Economics of Stabilizing Bentonite Soil with Lime-Gypsum

N. K. Ameta

Associate Professor, M. B. M. Engineering College, J. N. V. University, Jodhpur, Rajasthan, India

D.G.M. Purohit

Professor, M. B. M. Engineering College, J. N. V. University, Jodhpur, Rajasthan, India

Wayal A.S.

Research Scholar, M. B. M. Engineering College, J. N. V. University, Jodhpur, Rajasthan, India

Dangda Sandeep

P.G.Student, M. B. M. Engineering College, J. N. V. University, Jodhpur, Rajasthan, India

ABSTRACT

For solving problems of expansive soil it is necessary to stabilize it with any of additive substance such as lime, gypsum etc. After stabilization soil properties are altered such as bearing capacity, shear strength and stability of soil which are increased and the shrinkage, swelling are decreased. While planning for treatment of expansive soils with chemical additives, it must be kept in mind that how much addition of additive would be economical to get higher strength and to get higher reduction in plasticity. It is necessary to keep the cost of treatment as much as low without compromising with the strength. In present investigations locally available lime and gypsum of commercial grade has been used for studying the effect of lime and gypsum mixture on the plasticity and swelling properties of bentonite soil .It is found that addition of 2% lime and 4% gypsum is more economical in reducing plasticity and swelling as compared to the other mixes under study.

KEYWORDS: Bentonite, Lime, gypsum, swelling pressure, plasticity index, economics.

INTRODUCTION

General

The expansive soils, which are spread over extensive areas of India in states, like Rajasthan, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka and Tamilnadu posed serious problems for buildings and roads. In our country the typical example of expansive soils are black cotton soil, bentonite, mar and kabar.

Bentonite is a highly expansive soil. It exhibits a tendency of swelling on coming in contact with water and shrinks on removal of water which may result in structural damage to engineering construction. In case of bentonite, free swelling is up to ten times to fifteen times to its original volume.

Since expansive soils have a tendency to change their volume to a large extent, they cause heavy distress to engineering constructions. The lightweight structures are severely affected due to high swelling pressure exerted by these soils. Such type of large scale distress, due to expansive shrinking nature of expansive soil, can be prevented by either obstructing the soil movement and reducing the swelling pressure of soil or making the structure sufficiently resistant to damage from soil movement.

Limestone belts are spread in 26 districts. Rajasthan has about 7,000 million tonnes of all grades of limestone. It is the third largest producer of limestone in the country. The districts with large deposits of limestone are Ajmer, Banswara, Bundi, Pali, Sirohi, Chittaurgarh, Jaisalmer, Jodhpur, Nagaur, Sawai Madhopur and Udaipur districts. Rajasthan contributes 95 per cent of the country's gypsum production. Gypsum is widely distributed throughout the northeastern part of the state, particularly in the districts of Bikaner, Ganganagar, Nagaur, Churu, Barmer, Jaisalmer and Pali . The locally available materials lime and gypsum are used for investigations.

As a result of extensive research work carried out in India and abroad on stabilization of soil with lime and gypsum, it has been established that all soils do not respond favorable to lime-gypsum treatment. Only reactive soils respond favorably to lime-gypsum treatment to form chemical compounds of well-developed crystalline structures under suitable sets of conditions.

SCOPE OF PRESENT INVESTIGATION

The swelling nature of bentonite is due to the presence of imbalance electrical charge and cation exchange capacity produced by sodium based montmorillonite. Replacing the sodium ions by inorganic compounds, which may produce such type of cation having less ion exchange capacity and also form a balanced electrical charge in soil structure, therefore, can reduce its swelling nature. Replacement of monovalent sodium by calcium ions may leads to a marked reduction in diffuse double layer thickness leading to decrease in liquid limit, plastics limits and swelling pressure. Keeping this aspect in view, an attempt has been made to study the alteration brought out by lime and gypsum mixture. Therefore, tests have been conducted on bentonite soil, obtained from Barmer-District (Rajasthan), mixed with different percentage of lime and gypsum to study the effects of lime and gypsum mixture swelling pressure, differential free swell, and consistency limits of bentonite soil.

