SOIL STABILIZATION USING GEOPOLYMER AND BIOPOLYMER

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ABSTRACT

As stabilization of soil improves its engineering properties, chemical and mechanical stabilization processes are in use. In the present study two difficult soils; expansive soil and dispersive soil are stabilized with geopolymer and biopolymer. Sodium based alkaline activators and fly ash as an additive is used as geopolymer and Xanthan gum and Guar gum are used as biopolymers. The effectiveness of geopolymer is studied in terms of unconfined compressive strength (UCS), differential free swelling (DFS), swelling pressure (SP), durability and dispersion tests. The swelling pressure got reduced by 97.14% finally with addition of 40% fly ash and 15% bentonite. The dispersion test showed bentonite to be an extremely dispersive soil, whose dispersiveness is controlled by addition of alkali activated fly ash. From UCS and durability test it is observed that bentonite added with 40% fly ash and 10% solution gave better results. The effectiveness of biopolymer is studied based on UCS tests on dispersive soil and pond ash at their moisture content. For dispersive soil, durability, dispersion and DFS tests are also done. It is observed that dispersive soil and pond ash mixed with various percentages of Xanthan gum and Guar gum are not dispersive and are more durable than ordinary bottom ash and dispersive soil samples. Guar gum is found to imparts higher confined compressive strength and durability than Xanthan gum.

INTRODUCTION

Soil stabilization in a broad sense includes various methods used for modifying the properties of soil to enhance its engineering performance. By stabilization the major properties of soil, i.e., volume stability, strength, compressibility, permeability, durability and dust control is improved, which makes the soil suitable for use. There are different methods of stabilization, which include physical, chemical and polymer methods of stabilization. Physical methods involve physical processes to improve soil properties. This includes compaction methods and drainage. Drainage is an efficient way to remove excessive water from soil by means of pumps, pipes and canal with an aim to prevent soil from swelling due to saturation with water. Compaction processes lead to increase in water resistance capacity of soil. Drainage is less common due to generally poor connection between method effectiveness and cost. But, compaction is very common method. Although, it makes soil more resistant to water, this resistance will be reducing over time. Chemical soil stabilization uses chemicals and emulsions as compaction aids, water repellents and binders. The most effective chemical soil stabilization is one which results in non-water-soluble and hard soil matrix. Polymer methods of stabilization have a number of significant advantages over physical and chemical methods. These polymers are cheaper and are more effective and significantly less dangerous for the environment as compared to many chemical solutions. In the present study difficult soil i.e, expansive soil is considered for effectiveness of geopolymer and biopolymer stabilization.

Objective and Scope

The objective of the current research work is to determine the suitability of geopolymer (alkali-activated fly ash) and biopolymer as soil stabilizing agent for expansive soil.

Scope

- Laboratory investigation for characterization of bentonite soil with alkali activated fly ash (geopolymer) as binding material.
- It includes laboratory investigation for characterization of bentonite soil with two commercially available biopolymers i.e., Xanthan gum and Guar gum.

LITERATURE REVIEW

Satyanarayana*et al.* (2004) studied the combined effect of addition of fly ash and lime onengineering properties of expansive soil and found that the optimum proportions of soil: fly ash: lime should be 70:30:4 for construction of roads and embankments.

Phani Kumar and Sharma (2004) observed that plasticity, hydraulic conductivity andswelling properties of the expansive soil fly ash blends decreased and the dry unit weight and strength increased with increase in fly ash content. The resistance to penetration of the blends increased significantly with an increase in fly ash content fora given water content. They presented a statistical model to predict the undrained shear strength of the treated soil.

Baytar (2005) studied the stabilization of expansive soils using the fly ash and desulpho-gypsum obtained from thermal power plant by 0 to 30 percent. Varied percentage of lime (0 to 8%) was added with the expansive soil-fly ash-desulphogypsum mixture. The treated samples were cured for 7 and 28 days. Swelling percentage was found to reduced and rate of swell was found to increase with increase in stabilizer percentage. Curing resulted in further reduction in swelling percentage. With addition of 25 percent fly ash and 30 percent desulphogypsum, the swelling percentage reduced to levels comparable to lime stabilization.

