Effect Of Lime and Road Building International Grade 81 On Geotechnical Properties Of Black Cotton Soil

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Abstract: Urban areas of the Bardoli in Surat district nowadays experience a considerable development because of a constantly increasing demography, from where its extension towards virgin zones often less favorable than those already urbanized. This Bardoli is located in a zone where deep black clayey soil is available. This study presents and analyzes the results of a series of Atterberg's limit tests, Proctor compaction tests, California bearing ratio tests and Unconfined Compressive Strength tests performed on Black cotton soil treated with mixture of various Lime and Road Building International (RBI) Grade 81 contents and compacted under the optimum Proctor conditions. These test results show that the geotechnical parameters values are concordant and confirm the bearing capacity improvement of this natural clay, which is translated by a significant increase in soil strength. However, the best performances are obtained for a mix treatment corresponding to 6% Lime and 5% RBI Grade 81 contents. Using 6% Lime we can save up to 25% & using 5% RBI Grade 81 we can save up to 18% pavement cost.

Keywords: RBI Grade 81, Lime, Black Cotton Soil, Atterberg's limit, Proctor Compaction, CBR, UCS, Flexible pavement.

1. Introduction

Black cotton soils usually have the potential to demonstrate undesirable geotechnical properties, such as low bearing capacity, high compressibility, shrinkage and swell characteristics and high moisture susceptibility. Several methods have been adopted to improve the geotechnical properties of such soils so that the stability and serviceability requirements can be met. Among these methods, stabilization of the black cotton soils using different additives can basically be considered, because the replacement of the unsuitable soil with good quality soils becomes more and more uneconomical and non-ecological practice. In addition, cement stabilization is nowadays not preferable because of the increasing cost of cement and the environmental concerns related to its production.

In Bardoli, black cotton soils cover around 42 km^2 of the country. In many places in Bardoli, these black cotton soils caused severe damage to infrastructures. In view of this, the need to improve these soils is necessary. Urban areas of the Bardoli in Surat district nowadays experience a considerable development because of a constantly increasing demography, from where its extension towards virgin zones often less favorable than those already urbanized. This Bardoli is located in a zone where deep black clayey soil is available.

Lime is the oldest traditional stabilizer used for soil stabilization (Mallela et al., 2004). Many significant geotechnical properties of clayey soils can be beneficially modified by lime treatment, as lime decreases the plasticity index (PI), increases the workability, shrinkage limit, strength and California bearing ratio (CBR) as well as eliminates almost all swelling problems (Rogers and Glendinning, 1996; Sakr et al., 2009). Lime stabilization refers to the stabilization of soil by the addition of burnt limestone products, either calcium oxide, CaO, or calcium hydroxide, Ca(OH)2. Quick lime is the most frequently used lime product for lime stabilization in Europe (Bell, 1989). Extensive studies have been carried out on the stabilization of clayey soils using lime (Bell,1996; Kassim and Chern, 2004; Rao and Shivananda, 2005; Sakr et al., 2009; Ghobadi et al., 2014). Bell (1996) indicated that the optimum addition of lime needed for maximum modification of the soil is normally between 1% and 3% lime by weight, and further addition of lime does not bring changes in the plastic limit (PL), but increases the strength. However, other studies reported the use of lime between 2% and 8% in soil stabilization (Basma and Tuncer, 1991). When lime is added to clayey soils in the presence of water, a number of reactions will occur, leading to the improvement of soil properties. These reactions include cation exchange, flocculation, carbonation and pozzolanic reaction. The cation exchange takes place between the cations associated with the surfaces of the clay particles and calcium cations of the lime. The effect of cation exchange and attraction causes clay particles to become close to each other, forming flocs; this process is called flocculation. Flocculation is primarily responsible for the modification of the engineering properties of expansive clayey soils when treated with lime (Ghobadi et al., 2014). Soil stabilization occurs when substances with inherent binder characteristics to improve the engineering characteristics of unstable soils are added. In the process of stabilization, cementitious material (aggregations) are formed, and this has also been associated with increased hydraulic conductivity (Al-Rawas 2002). Various ashes seem to have the capacity for soil stabilization (Mymrin and Ponte 2005). Portland cement, hydraulic lime, bitumen, and industrial by-products such as blast furnace slag, fly ash, rice husk ash (RHA), and cement kiln dust (CKD) have been used as soil stabilizers (Akbulut and Arasan 2010). Lime mortar, which can be produced using a traditional kiln at a low cost, is compatible with stone and ancient brickwork and would likely be a better stabilizer of expansive soils than cement (Rao et al. 2011).