Tests to determine liquid limit, plastic limit, shrinkage limit, swelling pressure and differential free swell have been performed with soil added with different percentages .The cost analysis for different combinations of mixtures is done and presented at later stage of the paper.

MATERIALS USED

The properties of materials used for investigations are determined as listed in Table 1.

Table 1: Physical properties of bentonite soil sample

1.	Natural moisture content	11.81%

2.	Activity	3.88
3.	Color	Light Brown
4.	Specific gravity	2.29
5.	Percentage of Clay (< 0.002 mm)	70.0 %
6.	Percentage of Slit (0.002 – 0.075)	24.5 %
7.	Liquid Limit	326 %
8.	Plastic Limit	54.22 %
9.	Shrinkage Limit	1.809 %
10.	Plasticity Index	271.78 %
11.	IS Classification of Soil	CH
12.	Maximum Dry Density	1.166 g/cm3
13.	Optimum Moisture Content	46.70 %
14.	Degree of expansion	Very High

Table 2: Chemical composition of the bentonite soil

S.No.	Constituents	Percentage
1.	Silica SiO_2	55.8 %
2.	Alumina Al_2O_3	19.63 %
3.	Ferric oxide Fe_2O_3	5.98 %
4.	Titanium oxide TiO_2	1.72 %
5.	Calcium oxide CaO	0.61 %
6.	Magnesium oxide MgO	2.63 %
7.	Alkalis K_2O & Na_2O	3.36 %
8.	Loss of ignition	9.61 %

Table 3: Chemical composition of Lime

S.No.	Constituents	Percentage
1.	$Ca(OH)_2$	90 %
2.	Silica	1.5 %
3.	Ferric oxide	0.5 %
4.	Magnesium oxide MgO	1 %
5.	Alumina	0.2 %
6.	CO2	3 %
7.	By free moisture	1 %

Table 4: Chemical composition of Gypsum

S.No.	Constituents	Percentage
1.	Silica	70.55 %
2.	Alumina	0.85 %
3.	Ferric oxide	0.47 %
4.	Sodium chloride	0.05 %
5.	CaCO3	2.47 %
6.	MgCO3	0.02 %

7.	CaO	25.59 %

RESULTS AND DISCUSSION

The various mixtures have been compared in the Table 5 along with pure lime and pure gypsum. This comparison is in percentage reduction in liquid limit, plasticity index, swelling pressure and the cost of additive material also. The market rate for calculation of the cost is been taken as 25 Rs/Kg of lime and 7 Rs/Kg of gypsum. Although these rates are retail market rates but still are useful for comparison and planning for projects.

The observations of Table 5 and comparison charts Figures 1 through 5 gives the comparision of reduction in plasticity and swelling at possible lowest cost.

Table 5: Comparison of optimum lime-gypsum mixtures w.r.t. pure lime and gypsum with bentonite soil

S. No.	Mix	Liquid Limit	% Decrease in Liquid Limit	Plasticity Index	% Decrease in PI	Swelling Pr.	% Decrease in Swelling Pr.	Cost in Rs./Kg
1	6 %Lime + 0 Gypsum	180.0	44.79	102.20	62.40	2.264	15.77	150.00
2	0 % Lime + 3% Gypsum	149.0	54.29	79.90	70.60	1.627	39.47	21.00
3	8 % Lime + 2% Gypsum	154.0	52.76	76.00	72.04	1.604	40.33	214.00
4	4 % Lime + 3% Gypsum	148.5	54.45	72.20	73.44	1.839	31.58	121.00
5	6 % Lime + 3% Gypsum	136.0	58.28	47.50	82.52	1.733	35.53	171.00
6	8 % Lime + 3% Gypsum	126.0	61.35	38.10	85.98	1.568	41.67	221.00
7	2 % Lime + 4% Gypsum	129.0	60.43	35.90	86.79	1.639	39.03	78.00
8	4 % Lime + 4% Gypsum	134.5	58.74	43.10	84.14	1.651	38.58	128.00
9	6 % Lime + 4% Gypsum	124.0	61.96	31.80	88.30	1.580	41.22	178.00
10	8 % Lime + 4% Gypsum	144.0	55.83	53.00	80.50	1.721	35.97	228.00

