle. Unconfined compressive strength test in normal state and after twelve cycles of wetting and drying state gives comparative results. Reduction in UCS value was 37% in cement waste stabilized black cotton soil, 9.6% in lime waste stabilized red soil and 5% in cement & lime waste stabilized saline sand. Weight loss in these three soils was observed at 1.55%, 1.15%, and 1.44% respectively. Indian roads congress and Indian standards recommendation are favourable to the tested soils.

Keywords: Black cotton soil, red soil, saline soil, the durability of soils, unconfined compressive strength, cement waste, lime waste.

1. INTRODUCTION

The entire region of Saurashtra is rich in black cotton soil under the earth. This black cotton soil, as we know, has a unique characteristic. Due to the presence of a mineral named montmorillonite, its nature is never trustworthy. Three-layered matrices with Si-O-Al in it, the soil has a very weak formation of bonds allowing water to enter in the layers. This process causes the overdose of water in black cotton soil, resulting in swelling of soil. On the contrary, in dry conditions, when layers of soil have no water, huge cracks are developed and shrinking of soil happens. The unforeseen nature of black cotton soil under dry and wet conditions is not reliable for civil works[3].

Also, in some parts of Saurashtra, where mostly rainfall history recorded is poor, red soil is abundantly available. Surendranagar and Morbi districts are the parts having red soils under the earth. If we talk about the attribute of the red soil, it is less clayey, sandier, red tint based by colour. Moisture retention capacity of red soil is weak due to these qualities of soil. Civil works on this soil may prove improper due to the porous structure of red soil[4].

Moreover, nature has a gifted long coastal strip of around 470 km to the Saurashtra region. As the coastal area is more, salinity due to marine sand is becoming the hurdle for roads near sea beaches. Salinity, as well as zero friction property of saline sand, are the points of interrogations for the civil engineering experts[5]. Road surfaces are facing issues like honeycombing, rutting of pavements and subgrades, etc.

A study was done by the author of this paper to derive the proportion of cement waste and lime waste to stabilize these soils mentioned above[4][6]. According to this study, the following proportions (Table-01) are best suited

for achieving desired index properties. Table-02 shows the achieved index properties of these soft soils at the final proportion of stabilizers.

Table-01 Proportion of stabilizers for black cotton soil-red soil-saline sand

Sr.No.	Type of soil	Name of stabilizers	Proportion
1	Black cotton soil	Cement waste	15%
2	Red Soil	Lime waste	15%
3	Saline sand	Cement & lime waste (combined)	7.5% each

Table-02 Index properties of cement & lime stabilized black cotton soil-red soil-saline sand

Sr.No.	Property of Soil	Black cotton soil in natural state	Black cotton soil with cement waste@15%	Red soil in natural state	Red soil with lime waste@ 15%	Saline sand in natural state	Saline sand with cement waste @ 7.5% and lime waste 7.5%
01	Liquid Limit (%)	59.79	34.60	36.50	30.20	--	--
02	Plastic Limit(%)	36.80	25.80	12.50	25.50	--	--
03	Max Dry Density (gm/cc)	1.449	1.760	01.59	01.85	01.49	1.770
04	Optimum moisture content (%)	14.50	17.40	10.00	17.00	14.00	18.30
05	Cohesion Value(gm/sqcm)	0.885	1.425	01.30	04.20	0	0
06	Angle of friction (“)	19.00	23.15	21.00	27.50	20.00	30.00
07	Un soaked CBR(%)	05.00	78.00	14.00	82.00	11.00	93.00
08	Soaked CBR(%)	00.45	07.30	01.30	07.50	01.00	08.50
09	Free swell pressure (kg/sqcm)	14.00	00.03	10.00	00.05	17.00	00.20

