Unconfined Compressive Strength of Bentonite-Lime-Phosphogypsum Mixture Reinforced with Sisal Fibers

Sujeet Kumar [1)*] ***and Rakesh Kumar Dutta*** [2)]

[1)] PG Student, Department of Civil Engineering, National Institute of Technology, Hamirpur – 177005, Himachal Pradesh, India. * Corresponding Author. E-Mail: sujeetkumar.ce@gmail.com
[2)] Professor, Department of Civil Engineering, National Institute of Technology, Hamirpur – 177005, Himachal Pradesh, India. E-Mail: rakeshkdutta@yahoo.com

ABSTRACT

This paper presents the effect of sisal fibers on the unconfined compressive strength of bentonite. The present study is aimed at determining the behavior of bentonite-lime-phosphogypsum reinforced with sisal fibers in a random manner. The sisal fiber content was varied from 0.5 to 2 %. The results indicated that the unconfined compressive strength of bentonite can be increased by the addition of lime, phosphogypsum and sisal fibers. The increase in unconfined compressive strength was highest with 8 % lime, 8 % phosphogypsum and 1 % sisal fibers. The reference mix reinforced with sisal fibers was able to bear higher strains at failure as compared to bentonite and bentonite- lime-phosphogypsum mixture. With the increase in sisal fiber content (0.5 to 2 %) in reference mix, there was an increase in the unconfined compressive strength. The bentonite - lime-phosphogypsum-sisal fiber mixture will boost the construction of temporary roads on such problematic soils. Further, its use will also provide environmental motivation for providing a means of consuming large quantities of phosphogypsum and natural fibers.

KEYWORDS: Bentonite, Lime, Phosphogypsum, Unconfined compressive strength, Sisal fibers.

INTRODUCTION

In India, adequate deposit of black cotton soil, bentonite, mar and kabar exists in a state like Rajasthan, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka and Tamilnadu (Ameta et al., 2007). These soils exhibit high swelling, shrinkage, compressibility and poor strength in contact with water leading to cracks in overlying temporary roads. The current practices to deal with these soils are to modify the properties with the use of some additives like lime and gypsum/phosphogypsum. To further improve the mechanical properties of these soils, a variety of materials are used as reinforcement such as metallic elements, geosynthetics and other materials. The majority of reinforcement materials available in the market are polymeric in composition. These products generally have a long life and do not undergo biological degradation, but are liable to create environmental problems from their manufacture till the end use. In the light of this, the use of biodegradable natural fibers is gaining popularity in India. In the present paper, an attempt has been made to study the unconfined compressive strength of bentonite-lime-phosphogypsum mixture reinforced with sisal fibers for possible use in ground improvement.

BACKGROUND

Reinforced soil is a composite material, where soil

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is reinforced by the elements which can take tension. The incorporation of reinforcement in the soil mass is aimed at either reducing or suppressing the tensile strain which might develop tensile stresses due to the movement of traffic on temporary roads. As such, soils possess very low tensile strength which may be significantly improved by providing reinforcement in the direction of tensile strains. Many researchers (Andersland and Khattack, 1979; Maher and Ho, 1994; Al-Wahab and El-Kedrah, 1995; Nataraj and McManis, 1997; Zeigler et al., 1998; Feuerharmel, 2000; Kumar and Tabor, 2003; Casagrande et al., 2006) in the past have shown that fiber reinforcement can significantly improve engineering properties of clay. Maher and Ho (1994) reported that the peak compressive strength of kaolinite clay increased by the inclusion of randomly distributed paper pulp fibers. Al-Wahab and El-Kedrah (1995) reported that fiber reinforcement decreased the swelling potential of low plasticity clay. Casagrande et al. (2006) reported that the inclusion of randomly distributed fibers increased the peak shear strength of bentonite. The use of sisal fibers as soil reinforcement is a cost-effective method of soil improvement in countries like India and Bangladesh, where it is cheap and locally available. Krishna and Sayida (2009) reported the improvement in unconfined compressive strength of black cotton soil with the addition of sisal fibers. Manjunath et al. (2013) studied the effect of random inclusion of sisal fibers on strength behavior of lime treated black cotton soils and reported an increase in unconfined compressive strength of lime treated expansive soil with the addition of sisal fibers and with the curing period. Priya and Girish (2010) studied the effect of sisal fibers on the compaction behaviour of lime treated black cotton soil and reported a decrease in optimum moisture content and an increase in maximum dry unit weight with the addition of sisal fibers. They further reported that addition of sisal fibers to lime treated black cotton soil increased the unconfined compressive strength and changed the behaviour from brittle to ductile. Hejazi et al. (2012) reviewed the use of natural and synthetic fibers as a construction and building material. They reported that fiber reinforcement improves the strength and stiffness of the composite soil. Addition of fibers to expansive soils improves the strength. Further, hardly any literature is available to study the effect of sisal fibers on the unconfined compressive strength of bentonite-lime-phosphogypsum mixture. The present study tries to fill this gap. In the present work, the effect of sisal fibers on the unconfined compressive strength of bentonite-lime-phosphogypsum mixture is studied. The load deformation response in various cases is plotted, compared and discussed for possible use in ground improvement.