1.1 Objective Of Study

- The objective of this study is to investigate the influence of Lime and RBI Grade 81 on some geotechnical properties of Black Cotton soils. The study is of particular importance not only for Bardoli but also for other areas of similar geology.
- Cost effectiveness of flexible pavement on stabilized and unstabilized Black Cotton Soil.

1.2 Scope Of Study

- Stabilized agents are used up to 7% (Lime) & 6% (RBI Grade 81) to alter the three dimensional of the clay materials.
- Consistency, compaction, CBR & UCS properties have particularly been investigated.

2. Experimental Investigation

(A) Material Used

2.1 RBI GRADE81 (Road Building International Grade81)

RBI Grade 81 is an odorless light brown powder that is composed of a number of naturally occurring compounds. The pH of saturated paste is 12.5. It improves the structural properties of a wide range of soils. It is particularly effective with silty-clayey soil with low geo-mechanical qualities. RBI Grade 81 works by hydration reaction. Pore space is filled by a crystalline growth. Through the addition of low dosages of RBI Grade 81 the volume stability of the soil is increased significantly. The reaction of RBI Grade 81 with soil particles produces as an inter-particle matrix that binds soil particles together into a rigid mass.

Fig.1 RBI Grade 81
Source: Collected from Alchemist, New Delhi

2.2 Lime

Commercially available hydrated lime contains 62% of effective calcium oxide and magnesium oxide was used in the investigation.

2.3 Soil

The soil used in this study was collected in disturbed state by manual excavation at a depth of 0.5m from Mota Road, Umrakh, Bardoli, Dist.Surat in Gujarat state. This soil is

classified as inorganic Clay of high compressibility (CH) according to the Indian Standard Classification System.

Fig.2 Map of studied area with a satellite view

(B) TEST RESULT

Results are discussed under four categories. (1) Properties of black cotton soil (2) Properties of black cotton soil after addition of LIME (3) Properties of black cotton soil after addition of RBI Grade-81.

Table 1 Properties of Black Cotton Soil

Sr. No.	Laboratory Test		Result	Relevant IS Codes
1	Grain Size Distribution			IS 2720 Part IV
		Gravel	0.00%	
		Sand	8.60%	
		Silt	21.40%	
		Clay	70.00%	
2	Liquid Limit (W_L)		65.93%	IS 2720 Part V
3	Plastic Limit (W_P)		22.10%	IS 2720 Part V
4	Plasticity Index (P.I)		43.83%	IS 2720 Part V
5	Free Swell Index (F.S.I)		72.72%	IS 2720 Part XL
6	Optimum Moisture Content (O.M.C.)		20.21%	IS 2720 Part VIII
7	Maximum Dry Density (M.D.D.)		1.48 gm/cc	IS 2720 Part VIII
8	California Bearing Ratio (C.B.R.)			IS 2720 Part XVI
		4 days Soaked	1.90%	
		4 days Soaked &7days curing	2.20%	
		4 days Soaked & 28days curing	2.40%	
9	Unconfined Compressive Strength (UCS)		120 kN/m^2	IS 2720 Part X

2.4 Addition of Lime

Black Cotton soil was treated with 0 to 7% Lime and cured for 7 days, 14 days and 28 days to study its effect on consistency limits, compaction characteristics, CBR & UCS value.

Effect of Lime on Consistency Limit

Liquid limit and Plastic limit of the soil mixed with varying percentage of Lime are given in Table 2. Study of Atterberg's limits indicates that LL and PI reduces with increasing percentage of Lime. It is observed that plastic limit of Lime mixed soil increases with the increasing proportion comparatively substantial improvement in PL observed with Lime dosage up to 4% but thereafter improvement is reduced.