Amu *et al.* (2005) used cement and fly ash mixture for stabilization of expansive clayey soil.The expansive soil was treated with (i) 12% cement and (ii) 9% cement + 3% fly ash and were tested for maximum dry densities (MDD), optimum moisture contents (OMC), California bearing ratio (CBR), unconfined compressive strength (UCS) and the undrainedtriaxial tests. The results showed that the soil sample stabilized with a mixture of 9% cement + 3% fly ash is better with respect to MDD, OMC, CBR and shearing resistance compared to samples stabilized with 12% cement, indicated the importance of fly ash in improving the stabilizing potential of cement on expansive soil.

Kumar *et al*. (2007) studied the effects of polyester fibre inclusions and lime stabilization onthe geotechnical characteristics of fly ash-expansive soil mixtures. Lime and fly ash were added with an expansive soil at ranges of 1–10% and 1–20%, respectively. The samples with optimum proportion of fly ash and lime content (15% fly ash and 8% lime) based on compaction, unconfined compression and split tensile strength, were added with 0, 0.5, 1.0,1.5 and 2% plain and crimped polyester fibres by weight. The MDD of soil-fly ash-lime mixes decreased with increase in fly ash and lime content. The polyester fibres (0.5–2.0%) had no significant effect on MDD and OMC of fly ash-soil-lime-fibre mixtures. However, the unconfined compressive strength and split tensile strength increased with addition of fibres.

Buhler and Cerato (2007) studied the stabilization of expansive soils using lime and Class C flyash**.** The reduction in linear shrinkage was better with lime stabilization as compared to same percentage of Class C fly ash.

Stabilization using quarry dust

The quarry dust/ crusher dust obtained during crushing of stone to obtain aggregates causes health hazard in the vicinity and many times considered as an aggregate waste.

Stalin et al. (2004) made an investigation regarding control of swelling potential (SP)of expansive clays using quarry dust and marble powder and observed that liquid limit and swelling pressure decreased with increase in quarry dust or marble powder content.

Stabilization using biopolymer

Chen et al. (2013) performed a preliminary study on using Xanthan gum and Guargum, two biopolymers that are naturally occurring and inexpensive, to stabilize mine tailings (MT). The addition of these two biopolymers increased both liquid limit and the undrained shear strength of the MT. Guar gum was found to be more effective than Xanthan gum in increasing the liquid limit and undrained shear strength of the MT, as the Guar gum solution was more viscous than the Xanthan gum solution at the same concentration. A comprehensive study on the mechanical, chemical and polymer stabilization of expansive soil.

From critical review of literature, it can be seen that the studies regarding geopolymer are limited to its use in concrete and a single literature (Parhi and Das, 2014) is available in its application for soil. Similarly, a single literature (Chen et al.) for the use of biopolymer in stabilization of soil is available. So, in this present study an attempt has been made to use geopolymer as an alternative cementitious material in stabilizing expansive soil and biopolymers (Xanthan gum and Guar gum) are used to stabilize expansive soil.

MATERIAL AND METHODOLOGY

In the present study soil are considered namely bentonite soil have been stabilized using geopolymers (alkali activators, sodium silicate: sodium hydroxide in 2:1 ratio) and biopolymers. The alkali solution sodium silicate: sodium hydroxide in 2:1 ratio was used in different concentrations.

In the present study, methodology of stabilizing soil using geopolymer and biopolymer is explained as follows.

Stabilization using geopolymer

In the present study, the alkali was prepared by taking sodium silicate and sodium hydroxide keeping in view, the ratio of sodium silicate to sodium hydroxide in their dry mass as 2. The prepared alkali (S) was added in varying percentages (5%, 10%and 15%) with fly ash (FA) in different percentages (20%, 30% and 40%) by dry weight of total solids to bentonite. The alkali, taken in 10% with fly ash 40% by dry weight of total solids was also added with bentonite soil. Then, optimum moisture content (OMC), maximum dry density (MDD), unconfined compressive strength (UCS), and durability of different samples were experimentally investigated and compared with only bentonite soil samples.