SCOPE OF PRESENT STUDY

The geotechnical characteristics of lime-bentonite specimens, lime-bentonite-phosphogypsum and lime-phosphogypsum-bentonite specimens mixed with varying percentages of sisal fibers were studied. The content of lime and phosphogypsym was varied from 2 to 10% and 0.5 to 10% by dry weight of bentonite, respectively. Compaction and unconfined compression strength tests were conducted on test specimens. The content of sisal fibers was varied from 0.5 to 2% by dry weight of bentonite. The results obtained from these tests are presented and discussed in this paper.

MATERIALS USED AND EXPERIMENTAL PROCEDURE

Commercially available bentonite was used in this study. Physical and engineering properties of bentonite used in the current study are given in Table 1. Hydrated lime phosphogypsum and sisal fibers used in this study were procured from the local market at Hamirpur, Himachal Pradesh, India. The specific gravity of lime, phosphogypsum and sisal fibers was 2.37, 2.20 and 1.40, respectively. The other physical and engineering properties of sisal fibers are tabulated in Table 2.

The standard proctor compaction tests were conducted as per IS 2720-Part-VII (1980) on bentonite-lime and bentonite-lime phosphogypsum mixtures by varying the content of lime and gypsum from 2 to 10% and 0.5 to 8%, respectively and water was added as needed to facilitate the mixing and compaction process.

Table 1. Physical and engineering properties of bentonite

Property	Value
Specific gravity	2.30
Liquid limit	220
Plastic limit	39.74
Optimum moisture content (%)	27.98
Maximum dry density (kN/m^3)	13.95
Type	CH

Table 2. Physical and engineering properties of sisal fibers

Property	Value
Average diameter (mm)	0.25
Average length (mm)	15
Average tensile strength (N/mm^2)	405.2
Specific gravity	1.40
Density (g/cc)	1.45
Type	Natural

For the unconfined compressive strength tests, a metallic mould having 38 mm inner diameter and 76 mm length, with additional detachable collars at both ends, was used to prepare cylindrical specimens. Required quantities of bentonite, lime and phosphogypsum were mixed and water corresponding to optimum moisture content was added and the mix was placed inside the mould. To ensure uniform compaction, the specimen was compressed statically from both ends till it just reached the dimensions of the mould. Then, the specimen was extracted with the hydraulic jack and placed in air tight polythene bags which were placed inside the dessicator for curing for 3, 7, 14 and 28 days. The specimen was taken out of the dessicator and polythene bag after the desired period of curing and tested for unconfined compressive strength using a strain rate of 1.2 mm/min. The unconfined compressive strength tests were conducted as per IS 2720-Part-X (1991).

RESULT

Compaction

The dry unit weight and moisture content curves for bentonite with varying percentages of lime, bentonite + 8% lime with varying percentages of phosphogypsum and for the reference mix mixed with varying percentages of sisal fibers are shown in Fig. 1 (a), (b) and (c). The results of the compaction study are shown in Table 3. The study of Fig. 1 (a) and Table 3 reveals that the maximum dry unit weight for the bentonite was 13.95 kN/m^3, which decreased to 13.72 kN/m^3, 13.45 kN/m^3, 13.37 kN/m^3, 13.34 kN/m^3 and 13.29 kN/m^3, respectively with the addition of 2, 4, 6, 8 and 10 % lime. The decrease in dry unit weight is attributed to the fact that lime reacts quickly with bentonite resulting base exchange aggregation and flocculation which leads to an increase in the void ratio of the mixture leading to a decrease in the dry unit weight of the bentonite-lime mixture. These observations are in agreement with Kumar et al. (2007) where the effect of lime on the compaction behaviour of black cotton soil was reported. Study of Fig. 1 (a) and Table 3 further reveals that the optimum moisture content of the bentonite was 27.98% which increased to 29.88 %, 31.71 %, 31.90 %, 32.40 % and 33.20%, respectively with the addition of 2, 4, 6, 8 and 10% lime. This increase in optimum moisture content is