Table 2 Variation of LL, PL & PI under varying % of Lime

% of Lime	LL (%)	PL (%)	PI (%)
0%	65.93	22.10	43.84
2%	63.10	24.20	38.90
3%	61.50	26.11	35.39
4%	59.25	27.92	31.33
5%	58.10	28.70	29.40
6%	57.60	28.95	28.65
7%	56.20	29.50	26.70

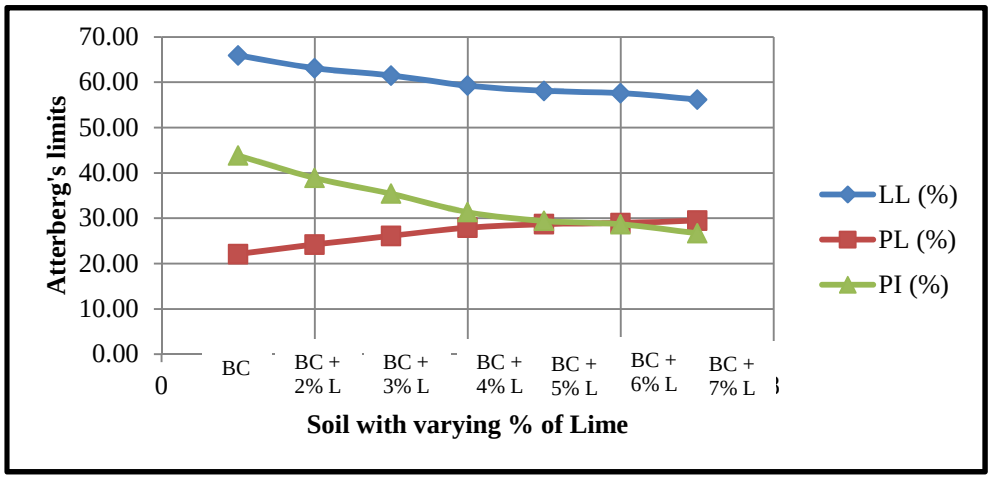

Fig.3 Variation of LL, PL & PI under varying % Lime

Effect of Lime on Compaction Characteristics

Modified proctor compaction tests were performed on the lime mixed soil samples. Fig.4 shows the effect of Lime stabilizer on compaction characteristics of the black cotton soil. As the dosage of lime increased from 0% to 7%, the optimum moisture content increased gradually from 20.21% to 23.50% and maximum dry density decreased marginally from 1.48g/cc to 1.39g/cc. The reason for increase in water content may be attributed to flocculation of particles requiring more water to coat the particles. The results of modified proctor test are indicated in Table 3.

Table 3 Variation of compaction characteristic under varying % of Lime

% of Lime	Optimum Moisture Content (%)	Maximum Dry Density(g/cc)
0%	20.21	1.48
2%	21.20	1.47
3%	23.10	1.46
4%	24.77	1.42
5%	25.10	1.40
6%	25.80	1.39
7%	23.50	1.41

