Improvement in Swelling, Strength and Deformation Characteristics of Expansive Soil using Lime and Brick Dust

G. Ramakrishna Reddy, Debjyoti Pal, A. K. Sinha, A. K. Choudhary

Abstract**: *In India concrete and rolled steel sections are used in construction activities, steel composites are often being used based on their advantages in heavy structure like multistoried structures and also in offshore structures. In this study we tried four composite structure models G+5, G+10, G+20, G+30 are considering with varying wind velocities 33,39,44,47,50,55m/s, as per IS875-part-3 and structure foundation depth is considered 2m below foundation level and the base conditions are fixed at the bottom or at the supports/footings. The structures modeled in ETABS structural analysis and design software by considering various loads and load combinations by their relative occurrence are considered the material properties considered are M30 concrete grade & FE415 reinforcing steel.***

Keywords: Composite Structures, Wind Speeds, RCC, Multistoried Structures, Varying Heights

I. INTRODUCTION

Expansive soils are generally of weak in nature in terms of bearing strength and experience excessive seasonal volume changes which are highly undesirable for infrastructure building. Various methods for prior treatment of such soils before construction have been implemented previously. This endeavor has focused on modifying undesirable properties of such soils using natural lime and waste brick dust. The main aim of this work is to find the optimum quantity of these admixtures corresponding to which unconfined compressive strength is maximum, swelling potential is minimum, settlement reduction is maximum. Finite element model of embankment has been created above the expansive soil layer using Plaxis 2D software to predict the amount of settlement which should be less than permissible limit for safe infrastructure building. The effect of mixing natural lime and waste brick dust with expansive soil in varying proportions on swelling potential, unconfined compressive strength, optimum moisture content, maximum dry density, and Atterberg's limits have been studied and presented in the paper.

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II. LITERATURE REVIEW

Nadgouda et al.[4] (2010); Studied the immediate benefit of addition of lime with soil and found that there is a considerable drop off in swelling potential upon contact with water. The plastic nature of the soil decreased and the stiffness of the soil increased as the lime content was increased. The optimum content obtained was 3.5% to 4.5% lime. These values were found to be in general agreement with work carried out by other researchers (Ranganatham, 1961, SubbaRao, et. al., 1983).

Kumar Vijay et al.[5] (2011); from Gulbarga studied and found that improvements for (35 % brick dust+5% lime) Liquid limit reduced by 26.3 % and reduction in plastic limit found to be 13%. Optimum moisture content was reduced by 7.13%. Maximum dry density increased by 18.3%. CBR increased by 200%.

Sachin N.Bhavskar et al.[4] (2014); Studied and discovered positive impact of waste brick dust on expansive soil. The maximum improvement in desired properties was achieved by replacing soil with 50% waste brick dust. Thus they concluded that this application was an eco-friendly way of disposal such waste product.

Kunal R. Pokale, Yogesh R Borker and Rahul R Jichkar[3] (2015); Studied on utilization of brick dust to improve the engineering property of expansive soil and found that water content showed reduction when samples were tested after a period of 7 and 28 days. The existing water content of 30% brick dust reduced to 26.46%. Swelling characteristics of expansive soil decreased by adding brick dust. Results obtained from unconfined compressive tests showed increased values. Hence replacement of brick dust was found to be effective.

III. MATERIALS AND METHODOLOGY

A. Materials

Expansive soil: Although very fertile, expansive soil is not suitable for road construction and foundation purpose. Expansive soils are clays which experience substantial shrinking and swelling because of varying moisture content. This abnormal behavior is mainly because of the presence of a mineral known as montmorillonite. The physical properties of expansive soil is given in table 1

Table 1: Physical properties of expansive soil

Natural water content(%)	17.37
Specific gravity	2.71
Free swell index(%)	55
Optimum moisture content(%)	16
Maximum dry density(g/cc)	1.82
Cohesion(kPa)	40
Angle of internal friction	16^0
Fines(<0.002mm) (%)	7.5
Unconfined compressive strength(kPa)	109.16
Failure strain(%)	7.46
Liquid limit(%)	55.8
Plastic limit(%)	18.4
Plasticity index(%)	37.4