Differential free swelling (DFS) with (3, 7 and 14 days) and without curing, swelling pressure and dispersion tests were also done for treated bentonite samples and compared with only bentonite samples. Evaluation of UCS of treated soil samples were done on an interval of 0, 3, 7 and 14 days and compared with only bentonite samples.DFS of treated soil samples were done on an interval of 0, 3, 7 and 14 days. The samples which were tested after 3, 7 and 14 days were wrapped in cling film and left at ambient temperature of 32-35º C and humidity conditions (50–60 % RH). Following Table 3.8 shows the details of the alkali activated fly ash mixed in various percentages with bentonite

Stabilization using biopolymer

S.NO.	Name of the mix	Particulars of the mix
1	Bentonite + FA (20%) + S (5%)	Soil+20%fly ash by weight of total solids+5% alkali by weight of total solids
2	Bentonite + FA (30%) + S (5%)	Soil+30%fly ash by weight of total solids+5% alkali by weight of total solids
3	Bentonite + FA (40%) + S (5%)	Soil+40%fly ash by weight of total solids+5% alkali by weight of total solids
4	Bentonite + FA (20%) + S (10%)	Soil+20%fly ash by weight of total solids+10% alkali by weight of total solids
5	Bentonite + FA (30%) + S (10%)	Soil+30%fly ash by weight of total solids+10%alkali by weight of total solids
6	Bentonite + FA (40%) + S (10%)	Soil+40%fly ash by weight of total solids+10%alkali by weight of total solids
7	Bentonite + FA (20%) + S (15%)	Soil+20%fly ash by weight of total solids+15%alkali by weight of total solids
8	Bentonite + FA (30%) + S (15%)	Soil+30%fly ash by weight of total solids+15%alkali by weight of total solids
9	Bentonite + FA (40%) + S (15%)	Soil+40%fly ash by weight of total solids+15%alkali by weight of total solids

The experimental investigations were made on soil and stabilized soil using biopolymer as per Indian standards. It was observed that Guar gum (GG) is more viscous compared to Xanthan gum (XG). Hence, Xanthan gum solutions with percentages of 1, 2 and 3% and Guar gum solutions with percentages of 0.5, 1 and 2% were added with bentonite soil and pond ash (PA)toinvestigate the effect of biopolymers on compaction characteristics, unconfined compressive strength. Durability and dispersion tests were also done for biopolymer modified bentonite soil and compared to only bentonite soil sample. Table 3.4 and Table 3.5 shows the details of the biopolymer modified bentonite soil and pond ash samples, respectively. Evaluation of UCS of biopolymer modified bentonite soil samples were done on an interval of 0, 3 and 7days and also done for sample kept for sundried (1 day) and compared with only bentonite soil samples. The samples which were tested after 3 and 7 days were wrapped in cling film and left at ambient temperature of 32-35ºC and humidity conditions (50–60 % RH). Table 3.9 and Table 3.10 show details of the bentonite soil specimens and pond ash specimens mixed in different percentages with Xanthan gum (XG) and Guar gum (GG), respectively.

Table: Details of the Biopolymer Modified Bentonite Soil (B.S) Specimens

S.NO.	Name of the mix	Particulars of the mix
1	B.S+1% XG	bentonite soil added with 1% Xanthan gum
2	B.S+2% XG	bentonite soil added with 2% Xanthan gum
3	B.S+3% XG	bentonite soil added with 3% Xanthan gum
4	B.S+0.5% GG	bentonite soil added with 0.5% Guar gum
5	B.S+1% GG	bentonite soil added with 1% Guar gum
6	B.S+2% GG	bentonite soil added with 2% Guar gum

Table: Details of the Biopolymer Modified Pond Ash Specimens

S.NO.	Name of the mix	Particulars of the mix
1	PA+1% XG	Pond ash added with 1% Xanthan gum
2	PA +2% XG	Pond ash added with 2% Xanthan gum
3	PA +3% XG	Pond as added with 3% Xanthan gum
4	PA +0.5% GG	Pond ash added with 0.5% guar gum
5	PA +1% GG	Pond ash added with 1% guar gum
6	PA +2% GG	Pond ash added with 2% guar gum

STABILIZATION OF BENTONITE SOIL WITH ALKALI ACTIVATED FLY ASH

This paper presents the results of stabilization of bentonite soil with alkali activated fly ash. To determine the optimum moisture content (OMC) and maximum dry density (MDD) of bentonite and treated bentonite samples, light compaction test was done. The increase in strength condition was established by conducting unconfined compression test on samples at 0, 3, 7 and 14 days curing. The samples were of 50 mm diameter (D) and 100 mm height (L), thereby ensuring L/D ratio as 2. These samples comprises of bentonite added with fly ash in different percentages (20%, 30% and 40%) and alkali (sodium silicate to sodium hydroxide ratio taken by dry mass was kept 2) solution varying from 5%, 10% and 15%. The decrease in swelling condition was ascertained by conducting swelling pressure test using consolidometer test on treated soil samples. The decrease in percentage of swelling was also shown by conducting differential free swell (DFS) test on treated soil samples. Resistance to erosion was presented by conducting dispersion test on treated soil sampleswith respect to bentonite soil.