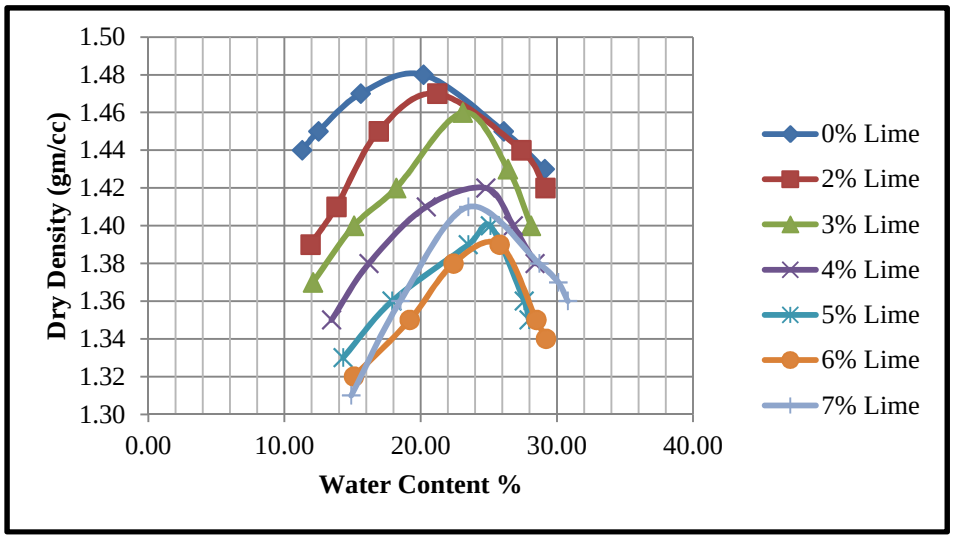

Fig.4 Variation of LL, PL & PI under varying % Lime

Effect of Lime on CBR

Three identical specimens were prepared as per IS 2720-PART XVI for each curing period (7 days, 28 days) , soaked for 4 days and tested for CBR. The results are tabulated in Table 4.

Table 4 Variation of CBR value under varying % of Lime

% Lime	CBR % Soaked (4 days)		
	0 days curing	7 days curing	28 days curing
0%	1.90	2.20	2.40
2%	3.20	3.78	4.20
3%	5.40	6.40	7.25
4%	6.50	7.80	8.90
5%	7.60	9.15	10.46
6%	11.40	13.80	15.95
7%	10.15	11.95	13.40

From Table 4, it is observed that untreated soil exhibits CBR of 1.90%. Upon treatment with Lime, there is an increase in CBR value. As the dosage of Lime increased from 0% to 7%, for specimens soaked & cured for 0 days CBR increased from 1.90% to 10.15%, Upon further curing up to 28 days, an overall increase ranging from 26.32% to 32.02% in CBR was observed. This indicates that increase in percentage of Lime and curing period results in improvements in CBR Value of the treated specimens.

From Fig.6, it is observed that for the curing period 0 to 7 days, maximum increase of CBR is 21% for 6% lime replacement and for the curing period 7 to 28 days, maximum increase of CBR is 16% for 6% lime replacement.