Lime: Lime is the oldest traditional stabilizer used for soil stabilization. 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. Lime, which is the dominant admixture, is varied in proportions of 5, 10, 15% of total weight. The chemical composition and physical properties of lime is given in table 2

Table 2: Chemical composition and physical properties of lime

Appearance	Dry white powder
CaO (%)	>85
MgO (%)	<0.5
Fe_2O_3 (%)	<2
Al_2O_3 (%)	<1
SiO_2 (%)	<3
Na_2O (%)	0.6
CO_2 (%)	<4
$CaCO_3$ (%)	<8
Insoluble material (%)	<2
Bulk density (g/cc)	0.88

Brick dust: Brick dust waste (BDW) is a waste material from the cutting of fired clay bricks. The inclusion of this waste product improves the gradation of the resulting soil along with providing mechanical strength. In order to investigate the clay replacement potential of BDW, three types of mixes were done at varying BDW replacement by 5% of dry weight of the composite mixtures. The chemical composition and physical properties of brick dust is given in table 3

Table 3: Chemical composition and physical properties of brick dust

Alumina	30
Silica (%)	60
Lime (%)	3
Oxides of iron (%)	6
Magnesia (%)	1
Specific gravity	2.1
Water absorption (%)	20
Strength (N/mm^2)	7.5

B. Methodology

Tests on soil properties were performed as per specifications of Indian standards IS: 2720.

Following tests were performed on expansive soil.

1. Free swell index
2. Grain size distribution
3. Atterberg limits
4. IS light compaction
5. Unconfined compressive strength
6. Tri-axial test

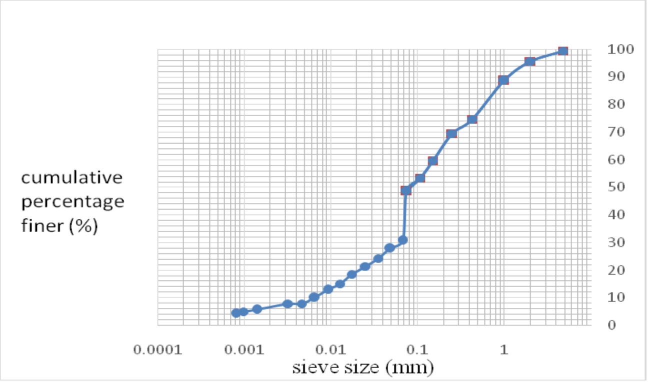

Fig. 1: Grain size distribution curve for expansive soil

Test on soil properties were performed on the following set of compositions:

1. Virgin soil, i.e. 100% soil.(soil:lime:brickdust=100:0:0)
2. 90% soil+ 5% lime+5% brick dust = (90:5:5)
3. 85% soil+ 10% lime+5% brick dust = (85:10:5)
4. 80% soil+ 15% lime+5% brick dust = (80:15:5)
5. 75% soil+15% brick dust+10% lime =(75:10:15)
6. 70% soil+15% brick dust+15% lime =(70:15:15)

These six proportions of admixtures will be named as following:

1. 0% additives.
2. 10% additives.
3. 15% additives.
4. 20% additives.
5. 25% additives.
6. 30% additives.

IV. RESULTS AND DISCUSSION

Comparison of properties treated and untreated expansive soil corresponding to optimum composition of admixture is given in table 4

Table 4: Comparison of properties of virgin and treated soil

Physical Property	Untreated soil (100:0:0)	Treated soil (80:15:5)
Free swell index (%)	55	10
Liquid limit (%)	55.8	60
Plastic limit (%)	18	46
Plasticity index (%)	37.8	14
Maximum dry density (g/cc)	1.82	1.74
Optimum moisture content (%)	15.56	17.8
Unconfined compressive strength (kPa)	110	177
Cohesion (kPa)	40	59
Angle of internal friction	16^0	20^0
Settlement (mm)	29	17.4

Various graphs have been plotted to depict the variation in soil physical properties for both treated and untreated expansive soil.