2. DURABILITY TEST ON STABILIZED SOILS [DRYING AND WETTING PROCESS]:

Durability test on Stabilized soils is performed to check whether stabilized soils are durable under change of dry and wet state. The test is done according to IS:4332 (Part-4) for soil-cement mixture[7]. We have also tested soil lime mixture for durability on the same line of action. The main purpose of the test is to check the stabilized soils for durability criteria. This test is alternatively known as the “Wetting and drying” test. One more procedure of durability test is the “Freezing and Thawing” test but keeping the average hot climate condition of the Saurashtra region, wetting and drying test is adopted. This test broadly determines the weight loss after every cycle with a proper application of brushing and cleaning the surface after each drying cycle. For black cotton soil, three samples were made of a natural state and three samples were made adding 15% cement waste as a stabilizing agent. For red soil also three samples were made of a natural state and three samples were made using 15% of lime waste as a stabilizer. For saline sand, the samples for the natural condition are not possible due to non-plastic behavior but saline sand with cement waste and lime waste each 7.5% of the weight of saline sand. Optimum moisture content was used to mix water quantity in the sample.

Figure:1 Wetting and drying process of samples

Figure:2 Samples of Black cotton soil in natural state and stabilized state

Figure:3 Samples of black cotton soils after twelfth cycle of drying

Figure:4 Samples of stabilized red soil under process of wetting and drying

Figure:5 Samples of stabilized saline sand under the process of wetting and drying

In the durability test, the samples are prepared in a square size of 10x10x10cm. The volume of the sample is kept 1000 ml. Wetting of samples is done for 5 hours in normal water. And drying is done by oven maintain temperature of 110 degrees for 24 hours. After every drying cycle, the samples are brushed upside down from all the sides of samples and check for the weight for loss if any. The residual unconfined compressive strength test is also carried out on the samples after completion of twelve cycles of drying and wetting. The results are compared with the unconfined compressive strength in the normal condition of the soil samples[8][9].

3. RESULT AND DISCUSSION

The durability test is done using stabilizers for the soft soils of Saurashtra. Black cotton soil, red soil, and saline sand are blended with cement waste and/or lime waste as per the proportions given in table-01. Index properties were already derived in early research study as shown in table-02. It can be seen that the change in properties of all these three soils is favouring the civil works and its requirements. All the properties are positively behaving after modification with stabilizing agents. But the issue can be raised whether the stabilized soils are durable for a long time or not. To make sure of the durability of the stabilized soils, we have performed the durability test of the soil as suggested by the Indian standard code. The results obtained after twelve cycles of drying and wetting process are satisfactory. Brushing was applied as suggested by IS code, after every cycle of the drying process to calculate the loss in weight at the end of each cycle. Finally, weight loss in samples was observed to be 1.55%, 1.15%, and 1.44% respectively for black cotton soil, red soil, and saline sand. Residual UCS and Normal UCS tests are also compared. Black cotton soil lost 37% strength after the test. Red soil was strong enough but lost 9.6% strength. And saline sand has a loss of 5% only after the durability test. In Table- 3, 4 & 5 observations of weight loss after each cycle are shown. Table-6 is a comparison of the UCS test in normal condition and residual condition after twelve cycles of wetting and drying. Figure-06, 07 & 08 are the graphical representation of the weight loss in gram per cycle of test. The secondary axis represents the percentage loss after every cycle. Figure-09 reflects the changes in UCS test reading before and after the durability test.