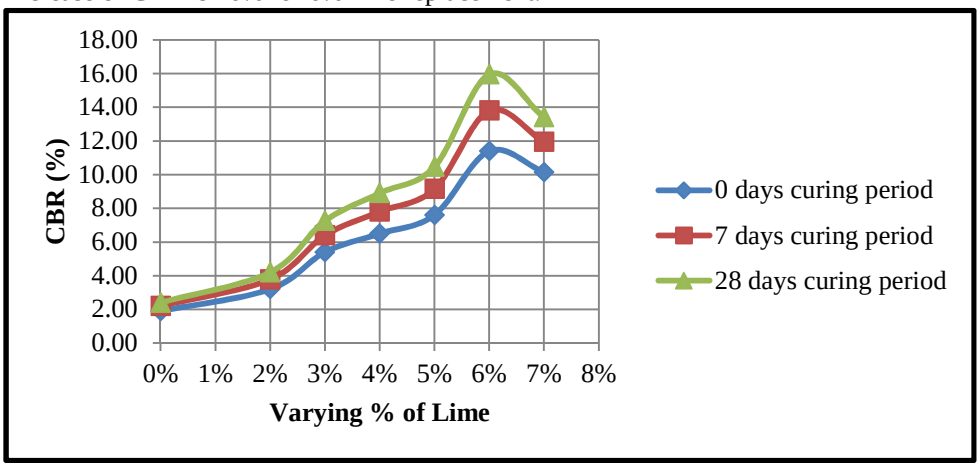

Fig.5 Effect of Lime and curing periods on CBR value

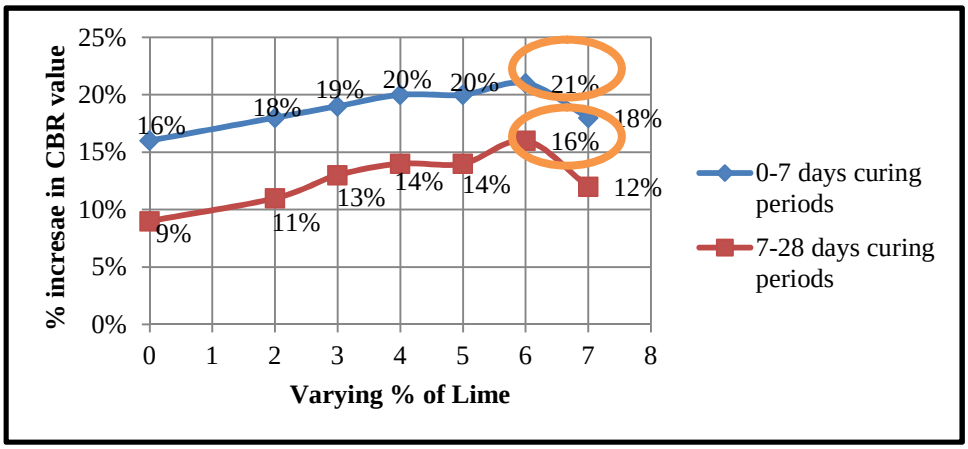

Fig.6 Variation of % increase in CBR with curing periods

Effect of Lime on UCS

The UCS value increase was low at 2% of lime content and the increase was more after 2% of stabilizer content. It was found that the increase in UCS values at 7 days curing for 2 to 6% were around 160, 205, 230, 280, 385, 396 kN/m^2. From the tests conducted on the soil, it was observed that the UCS value of treated soil increases with the increase in curing period, however the increase is marginal for the curing periods under study (Fig.7). The increase in UCS for 7-14 days & 14-28 days curing period from lime dosage of 0 to 6% was found around 19%, 20%, 21%, 20%, 21%, 19% and 16%, 15%, 17%, 16%, 17%, 15% respectively. Maximum increase in UCS value is 38% for the lime dosage 6% and then value decreases. This shows that the soil strength increases with the increase in lime content up to 6%. Similar trend was observed in 14days & 28days curing.

Table 5 Variation of CBR value under varying % of Lime

% Lime	UCS (kN/m^2)		
	7 days curing	14 days curing	28 days curing
0%		120	
2%	160	190	220
3%	205	245	282
4%	230	278	324
5%	280	335	388
6%	385	465	545
7%	396	470	540

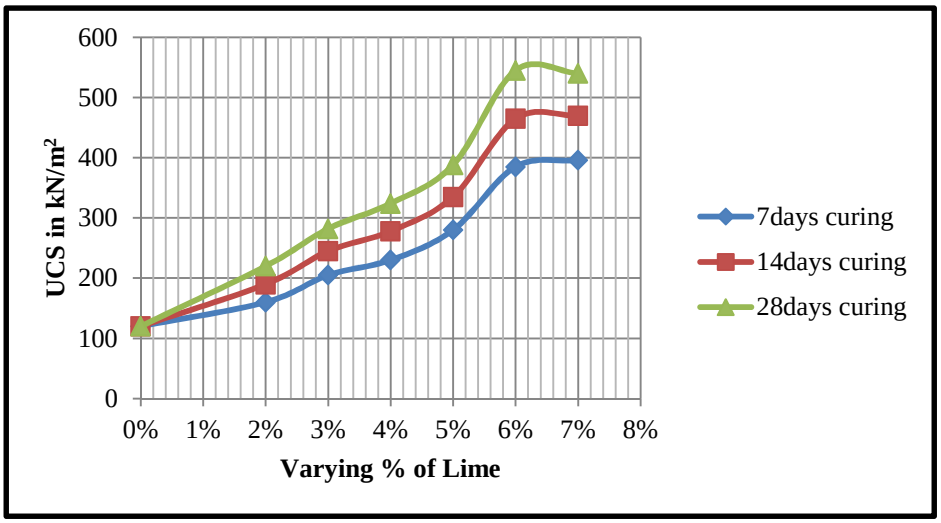

Fig.7 Effect of Lime and curing periods on UCS value

2.5 Addition of RBI Grade 81

Black Cotton soil was treated with 0 to 6% RBI Grade 81 and cured for 7 days, 14 days and 28 days to study its effect on consistency limits, compaction characteristics, CBR & UCS value.