Following graphs show variation of soil physical properties corresponding to different proportions of admixtures.

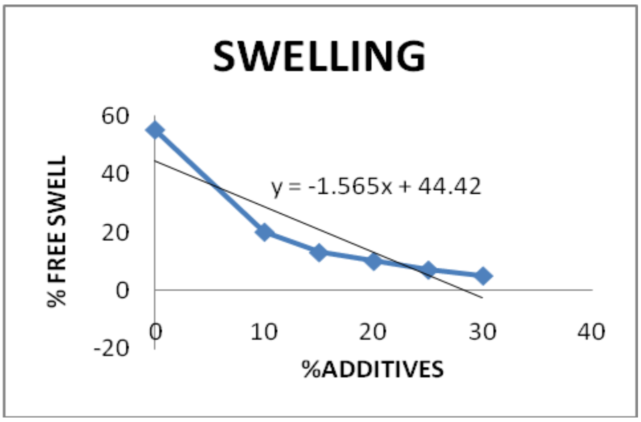

Fig. 2: Variation of percentage free swell with various proportions of admixture along with trend line.

From fig. 2 it can be said that there is a considerable reduction in swelling potential of an expansive soil. Result shows an asymptotic curve for the free swell index.

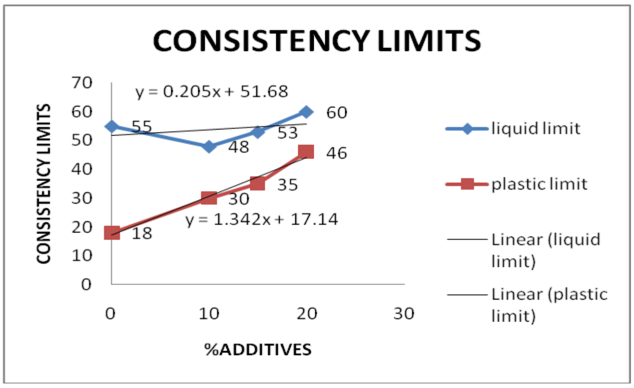

Fig. 3: Variation of consistency limits with respect to varying proportion of additives.

From fig. 3 by linear trend line it can be said that the gap between liquid limit and plastic limit is confining with the increment in percentage of additives. It can be concluded that there is a considerable reduction in plasticity index.

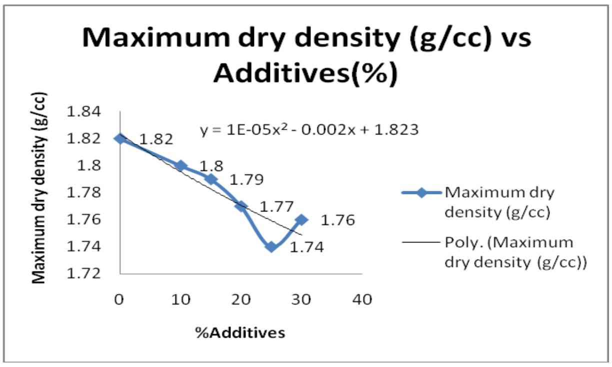

Fig. 4: Variation of maximum dry density with respect to percentage of additives along with polynomial trend line.

From the fig. 4 shown below it can be concluded that by keeping lime as a dominant factor it has been found that maximum dry density is decreasing. Polynomial trend line showing a positive sign with results showing minimum deviation.