Compaction characteristics

The following graphs show the compaction characteristics of bentonite and alkali activated fly ash added with bentonite, showing optimum moisture content (OMC) and maximum dry density (MDD) of the compacted samples. Fig. shows the comparison of OMC and MDD of bentonite and bentonite with fly ash (20%, 30% and 40%) and alkali solution (5%). Fig. shows the comparison of OMC and MDD of bentonite and bentonite with fly ash (20%, 30% and 40%) and alkali solution (10%). Similarly results of bentonite with fly ash (20%, 30% and 40%) and 15% alkali solution are presented in Fig.

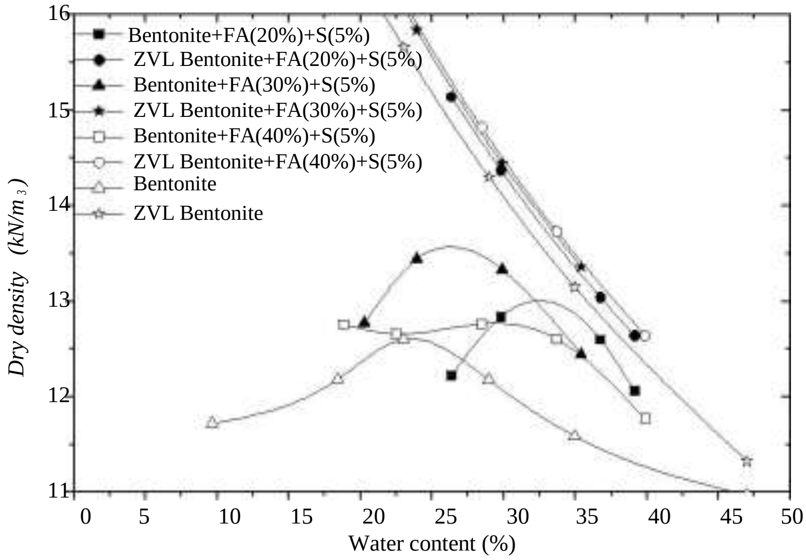
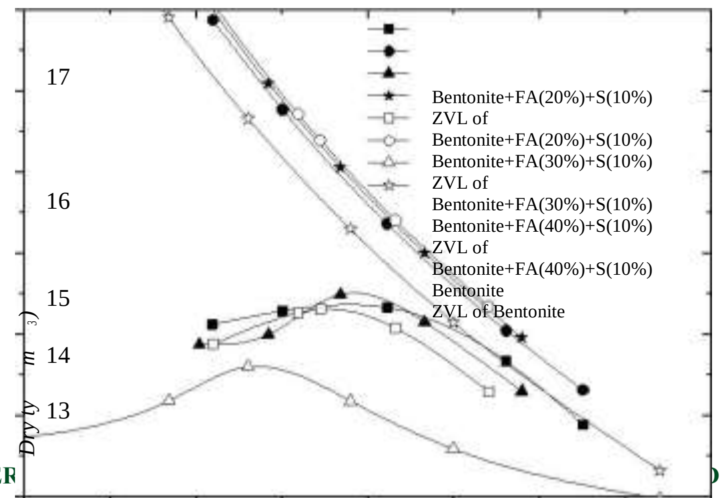


Fig. Compaction Characteristics for Bentonite and Bentonite with Flyash (20%, 30% and 40%) and Alkalisolution(5%)



12

11

10 20 30 40 50

Water content (%)

FigCompaction Characteristics for Bentonite and Bentonite with Flyash (20%, 30% and 40%) and Alkalisolution(10%)

It can be seen that the variation in MDD marginal with change in fly ash content and percentage of alkali solution.

Dispersion test

The dispersion ratio of bentonite soil as per double hydrometer test was found to be 89.57%, which is extremely dispersive as per Volk (1937) (Table). Crumb test was also done to assess the dispersiveness of bentonite soils. show cubes of bentonite soil added with Xanthan gum (1%), Xanthan gum (2%),Xanthan gum (3%), Guar gum (0.5%), Guar gum (1%) and Guar gum (2%), respectively, where, it can be seen that bentonite soil added with gums did not get disperse after five to seven minutes. Hence, both XG and GG are effective in stabilizing bentonite soil.