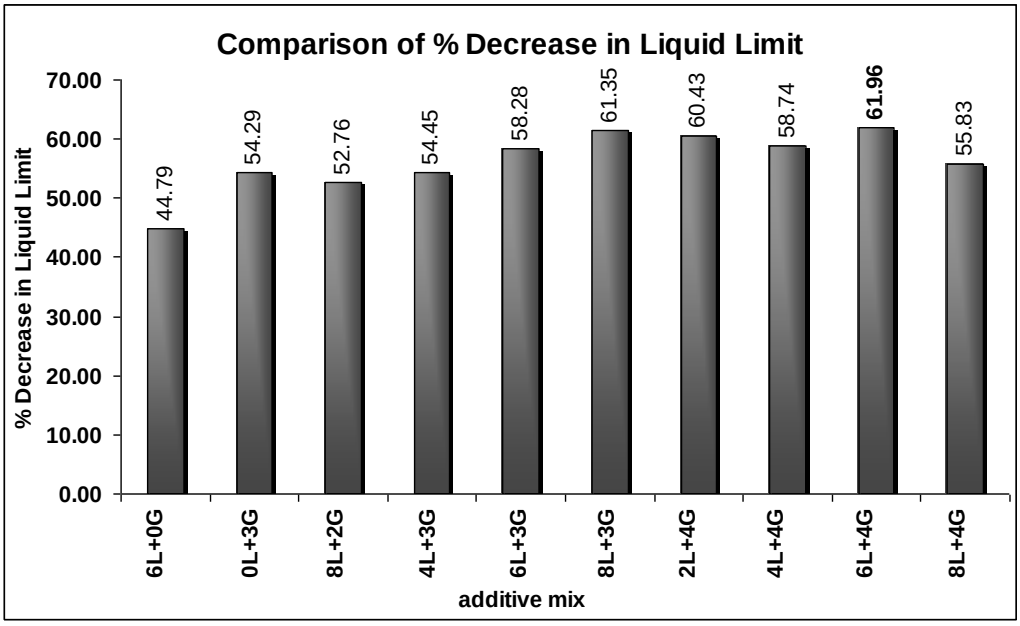

Figure 1: Comparison of % decrease in liquid limit of Bentonite soil by addition of different lime-gypsum mixture

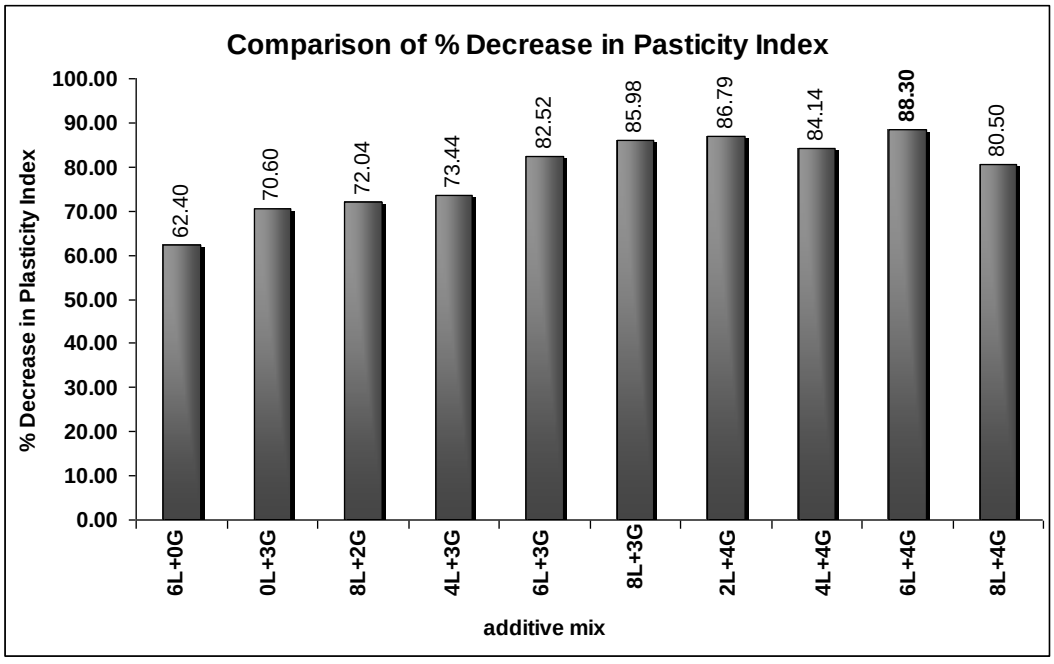

Figure 2: Comparison of % decrease in plasticity index of bentonite soil by addition of different lime-gypsum mixture