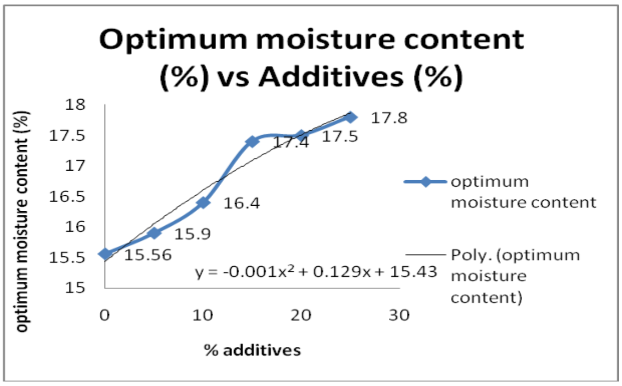

Fig. 5: Variation of optimum moisture content with respect to varying proportion of additives along with polynomial trend line.

From fig. 5 it can be seen that optimum moisture content tends to increase with a minimum deviation from a 20 polynomial trend line.

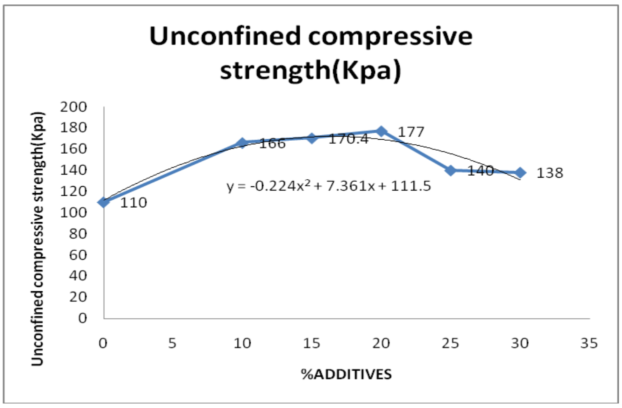

Fig. 6: Variation of unconfined compressive strength with varying proportion of additives.

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From fig. 6 it can be seen that unconfined compressive strength of a soil specimen is optimum corresponding to twenty percentage of additives. Results are in good agreement with 20 polynomial equation.

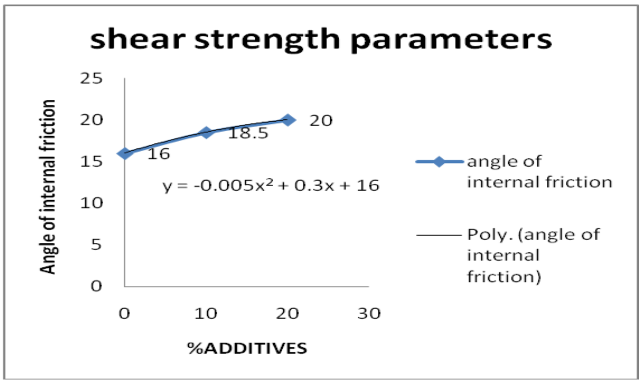

Fig. 7: Variation of cohesion corresponding to different proportion of additives.

From fig. 7 results for angle of internal friction is in good agreement with 2^0 polynomial trend line.

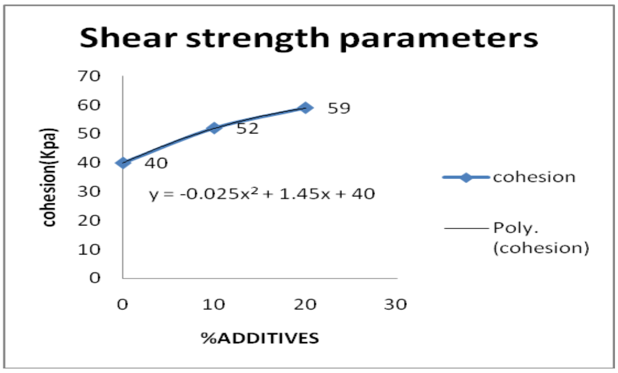

Fig. 8: Variation of Angle of internal friction

corresponding to varying proportion of additives. From fig. 8 it is clearly seen that cohesion is increasing corresponding to increment in percentage of additives.