Table-03 Durability test of cement waste stabilized black cotton soil

Durability Wetting and Drying Test (According to IS-4332 (Part-4)								
Material Description : Cement Waste Stabilized Black cotton Soil Stabilizer (by weight) 15% of weight of BC Soil								
Sample-1			**Sample-2**			**Sample-3**		
Initial Wt.(gm)	**1936**		Initial Wt.(gm)	**1942**		Initial Wt.(gm)	**1903**	
Cycle No	**Weight loss after each cycle**	**%Loss**	**Cycle No**	**Weight loss after each cycle**	**%Loss**	**Cycle No**	**Weight loss after each cycle**	**%Loss**
1	1928	0.41	1	1936	0.31	1	1898	0.26
2	1926	0.52	2	1935	0.36	2	1896	0.36
3	1923	0.67	3	1934	0.41	3	1895	0.41
4	1921	0.77	4	1932	0.52	4	1893	0.52
5	1920	0.83	5	1930	0.62	5	1890	0.67
6	1918	0.93	6	1928	0.72	6	1888	0.77
7	1915	1.08	7	1927	0.77	7	1885	0.93
8	1913	1.19	8	1925	0.88	8	1882	1.08
9	1910	1.34	9	1923	0.98	9	1879	1.24
10	1908	1.45	10	1921	1.08	10	1877	1.34
11	1906	1.55	11	1919	1.19	11	1874	1.50
12	1903	1.70	12	1917	1.29	12	1871	1.65

Average percentage loss in weight of sample= 1.55%

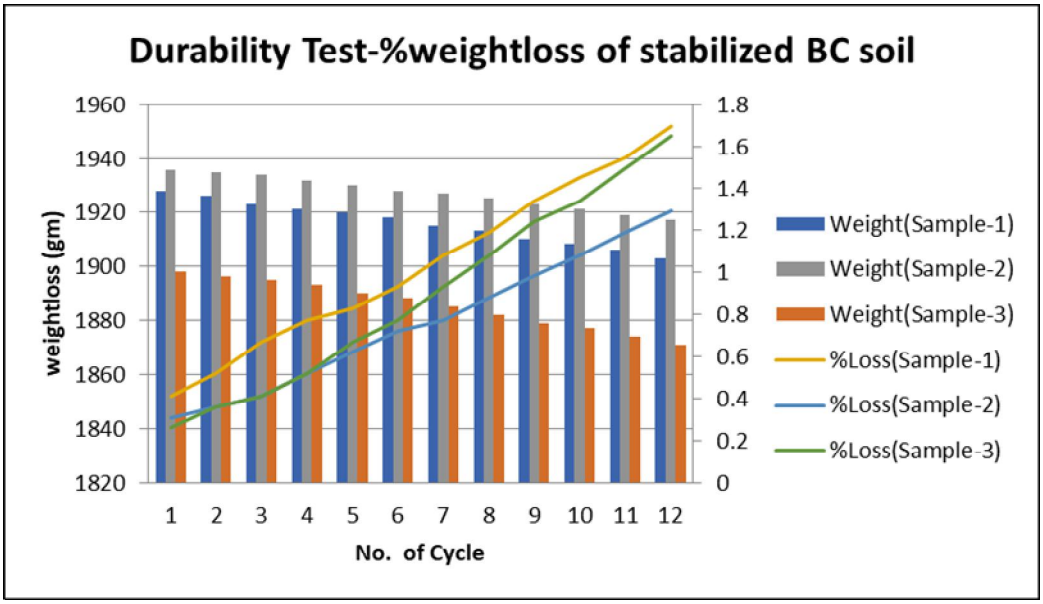

Figure-06 Graphical representation of weight loss after each cycle of drying and wetting

Table-04 Durability test of cement waste stabilized black cotton soil

Durability Wetting and Drying Test (According to IS-4332 (Part-4)								
Material Description: Lime Waste Stabilized Red Soil Stabilizer (by weight) 15% of the weight of Red Soil								
Sample-1			**Sample-2**			**Sample-3**		
Initial Wt. (gm)	**1966**		Initial Wt. (gm)	**1958**		Initial Wt. (gm)	**1982**	
Cycle No	**Weight loss after each cycle**	**%Loss**	**Cycle No**	**Weight loss after each cycle**	**%Loss**	**Cycle No**	**Weight loss after each cycle**	**%Loss**
1	1964	0.10	1	1957	0.05	1	1980	0.102
2	1962	0.20	2	1955	0.15	2	1978	0.203
3	1961	0.25	3	1953	0.25	3	1977	0.254
4	1960	0.31	4	1952	0.31	4	1975	0.356
5	1958	0.41	5	1950	0.41	5	1974	0.407
6	1956	0.51	6	1948	0.51	6	1972	0.509
7	1955	0.56	7	1946	0.61	7	1970	0.610
8	1953	0.66	8	1945	0.66	8	1967	0.763
9	1951	0.76	9	1942	0.81	9	1965	0.865
10	1950	0.81	10	1939	0.97	10	1963	0.966
11	1949	0.86	11	1935	1.17	11	1961	1.068
12	1947	0.97	12	1933	1.27	12	1958	1.221