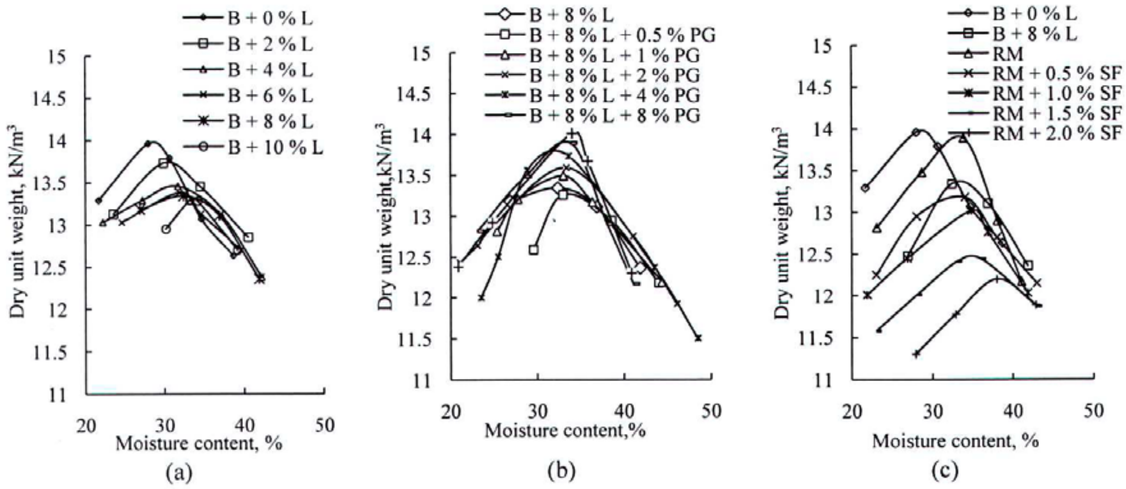

Figure (1): Compaction curves for (a) bentonite with varying percentages of lime (b) bentonite + 8% lime with varying percentages of phosphogypsum (c) bentonite + 8% lime + 8% phosphogypsum with varying percentages of sisal fibers

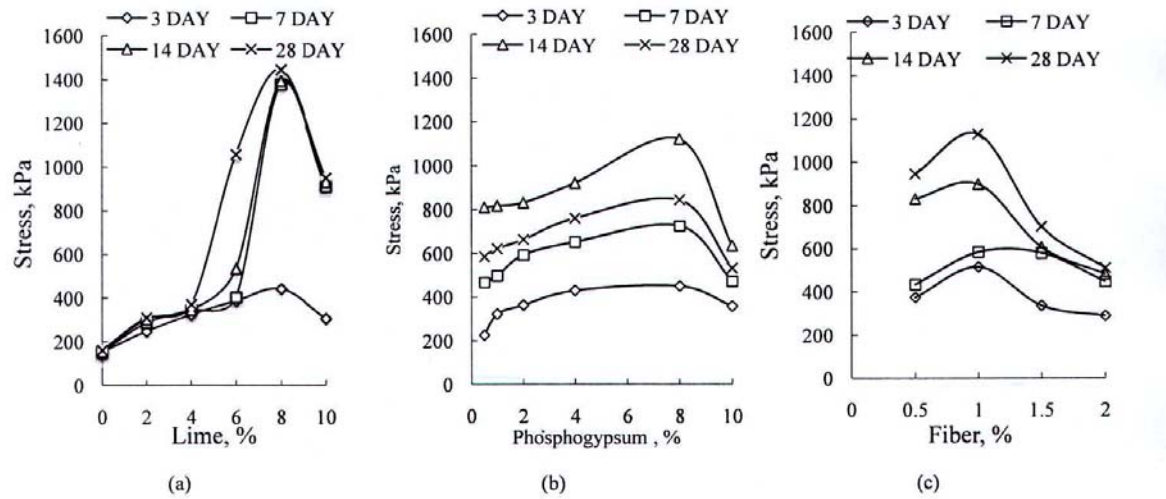

Figure (2): Variation of unconfined compressive strength of (a) bentonite with varying percentages of lime and curing periods (b) bentonite + 8% lime with varying percentages of phosphogypsum and curing periods (c) bentonite + 8 % lime + 8% phosphogypsum with varying percentages of sisal fibers and curing periods

Table 3. Compaction characteristics of bentonite –lime–phosphogypsum-sisal fiber mixtures

Mixes	MDD (kN/m^3)	OMC (%)
B	13.95	27.98
B+2 % L	13.72	29.88
B+4 % L	13.45	31.71
B+6 % L	13.37	31.9
B+8 % L	13.34	32.4
B+10 % L	13.29	33.2
B+8 %L+0.5%PG	13.25	32.98
B+8 % L+1 %PG	13.49	33.05
B+8 % L+2 %PG	13.59	33.38
B+8 % L+4 %PG	13.73	33.65
B+ 8 % L +8 % PG	13.89	33.89
B + 8 % L + 10 % PG	14.01	34.05
RM+0.5 % SF	13.18	34.02
RM+1 % SF	13.02	34.83
RM+1.5 % SF	12.44	36.07
RM+2.0 % SF	12.20	38.00