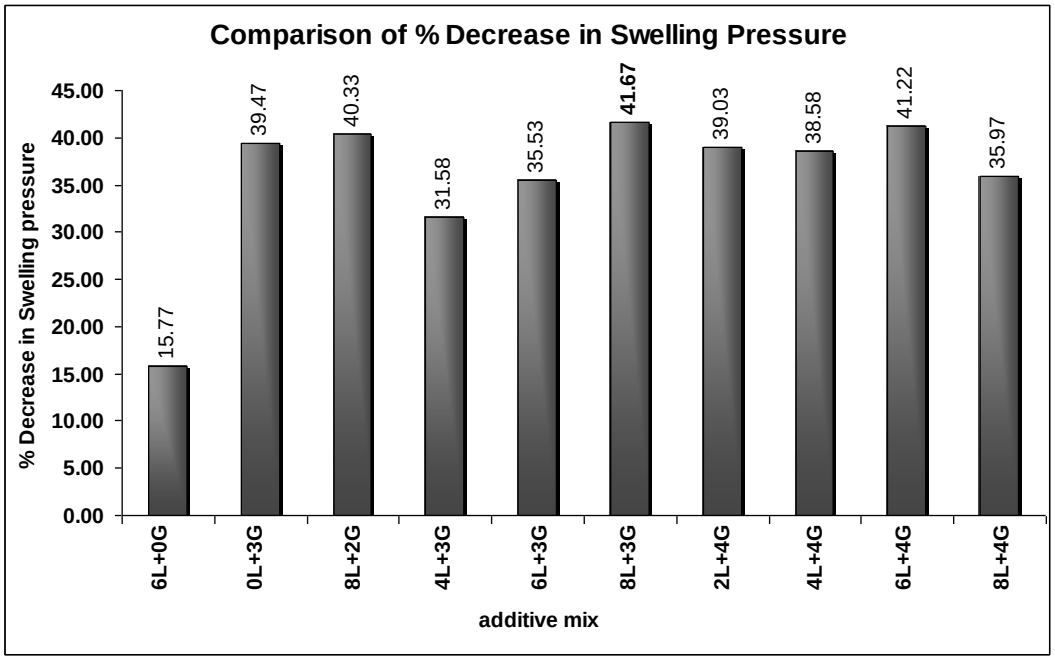

Figure 3: Comparison of % decrease in swelling pressure of bentonite soil by addition of different lime-gypsum mixture