Average percentage loss in weight of sample= 1.15%

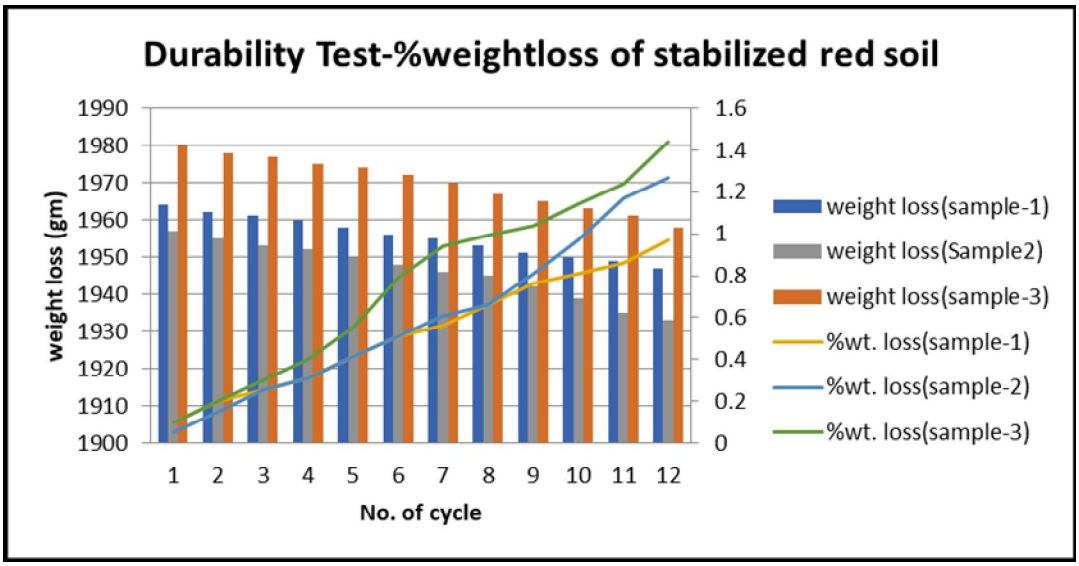

Figure-07 Graphical representation of weight loss after each cycle of drying and wetting

Table-05 Durability test of cement and lime waste stabilized saline sand

Durability Wetting and Drying Test (According to IS-4332 (Part-4)								
Material Description: Cement + Lime Waste Stabilized Saline Sand Stabilizer (by weight) 15% of the weight of Saline Sand								
Sample-1			**Sample-2**			**Sample-3**		
Initial Wt. (gm)	**2018**		Initial Wt. (gm)	**1997**		Initial Wt. (gm)	**1993**	
Cycle No	**Weight loss after each cycle**	**%Loss**	**Cycle No**	**Weight loss after each cycle**	**%Loss**	**Cycle No**	**Weight loss after each cycle**	**%Loss**
1	2017	0.05	1	1994	0.15	1	1991	0.10
2	2015	0.15	2	1992	0.25	2	1989	0.20
3	2014	0.20	3	1990	0.35	3	1987	0.30
4	2012	0.30	4	1988	0.45	4	1985	0.40
5	2010	0.40	5	1985	0.59	5	1982	0.55
6	2008	0.50	6	1982	0.74	6	1977	0.79
7	2006	0.59	7	1980	0.84	7	1974	0.94
8	2003	0.74	8	1978	0.94	8	1973	0.99
9	2000	0.89	9	1975	1.09	9	1972	1.04
10	1996	1.09	10	1972	1.24	10	1970	1.14
11	1994	1.19	11	1969	1.39	11	1968	1.24
12	1992	1.29	12	1965	1.59	12	1964	1.44