attributed to the fact that additional water was held within the flocs resulting from flocculation due to lime reaction. These observations are in agreement with Kumar et al. (2007) where the effect of lime on the compaction behaviour of black cotton soil was reported. In order to decide the optimum mix of bentonite and lime, it was decided to conduct unconfined compressive strength tests. Similar procedure was adopted by Kumar et al. (2007) for fixing the optimum mix with lime. The unconfined compressive strength of the bentonite cured for 3 days was 154.25 kPa which increased to 248.25 kPa, 325.25 kPa, 387.47 kPa, 442.77 kPa with the addition of 2, 4, 6, 8 % lime and decreased to 306.54 kPa with the addition of 10 % lime at the same curing period. Similar trend was observed for other curing periods of 7, 14 and 28 days and the results are shown in Fig. 2 (a). Therefore, on the basis of the results shown in Fig. 2 (a), a mix of bentonite + 8 % lime was chosen for studying the compaction behaviour by varying the content of phosphogypsum. The results of dry unit weight and moisture content for bentonite + 8 % lime with varying percentages of phosphogypsum are shown in the Fig. 1(b) and Table 3. The study of Fig. 1 (b) and Table 3 reveals that the maximum dry unit weight for the bentonite + 8 % lime was 13.34 kN/m^3 which increased to 13.41 kN/m^3, 13.49 kN/m^3, 13.59 kN/m^3, 13.72 kN/m^3, 13.89 kN/m^3 and 14.01 kN/m^3, respectively with the addition of 0.5, 1, 2, 4, 8 and 10 % phosphogypsum. The increase in dry unit weight is attributed to the fact that the phosphogypsum fills up the void spaces left out after quick reaction of bentonite with lime resulting base exchange aggregation and flocculation. Study of Fig. 1 (b) and Table 3 further reveals that the optimum moisture content of the bentonite + 8 % lime was 32.40 % which increased to 32.98 %, 33.05 %, 33.38 %, 33.65 %, 33.89% and 34.05%, respectively with the addition of 0.5, 1, 2, 4, 8 and 10 % phosphogypsum. The effect of addition of phosphogypsum to the bentonite + 8% lime is to produce a greater maximum dry unit weight and optimum moisture content. These observations are in agreement with Wild et al. (1996) where the compaction behvaiour was reported on lime-stabilized kaolinite in the presence of sulphates. Thus, from the above discussion it is concluded that the dry unit weight and optimum moisture content of bentonite + 8% lime increased with the addition of 8%

phosphogypsum. In order to decide the reference mix of bentonite-lime-phosphogypsum, it was decided to conduct unconfined compressive strength tests. Similar procedure was adopted by Kumar et al. (2007) for fixing the optimum mix with lime. The unconfined compressive strength of the bentonite + 8 % lime cured for 3 days was 442.77 kPa which changed to 225.15 kPa, 321.67 kPa, 362.53 kPa, 429.19 kPa, 450.24kPa with the addition of 0.5, 1, 2, 4 and 8% phosphogypsum and decreased to 357.65 kPa with the addition of 10 % phosphogypsum at the same curing period. Similar trend was observed for other curing periods of 7, 14 and 28 days and the results are shown in Fig. 2 (b). Therefore, on the basis of the results shown in Fig. 2 (b), a reference mix of bentonite + 8% lime + 8% phosphogypsum was chosen for further study.

The compaction curves for the reference mix mixed with varying percentages of sisal fibers are shown in Fig. 1 (c) and Table 3. Study of this figure and table reveals that the maximum dry unit weight for the reference mix was 13.89 kN/m^3 which decreased to 13.18 kN/m^3, 13.02 kN/m^3, 12.44 kN/m^3, 12.2 kN/m^3, respectively with the addition of 0.5, 1, 1.5 and 2% sisal fibers. The decrease in dry unit weight of the reference mix with the increase in sisal fiber content is perhaps attributed to lower specific gravity of the sisal fibers in comparison to the reference mix. Krishna and Sayida (2009) made similar observations where the effect of sisal fiber on the compaction behaviour of black cotton soil was reported. Study of Fig.1(c) and Table 3 further reveals that the optimum moisture content of the reference mix was 33.89% which increased to 34.02%, 34.83 %, 36.07 % and 38%, respectively with the addition of 0.5, 1, 1.5 and 2 % sisal fibers. This increase in optimum moisture content with the increase in sisal fiber content is attributed to water absorption tendency of sisal fibers. Krishna and Sayida (2009) and Priya and Girish (2010) made similar observations where the effect of sisal fibers on black cotton soil and lime treated black cotton soil was reported, respectively. In order to decide the optimum mix of bentonite-lime-phosphogypsum-sisal fibers, it was decided to conduct unconfined compressive strength tests. The unconfined compressive strength of the reference mix cured for 3 days was 450.24 kPa which changed to 373.90 kPa, 515.48 kPa, 335.90 kPa and 289.20 kPa, respectively with the addition of 0.5, 1, 1.5 and 2 % sisal fibers at the same curing period. Similar trend was observed for other curing periods of 7, 14 and 28 days and the results are presented in Fig. 2 (c).