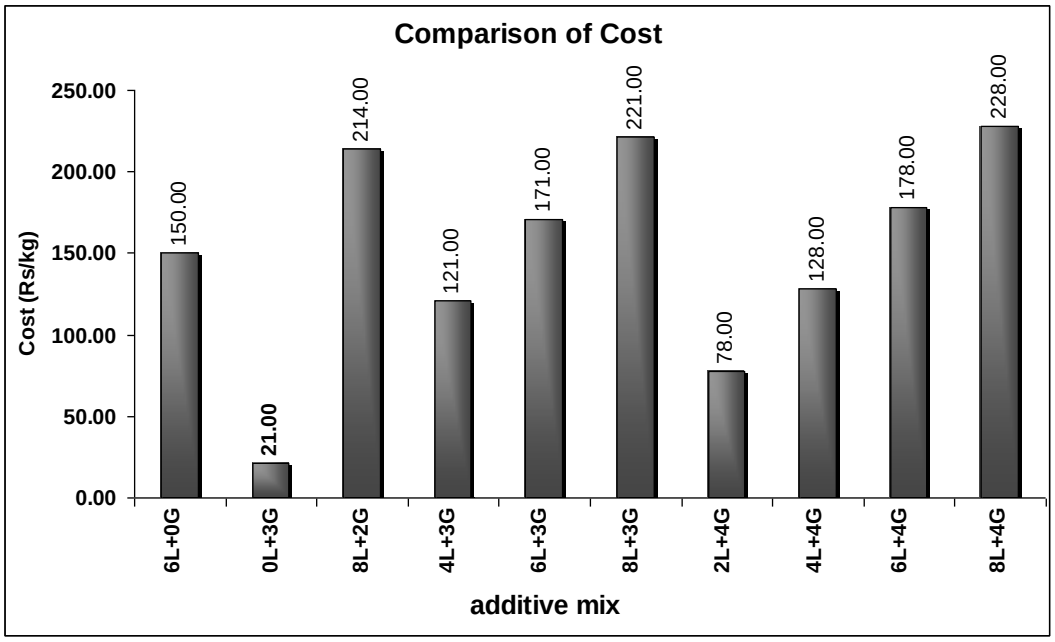

Figure 4: Comparison of cost of addition of different lime-gypsum mixture

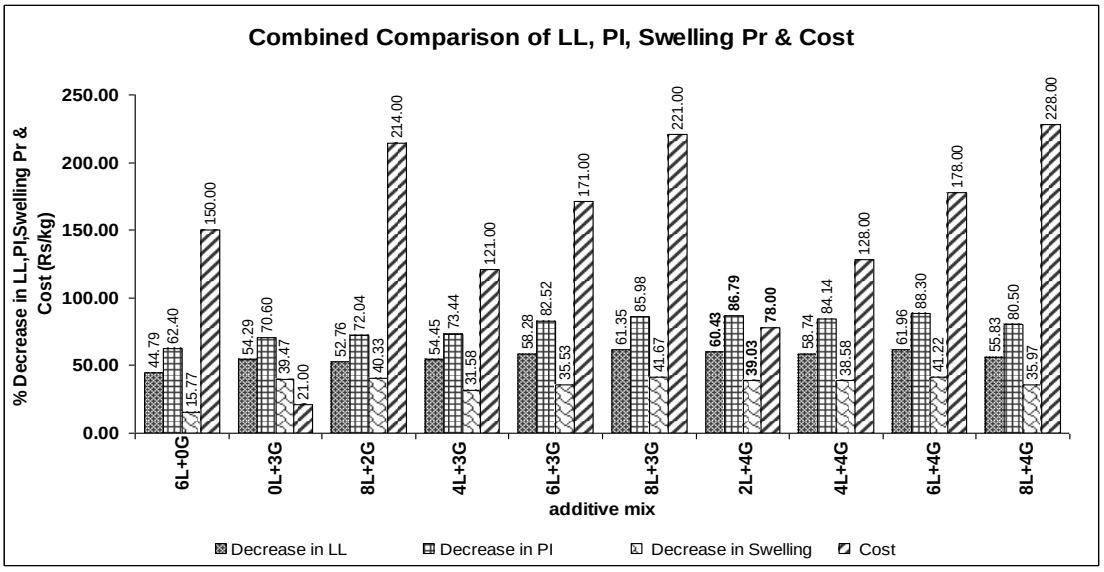

Figure 5: Combined comparison of decrease in liquid limit, plasticity index, swelling pressure and cost of additive

CONCLUSIONS

In this investigation we have used lime and gypsum in combination and in different proportions to study its effect on swelling properties of bentonite soil of Rajasthan. There is considerable decrease in plasticity and swelling of bentonite soil by adding lime-gypsum mixture. We found that following mixtures of lime-gypsum have reduced plasticity and swelling of bentonite soil:

(8% Lime + 2% Gypsum); (4% Lime + 3% Gypsum); (6% Lime + 3% Gypsum); (8% Lime + 3% Gypsum); (2% Lime + 4% Gypsum); (4% Lime + 4% Gypsum); (6% Lime + 4% Gypsum); (8% Lime + 4% Gypsum).

Also the cost analysis of different mixtures is studied and it is found that the mixture (2% Lime + 4% Gypsum) is quiet suitable for reduction in plasticity and swelling at possible lowest cost.

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