Average percentage loss in weight of sample= 1.44%

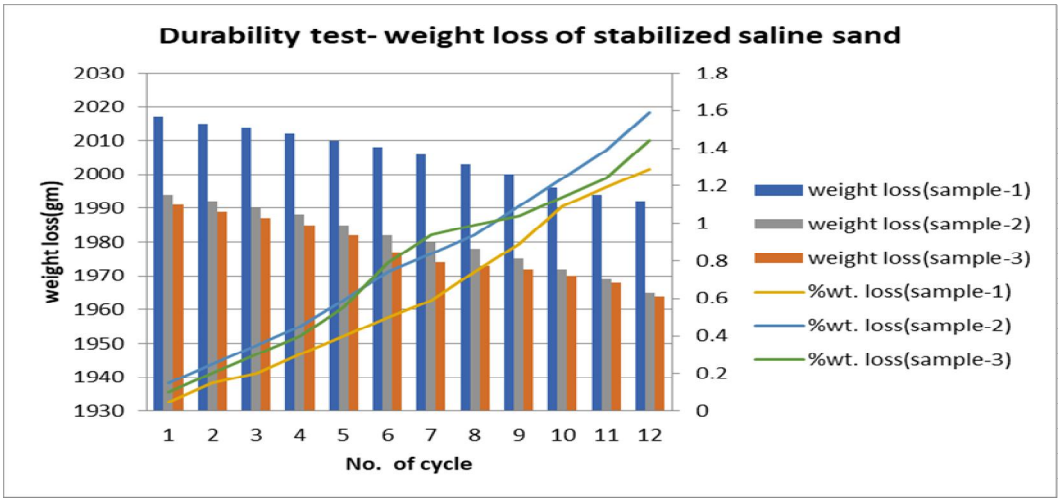

Figure-08 Graphical representation of weight loss after each cycle of drying and wetting

Table: 06 Unconfined compressive strength test for soils

Sr No.	Type of Specimen	Residual Compressive Strength (N/mm^2)	Actual Compressive strength in normal condition (N/mm^2)
1	Black cotton soil treated with cement waste	11.0	17.48
2	Red Soil treated with Lime waste	16.5	18.25
3	Saline Sand with cement and lime waste	19.0	20.0