Unconfined Compressive Strength

The axial stress-strain curve of the bentonite with varying percentages of lime and cured for 3, 7, 14 and 28 days, respectively is shown in Fig. 3 (a). Fig. 3 (a) also contains the axial stress-strain curves for the bentonite cured for 3, 7, 14 and 28 days, respectively. Study of Fig. 3 (a) reveals that the axial stress at failure of the bentonite does not improve appreciably with the increase in curing period. For example, the axial stress at failure of the bentonite cured for 3 days was 154.25 kPa which marginally increased to 154.263 kPa, 158.89 kPa and 162.03 kPa, respectively after 7, 14 and 28 days, of curing. The improvement in unconfined compressive strength with curing period is within the experimental error. Hence, for all practical purposes, it is concluded that there is no change in the unconfined compressive strength of the bentonite with the curing period. Further examination of Fig. 3 (a) reveals that the axial stress at failure increased with the increase in curing period. For example, for the bentonite + 2% lime mix cured for 3 days, the axial stress at failure was 248.25 kPa which increased to 287.51 kPa, 303.60 kPa and 311.01 kPa with the increase in curing period to 7, 14 and 28 days, respectively. The increase in axial stress at failure with the curing period is attributed to the pozzolanic reactions of lime with the bentonite leading to an increase in axial stress at failure. Similar trend of increase in axial stress at failure was observed for a lime content of 4, 6, 8 and 10%. A close examination of Fig. 3 (a) reveals that the axial stress at failure increased with the increase in lime content up to

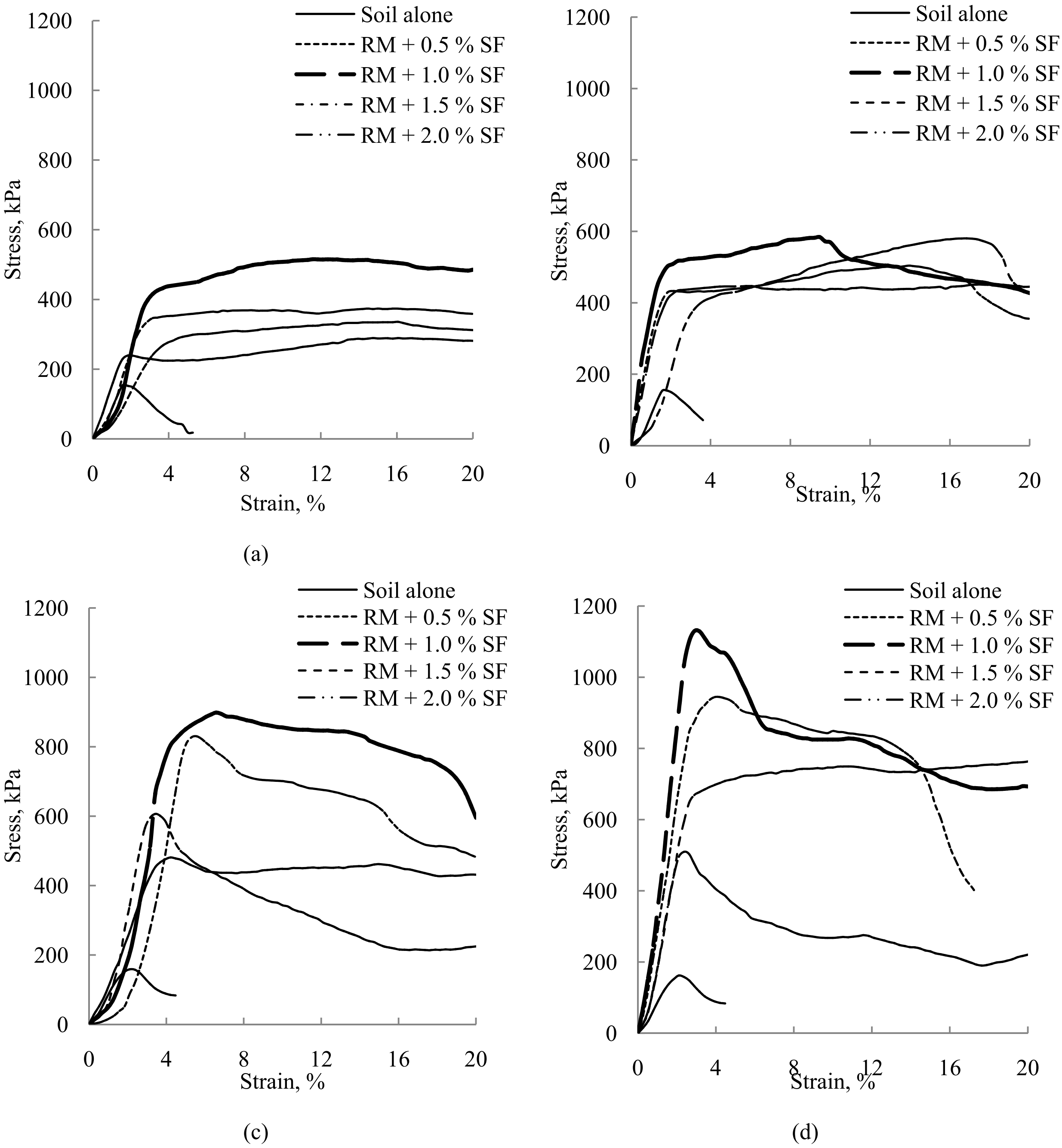

Figure (3): Variation of unconfined compressive strength for reference mix mixed with varying percentages of sisal fibers at (a) 3 days (b) 7 days (c) 14 days (d) 28 days