(a) (b)

(c) (d)

(e) (f)

(g)

Modified Free Swell Index (MFSI):

The MFSI test is also conducted to check expansive nature of bentonite soil. The MFSI obtained for bentonite soil is 1.4, which indicated that it is a non- bentonite soil.

Results of biopolymer stabilized pond ash

Compaction characteristics

The compaction characteristics of different pond ash (PA) and biopolymer modified pond ashes are presented in Figs. 5.16 to 5.20. Fig. 5.16 shows the comparison of OMC and MDD of three pond ash samples. Similarly, Fig. 5.17 and Fig. 5.18 show the comparison of OMC and MDD of pond ash samples being collected from Vishnu Chemicals Pvt Ltd (VCP) and PS respectively mixed with XG (2%) and GG (2%). Fig. 5.19 and Fig. 5.20 show the comparison of OMC and MDD of pond ash sample being collected from PS mixed with various more percentages of gum to know the variation of moisture content when mixed with higher and lower gum percentages. Table 5.5 shows OMC and MDD of various pond ash samples and biopolymer modified pond ash. It can be seen that PS2 has maximum dry density (11.57 kN/m^3) compared to PS1 (10.8 kN/m^3) and VCP (11.3kN/m^3). It was also observed that there is reduction in MDD and increase in OMC with addition of biopolymer for the three biopolymer modified pond ashes considered here. This may be due to difficulty in compacting with standard Proctor for the biopolymer stabilized pondash.

CONCLUSIONS AND FUTURE SCOPE

Based on the obtained results and discussion there of following conclusions can be drawn.

1.The maximum optimum moisture content was for bentonite added with geopolymer with fly ash (20%) and alkali solution (10%) and MDD was maximum for bentonite added with fly ash (40%) and alkali solution (15%).

2. The UCS value of the geopolymer stabilized bentonite found to vary with percentage of fly ash and alkali solution, and maximum UCS value was obtained with 40% fly ash and 10% alkali solution.

3.Based on durability test, the resistance to loss in strength (RLS) was maximum for bentonite with 40% fly ash and 10% alkali solution and it got reduced with addition of 15% solution.

4.Based on differential free swell test, it was observed that with increased percentage of alkali activated fly ash, the swelling percentage decreased considerably. After 3 days of curing for bentonite + FA (20%) + S (10%), and bentonite + fly ash (20%, 30% and 40%) + S (15%), the swelling percentage became negligible and the treated soil became non-swelling. Similar observations were made for bentonite + fly ash (20%, 30% and 40%) + S (5%, 10% and 15%) after 7 days and bentonite + fly ash (20%, 30% and 40%) + S (5%, 10% and 15%) after 14 daysof curing.

5.Based on crumb test and double hydrometer test it was observed that bentonite was extremely dispersive (84.87%). However, it became non-dispersive with addition of more than 5 % of geopolymer.

6.It was observed that with addition of biopolymer, OMC increased and MDD decreased for bentonite soil. However, The UCS value increased with addition of biopolymer.

7.With same percentage of gum, it was observed that bentonite soil stabilized with guar gum has better strength compared to that of Xanthan gum.

8.Based on durability test the RLS was maximum for Xanthan gum (1%) and guar gum (1%). The RLS decreased with increased percentage of Xanthan gum but, for guar gum. RLS obtained was optimum at 1%.

9.Based on crumb test and double hydrometer test it was seen that bentonite soil was extremely dispersive (89.57%) and became non-dispersive with addition of biopolymer.

10.It was observed that with addition of biopolymer, OMC increased and MDD decreased for pond ash. However, The UCS value increased with addition of biopolymer.

11.With same percentage of gum, it was observed that pond ash stabilized with Guar gum had better strength compared to that of Xanthan gum.

12.It was observed that sundried sample has better UCS value than sample stored inside coated with film/wax.

The present study showed that biopolymer and geopolymer can be effectively used as stabilizing agents for bentonite soil. It was also observed that geopolymer is more effective than biopolymer in terms of stabilization.

FUTURE SCOPE

Some recommendations made based on the present study for practical applications:

- Efforts to reduce the cost of operation by searching other natural alkaline materials.
- Filed applications of this method by using suitable technology.
- Application of geopolymer in stabilization of other low strength high compressible lays.
- Applications of biopolymer in mine reclamation as is is environmental friendly in controlling erosion and dust.

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