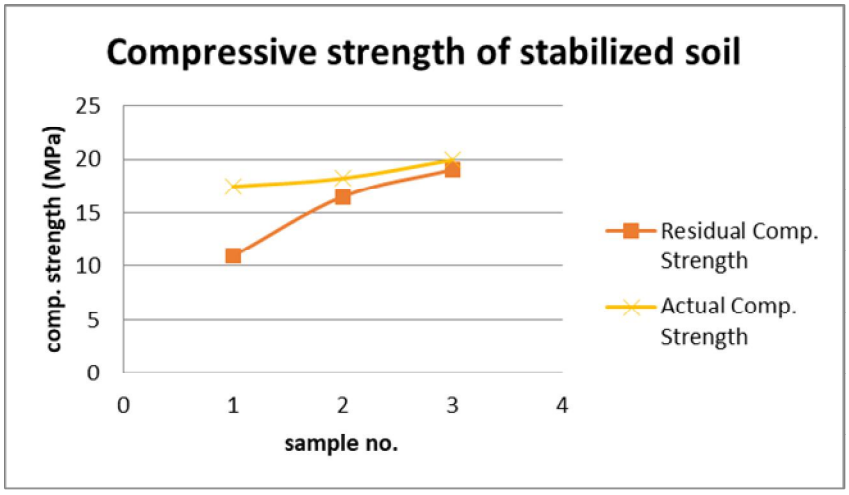

Figure-09 UCS comparison for stabilized soil after the durability test

3.1 Discussion on the obtained results:

The durability test of stabilized soils using drying and wetting of soil samples gives a positive response to the use of stabilizing agents. This test gives the actual result of the performance of the soils under cycles of wet and dry situations. Black cotton soil crumbles after 3 cycles and could not retain the shape in alternate drying and wetting process and loses the shape as well as volume. But at the same time, stabilized black cotton soil with cement waste has very good resistance against drying and wetting even after 6 cycles. And further, the samples are still in good condition of shape and volume. There is not much impact of weight loss on brushing every cycle. The weight of the first sample is reduced from 1928 gms to 1903 gms. And after 12 cycles average weight loss in black cotton soil is 1.55%. Stabilized black cotton soil samples are observed to be tough enough due to cement-soil interaction in the presence of water. The hydration process reduces voids and the dense solid mix is obtained. In red soil also samples without stabilizing agents cannot sustain after two cycles and crumble in powder. But stabilized red soil with lime waste has an excellent result in the drying and wetting process. No effect was observed on samples after 8 cycles and further can sustain even more cycles without losing even weight. The average weight loss in stabilized red soil is 1.15%. Weight loss is 1957 gm to 1933 gm for samples of red soil. When brushing is applied, weight loss in red soil is observed at less than 2 gms. Lime and red soil mixers are absorbing water and a very stuff consistence mix is produced. In lime waste CaO content is 40.24% and the required CaO in pure lime is 56.2%.[3] This lime waste will slowly improves hardness in the red soil as the conversion of Cao to carbon dioxide will be slow. This rate of hardness will retain the water content in the red soil for long and so strength will be gained more. This characteristic of lime waste provides durability to red soil for long

time[10].While in saline soil, it is not possible to prepare samples of saline soils in natural state being non-plastic behavior of sand. But saline sand stabilized with cement and lime waste becomes solid stone to resist the drying and wetting action on it. After 7 cycles, shape and volume of the samples are intake. And can stood firm in further action of drying and wetting. Weight loss (average 1.44%) is also not much affect to the samples as it is very less in percentage. Cement waste content with lime waste content makes hardening process fast and durability is achieved after hardening of samples. Overall, all stabilized soils are showing best durability in this procedure of drying and wetting.

After twelve cycles of durability test, the residual samples are tested for unconfined compressive strength tests. The readings taken are compared with the UCS results of normal samples of soil. There is a loss of 37% strength in stabilized black cotton soil. Similarly, loss of strength in red soil and saline sand is 9.45% and 5% respectively. Black cotton soil loses much after 12 cycles. This is due to swelling/cracking phenomena in wet and dry conditions. The stabilizer-cement waste- is though does well to reduce loss in strength of black cotton soil. Red soil with lime waste is very much insistent to survive the strength even after 12 cycles. Weight loss in the durability test is 1.15% which supports reasonable loss (9.45%) in the residual strength. Saline sand mixer with cement waste and lime waste is very stubborn and act like a stone. Only 5% lost in strength is because of salinity criteria of sand. Even though, saline sand is providing many fruitful results when stabilized**.**

4. CONCLUSION

The durability test of the stabilized soils using cement waste & lime waste separately or jointly proves to be satisfactory under all codal provisions. Weight loss after drying and wetting process in all the soils are merely below limits. If the black cotton soil, red soil, and saline sand of Saurashtra are stabilized as per the guidelines, they are much durable under any moisture change. The study concludes the following results to use them in the practice of pavement works.

1. Weight loss in cement waste stabilized black cotton soil after 12 cycles of drying and wetting	1.54%
2. Weight loss in lime waste stabilized red soil after 12 cycles of drying and wetting	1.15%
3. Weight loss in cement & lime waste stabilized saline sand after 12 cycles of drying and wetting	1.44%

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