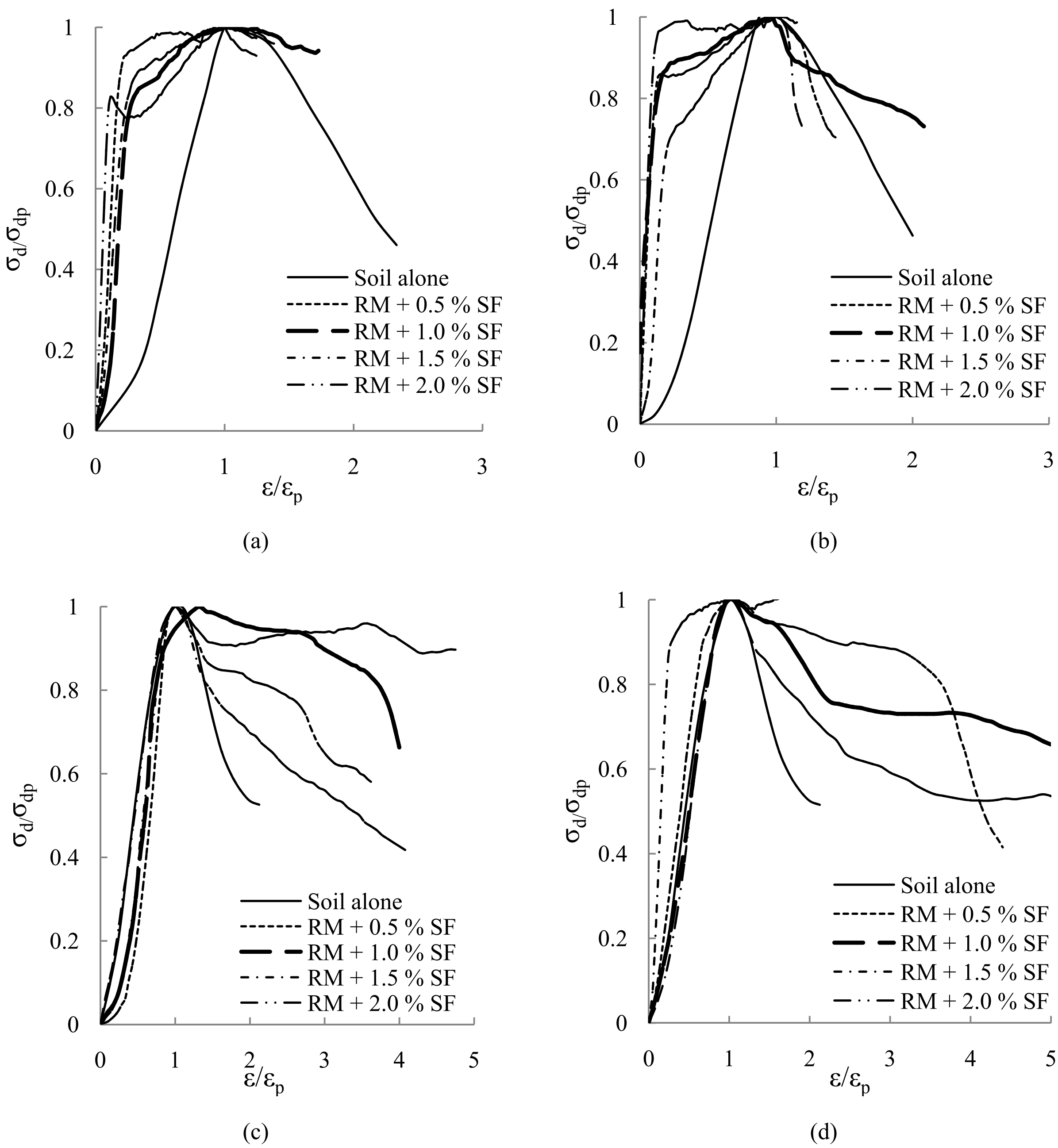

Figure (4): Normalized stress-strain curve for reference mix mixed with varying percentages of sisal fibers at (a) 3 days (b) 7 days (c) 14 days (d) 28 days