From the above data, the physical properties of both treated and untreated soil is used in creating an expansive soil layer of unit meter thickness below embankment model in Plaxis 2D. Ultimate deformation of expansive soil for both treated and untreated soil is found and reduction in deformation of soil is observed. Expansive soil layer is created between embankment fill and sand layer which is shown in fig. 9 and 10 given below.

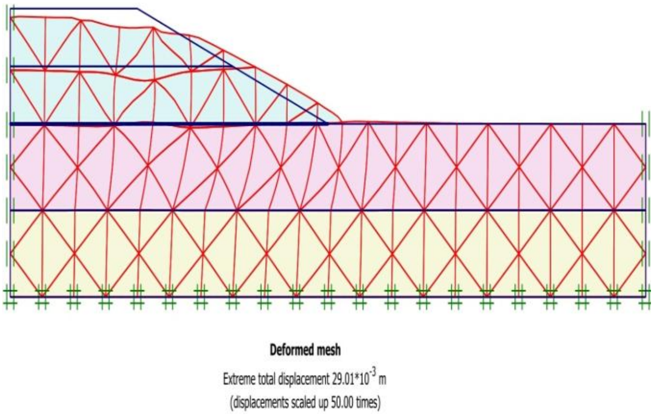

Fig. 9: Settlement of embankment model constructed using plaxis 2D for untreated expansive soil which is 29mm.

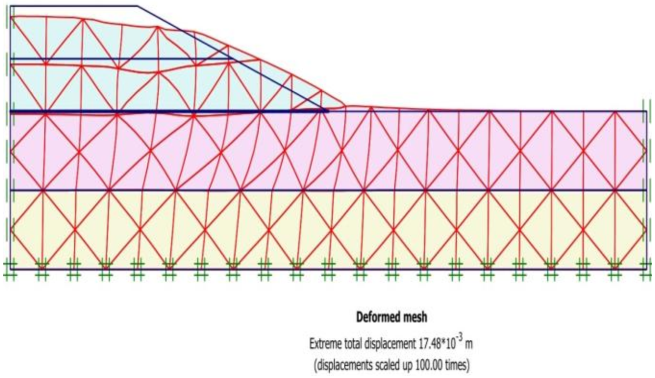

Fig. 10: Settlement of embankment model for treated expansive soil which 17mm.

V.CONCLUSION

1. In the present context, lime and brick dust have been adopted for stabilization of expansive soil with varying compositions in definite proportions out of which lime has been chosen as dominant in proportion. Differential free swell has been performed on the soil and identified an 81% reduction in swelling potential. Hence this type of stabilization can be given significant importance at places where soils are highly expansive.

2. The unconfined compressive strength of soil increases by 60.8% corresponding to 20% additives i.e., 15% lime and 5% brick dust. Corresponding to above composition, swelling was 10%.

3. If lime is kept as dominant additive it observed that both liquid and plastic limit start increasing with increment in composition. Rate of increment of plastic limit was more with respect to liquid limit finally at one point it is non plastic. In present work lime was kept as a dominant factor and found 62.2% reduction in plasticity index with respect to virgin soil.

4. A change in state of behavior of soil from plastic nature to brittle nature has been observed.

5. By consolidation analysis it has been found that 40% reduction settlement with respect to virgin soil. This is very much beneficial for infrastructure building on these expansive soils followed by proper stabilization.

6. A tri-axial test was performed and found that cohesion and angle of internal friction have been increased by 47% and 25%. Therefore it contributes towards increment in shear strength. This helps in increasing factor of safety against slope failure keeping magnitude of loading as constant.

7. By keeping lime as a dominant factor it has been found that maximum dry density is decreasing and optimum moisture content is increasing. Maximum dry density decreased by 5% and optimum moisture content increased by 12%. Here it can be noted that corresponding to 20% additives lime is the dominant factor.

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