Table 6 Properties of black cotton soil with varying % of RBI Grade 81

Type Of Soil	LL (%)	PL (%)	PI (%)	OMC (%)	MDD (gm/cc)	CBR (%) Soaked (4 days)			UCS (kN/m^2)		
						0 days curing	7 days curing	28 days curing	7 days curing	14 days curing	28 days curing
Soil	65.93	22.10	43.83	20.21	1.48	1.90	2.20	2.40	120	-	-
Soil + 2% R	64.10	23.40	40.70	23.10	1.47	5.20	6.40	7.10	230	270	310
Soil + 3% R	61.75	25.90	35.85	25.70	1.46	8.60	10.30	11.60	270	318	368
Soil + 4% R	58.10	27.10	31.00	27.90	1.43	12.50	15.10	17.15	320	385	442
Soil + 5% R	57.40	28.30	29.10	29.40	1.42	19.40	23.60	27.10	415	502	550
Soil + 6% R	55.10	30.10	25.00	30.10	1.40	18.30	22.20	24.70	460	520	565

2.6 Optimum dosage of Lime & RBI Grade 81

Table 7 % increase comparison of CBR value under varying % of Lime

	Curing Days after 4 days soaking period	0% Lime	2% Lime	3% Lime	4% Lime	5% Lime	6% Lime	7% Lime
	0.00	1.90	3.20	5.40	6.50	7.60	11.40	10.15
	7.00	2.20	3.78	6.40	7.80	9.15	13.80	11.95
	28.00	2.40	4.20	7.25	8.90	10.46	15.95	13.40
% increase up to 7 days		16	18	19	20	20	**21**	18
% increase 7- 28 days		9	11	13	14	14	**16**	12

From Table 7, it is observed that CBR value is increased up to 7 days & 28 days of curing after soaking periods of 4 days as the lime is varied from 0% to 7%. Percentage increase in CBR value up to 7 days is more compare to 7 to 28 days. Maximum increase in CBR value is 21% & 16% in 6% lime for 7 days & 28 days curing respectively. Optimum percentage of Lime is decided 6% .

Table 8 % increase comparison of CBR value under varying % of RBI Grade 81

	Curing Days after 4 days soaking period	0% R	2% R	3% R	4% R	5% R	6% R
	0.00	1.90	5.20	8.60	12.50	19.40	18.30
	7.00	2.20	6.20	10.30	15.10	23.60	22.20
	28.00	2.40	6.95	11.60	17.15	27.10	24.70
% increase up to 7 days		16	19	20	21	**22**	21
% increase 7- 28 days		9	12	13	14	**15**	11

From Table 8, it is observed that CBR value is increased up to 7 days & 28 days of curing after soaking periods of 4 days as the RBI Grade 81 is varied from 0% to 6%. Percentage increase in CBR value up to 7 days is more compare to 7 to 28 days. Maximum increase in CBR value is 22% & 15% in 5% RBI Grade 81 for 7 days & 28 days curing respectively. Optimum percentage of RBI Grade 81 is decided 5% .

3. Conclusion

Based on the experimental investigation on effect of Lime and RBI Grade-81 on black cotton soil, the following conclusions are drawn:

1) Addition of 0% to 7% Lime to the soil resulted reduction in plasticity index. However, the reduction in plasticity characteristics was marginal between 5% and 7% of Lime.
2) Upon addition of Lime (0% to 7%), the CBR increased from 1.9% to 10.15% for 0 days curing, 2.20% to 11.95% for 7 days curing and 2.40% to 13.40% for 28 days curing. Maximum increase in CBR value is 21% & 16% with 6% lime for 7 days & 28 days curing respectively. Thus Optimum percentage of Lime is decided 6% .
3) Unconfined compressive strength increased from 120kN/m^2 to 396kN/m^2, 470kN/m^2 and 540kN/m^2 for specimens cured for 7days 14days and 28 days respectively. Maximum increase in UCS value is 38% for the lime dosage 6% and then value decreases. This shows that the soil strength increases with the increase in lime content up to 6%. Similar trend was observed in 14days & 28days curing. The increase in strength for the treated soil can be as a result of formation of cementitious materials.
4) Addition of 0% to 6% RBI Grade 81 to the soil resulted reduction in plasticity index.
5) OMC increases and MDD decreases with addition of RBI Grade 81. MDD is decreasing with addition of RBI Grade 81 but there is increase in soaked CBR value with increased the addition of RBI Grade 81. So strength does not decrease with decrease in MDD.
6) Upon addition of RBI Grade 81 (0% to 6%), the CBR increased from 1.9% to 18.30% for 0 days curing, 2.20% to 22.20% for 7 days curing and 2.40% to 24.70% for 28 days curing. For the curing period 0 to 7 days, maximum increase of CBR is 22% for 5% RBI Grade 81 replacement and for the curing period 7 to 28 days, maximum increase of CBR is 15% for 5% RBI Grade 81 replacement. Optimum percentage of RBI Grade 81 is decided 5%.
7) The increase in UCS for 7-14 days & 14-28 days curing period with RBI Grade 81 dosage of 0 to 6% was found around 17%, 18%, 20%, 21%, 13% and 15%, 16%, 15%, 10%, 9% respectively. Maximum increase in UCS value is 21% for the RBI Grade 81 with 5% dosage. This shows that the soil strength increases with the increase in RBI Grade 81 up to 5% . Similar trend was observed in 14-28 days curing.
8) Using 6% Lime we can save up to 25% & using 5% RBI Grade 81 we can save up to 18% pavement cost.

4. References

1) Ahmed Naseem A. K., Dr. R. M. Damgir & S. L. Hake. (2014) "Effect of RBI Grade-81 and Fly ash on BC soil used as a sub grade for flexible pavements". International Journal of Innovations in Engineering and Technology (IJIET), ISSN: 2319-1058, Vol. 4.

2) Akbulut, S., and Arasan, S. (2010). “The variations of cation exchange capacity, pH, and zeta potential in expansive soils treated by additives.” Int. J. Civ. Struct. Eng., 1(2), 139–154.
3) Al-Rawas, A. (2002). “Microfabric and mineralogical studies on the stabilization of an expansive soil using cement bypass dust and some types of slags.” Can. Geotech. J., 39(5), 1150–1167.
4) Anitha.K.R, R.Ashalatha, ArveeSujil & Johnson, "Effects of RBI Grade 81 on different types of sub grade soil", 10th National Conference on Technological Trends, Nov 2009.
5) Basma AA, Tuncer ER. Effect of lime on volume change and compressibility of expansive clays. Transportation Research Record 1991;1296:54e61.
6) Bell F. G (1996), "Lime Stabilization of Clay Minerals and Soils", Engineering Geology, 42, pp. 223-237.
7) B.M.Patil & K.A.Patil, "Improvement in properties of Sub grade Soil by Using Moorum and RBI Grade 81", International Journal of Scientific & Engineering Research, ISSN 2229-5518, Vol- 4, Issue- 5, May 2013.
8) Ghobadi MH, Abdilor Y, Babazadeh R. Stabilization of clay soils using lime and effect of pH variations on shear strength parameters. Bulletin of Engineering Geology and the Environment 2014;73(2):611e9.
9) Mallela J, Harold Von Quintus P, Smith KL. Consideration of lime-stabilized layers in mechanistic-empirical pavement design. Arlington, Virginia, USA: The National Lime Association; 2004.
10) Mamta & Mallikarjun.Honna, "Using RBI Grade 81 a Comparative Study of Black Cotton Soil and Lateritic Soil", International Journal of Research in Engineering and Technology, eISSN: 2319-1163, pISSN: 2321-7308, Vol- 03, Special Issue: 03, May-2014.
11) Mymrin, V. A., and Ponte, H. A. (2005). “Oil shale fly ash utilization as independent binder of natural clay soil for road and airfield base construction.” Part. Sci. Technol., 23(1), 99–107
12) Rao SM, Shivananda P. Compressibility behavior of lime-stabilized clay. Geotechnical and Geological Engineering 2005;23:309e19.
13) Rogers C, Glendinning S. Modification of clay soils using lime. Ground Engineering. London, UK: Thomas Telford Limited; 1996. p. 99e114.
14) Sakr MA, Shahin MA, Metwally YM. Utilization of lime for stabilization soft clay soil of high organic content. Geotechnical and Geological Engineering 2009;27:105e13.