a content of 8 %. For example, for the bentonite + 2% lime mix cured for 3 days, the axial stress at failure was 248.25 kPa which increased to 325.25 kPa, 387.47 kPa, 442.47 kPa and decreased to 311.01 kPa with the increase in lime content to 4, 6, 8 and 10%, respectively. The decrease in axial stress at failure beyond a lime content of 8% is attributed to the platy shapes of the unreacted lime particles in bentonite. These observations are in agreement with Kumar et al. (2007) where the effect of lime on the unconfined compressive strength of black cotton soil was reported. Similar trend of increase in axial stress at failure was observed for other curing periods of 7, 14 and 28 days as evident from Fig.3 (a). The axial stress-strain curve of the bentonite + 8% lime mixture with varying percentages of phosphogypsum and cured for 3, 7, 14 and 28 days, respectively is shown in Fig. 3(b). Fig. 3(b) also contains the axial stress-strain curves for the bentonite and bentonite + 8% lime mixture cured for 3, 7, 14 and 28 days, respectively. Study of Fig. 3(b) reveals that the axial stress at failure increased with the increase in curing period up to 14 days of curing. For example, for the bentonite + 8% lime + 0.5% phosphogypsum cured for 3 days, the axial stress at failure was 225.15 kPa which increased to 592.26 kPa, 810.00 kPa and decreased to 661.91 kPa with the increase in curing period to 7, 14 and 28 days, respectively. The increase in axial stress at failure with the curing period is attributed to the acceleration in the pozzolanic reactions of lime with the bentonite in the presence of phosphogypsum leading to an increase in axial stress at failure up to 14 days of curing. Beyond 14 days of curing, the formation of ettringite perhaps decreased the unconfined compressive strength. However, this needs to be verified through SEM study. Similar trend of increase in axial stress at failure was observed for a phosphogypsum content of 1, 2, 4, 8 and 10%. A close examination of Fig. 3 (b) reveals that the axial stress at failure increased with the increase in phosphogypsum content up to a content of 8%, it further decreased with the phosphogypsum content of 10%. For example, for the bentonite + 8% lime + 0.5% phosphogypsum mix cured for 3 days, the axial stress at failure was 225.15 kPa which increased to 321.67 kPa, 362.53 kPa, 429.19 kPa, 450.24 kPa at phosphogypsum content of 1, 2, 4 and 8%, respectively and decreased to 357.65 kPa with the addition of phosphogypsum content of 10%. The decrease in axial stress at failure beyond a phosphogypsum content of 8% is perhaps attributed to the platy shapes of the unreacted lime particles in bentonite even in the presence of phosphogypsum. Similar trend of increase in axial stress at failure was observed for other curing periods of 7, 14 and 28 days as evident from Fig. 2 (b). Since the unconfined compressive strength of the reference mix decreased beyond a curing period of 14 days, it was decided to improve its strength with the addition of sisal fibers. The axial stress-strain behavior of the reference mix reinforced with varying percentages of sisal fibers is shown in Fig. 3 (c). A close examination of Fig. 3 (c) reveals that the axial stress increases with the curing period. For example, the axial stress of reference mix reinforced with 0.5 % sisal fibers and cured for 3 days was 373.902 kPa which increased to 433.22 kPa, 830.53 kPa and 944.31 kPa, respectively after 7, 14 and 28 days. Similar trend of increase in axial stress at failure was observed for a fiber content of 1, 1.5 and 2%. A close examination of Fig. 3 (c) reveals that the axial stress at failure increased with the increase in fiber content up to a content of 1%. For example, for the reference mix + 0.5% sisal fiber mix cured for 3 days, the axial stress at failure was 373.91 kPa which increased to 515.48 kPa for reference mix + 1% sisal fiber and decreased to 335.90 kPa and 289.20 kPa with the increase in fiber content to 1.5 and 2%, respectively. Similar trend of increase in axial stress at failure was observed for other curing periods of 7, 14 and 28 days as evident from Fig. 3 (c). The increase in unconfined compressive strength with the addition of sisal fibers up to a fiber content of 1% is attributed to the fact that the cementing gel formed due to the reaction of bentonite with lime binds the sisal fibers with the bentonite particles leading to an enhancement in the unconfined compressive strength. Sabat (2012) made similar observations where the effect of polypropylene fiber on the engineering properties of rice husk ash–lime stabilized expansive soil was reported. The unconfined compressive strength decreased beyond a fiber content of 1%. This is attributed to the fact that the formation of lump of fibers due to excessive adhesion and poor contact of fibers with bentonite particles results in a decrease in unconfined compressive strength. Similar observations were made by Sabat (2012) where the effect polypropylene fiber on the unconfined compressive strength of rice husk ash–lime stabilized expansive soil was reported. The unconfined compressive strengths of various optimum mixes are shown in Table 4 for comparison purposes. Thus, from the above discussion, it is concluded that the unconfined compressive strengths of bentonite does not change with the increase in curing period. The unconfined compressive strength of the reference mix increased with the addition of 1% sisal fibers. Beyond a fiber content of 1%, the unconfined compressive strength decreased.

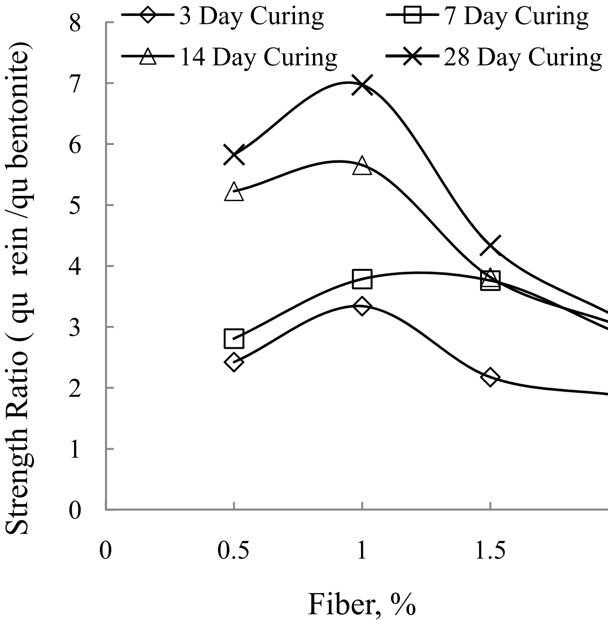

Figure (5): Variation of normalized unconfined compression strength for different sisal fiber percentages

Table 4. Unconfined compressive strength of various optimum mixes

Mixes	Unconfined compressive strength (kPa) at different curing periods (days)			
	3	7	14	28
B	154.256	154.263	158.89	162.03
B+8 % L	442.772	13.78.89	13.95.02	1446.11
RM	450.240	726.242	843.197	1122.3
RM+1 %SF	515.4768	584.12	898.63	1129.635

Post Peak Behaviour

To better understand sisal fiber toughening characteristics in the post peak region, the stress axis of the stress-strain diagram was normalized with respect to the peak axial stress, and the strain axis was normalized with respect to the strain at the peak axial stress. The variation of normalized stress-strain curve for reference mix reinforced with sisal fibers is shown in Figs. 4 (a) to (d). An examination of Figs. 4 (a) to (d) reveals that the post peak behaviour of the bentonite-lime-phosphogypsum mixture improved with the addition of sisal fibers to the mix. The variation of strength ratios at different curing periods with fiber content is shown in Fig. 5. Study of Fig. 5 reveals that the unconfined compression strength (q_u) of soil reinforced with 1 % sisal fibers was about 3.34, 3.78, 5.65 and 6.97 times that of bentonite after 3, 7, 14 and 28 day curing periods. Thus, from the above discussion, it is concluded that the post peak behaviour of the bentonite-lime-phosphogypsum improves with the addition of sisal fibers.

Filho et al. (2000) studied the durability of sisal fibers conditioned in tap water and the results indicated that after 420 days, sisal fibers retained 83.3% of their original strength. Thus, the sisal fibers in bentonite-lime-phosphogypsum matrix may satisfy the durability requirement for temporary roads over problematic soils. However, further research is needed to verify this. The authors of this paper are of the opinion that the use of this composite material can be more economical in those areas where these materials are available in the nearby places.

CONCLUSIONS

An experimental study is carried out to investigate the compaction and unconfined compressive strength of bentonite stabilized with lime-phosphogypsum and random inclusion of sisal fibers. The study brings forth the following conclusions.

1. The dry unit weight and optimum moisture of bentonite- lime mix increased with the addition of phosphogypsum.
2. The dry unit weight of the reference mix decreased and the optimum moisture content increased with the addition of sisal fibres.
3. The unconfined compressive strength of the bentonite increased with the addition of 8% lime. Beyond 8 %, the unconfined compressive strength decreased.
4. The unconfined compressive strength of the bentonite + 8% lime increased up to 8% phosphogypsum. Beyond 8%, the unconfined compressive strength decreased.
5. The unconfined compressive strength of the reference mix increased with the addition of sisal fibers up to 1%. The trend was reversed after that.
6. The unconfined compressive strength of bentonite-lime-phosphogypsum increased with the addition of sisal fibers and with the increase in curing period.
7. The improvement in post peak region was better for the reinforced sisal fibers as compared to the unreinforced soil.
8. The optimum value of lime content, phosphogypsum content and sisal fiber content in bentonite- lime phosphogypsum-sisal fiber mixtures may be taken as 8%, 8 % and 1%, respectively.

On the whole, this study has attempted to provide an insight into the compaction and unconfined compressive strength of bentonite stabilized with lime and phosphogypsum reinforced with sisal fibres. The improved behavior of the bentonite-lime-phosphogypsum-sisal fiber mixture will boost the construction of temporary roads on such problematic soils. Further, its use will also provide environmental motivation for providing a means of consuming large quantities of phosphogypsum and sisal fibers.

NOTATION

B = Bentonite
L = Lime
PG = Phosphogypsum
SF = Sisal Fibre
RM = Reference mix = B + 8 % L + 8 % PG

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