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Study and Investigation on Soil Stabilization using Different Polymers

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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.

Keywords: Soil stabilization, polymers, biopolymer, and geopolymer.

I. 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. In the present study two difficult soils, expansive soil and dispersive soil are considered for effectiveness of geopolymer and biopolymer stabilization.

1.1 Definition of the problem

In India, almost 20% of the total area is covered by expansive soil. Due to rapid industrialization and huge population growth of our country, there is a scarcity of land to meet the human needs. Further, the cost of rehabilitation and retrofitting of the civil engineering structures established over these soils are increasing day by day. On the other hand, the safe disposal of fly ash from thermal power industries has been a challenging issue demanding urgent solution because of the decline effect of these materials on the environment and the hazardous risk it pose to the human and animals. However, production of cement requires lime-stone and with the rate with which we are utilising cement, the day is not so far when the lime stone mines will get depleted.

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II. Literature Review

Sharma *et al*. (1992)studied stabilization of expansive soil using mixture of fly ash,gypsumand blast furnace slag. They found that mixture of fly ash, gypsum and blast furnace slag in the proportion of 6: 12: 18 decreased the swelling pressure (SP) of the soil from 248 kN/m^2 to 17 kN/m^2 and increased the unconfined compressive strength by 300%.

Srivastava *et al.* (1997) studied the change in micro structure and fabric of expansive soildue to addition of fly ash and lime sludge from SEM photograph and found changes in micro structure and fabric when 16% fly ash and 16% lime sludge were added to expansive soil.

III. Materials and Methodology

3.1 Introduction

In the present study two difficult soils are considered namely expansive and dispersive soil. Both have been stabilized using geopolymers (alkali activators, sodium silicate: sodium hydroxide in 2:1 ratio) and biopolymers (commercially available Xanthan gum and Guar gum). The alkali solution sodium silicate: sodium hydroxide in 2:1 ratio was used in different concentrations.

3.2.1 Bentonite

The commercial available bentonite is used in the present study, which are from Kutch mining area, Bhuj district, Gujarat, India. A small amount (20 gm) of the sample was sealed in polythene bag for determining its natural moisture content. The soil was air dried and pulverized as required for laboratory test.

3.2.2 Fly ash

Safe disposal and management of fly ash are the two major issues concerned with the production of fly ash. At present, the generation of fly ash is far in excess of its utilization. In the present study, fly ash was collected from the hopper of a thermal power plant from Raigarh, Chhattisgarh, India. Two pond ashes were collected from Rourkela steel plant, Rourkela, Odisha, India at two different times and named as RSP1 and RSP2.

IV. RESULTS

4.1 Stabilization of bentonite and dispersive 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.

Table 1: OMC and MDD of bentonite and alkali activated fly ash added with bentonite

Sample Name	OMC (%)	MDD(KN/m^3)
Bentonite	23.01	12.60
Bentonite + FA (20%) + S (5%)	29.81	12.84
Bentonite + FA (40%) + S (5%)	28.48	12.76
Bentonite + FA (20%) + S (10%)	31.12	13.33
Bentonite + FA (30%) + S (10%)	28.38	13.49
Bentonite + FA (40%) + S (10%)	27.23	13.31
Bentonite + FA (20%) + S (15%)	26.99	13.30
Bentonite + FA (30%) + S (15%)	29.66	13.08
Bentonite + FA (40%) + S (15%)	25.60	13.57

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Table 2: UCS of bentonite and bentonite with fly ash (20%, 30% and 40%) and alkali solution (5%, 10% and 15%) without curing and with curing (3 days, 7 days and 14 days)

Sample Name	UCS (kPa)	UCS (kPa)	UCS (kPa)	UCS (kPa)
	0 day	3 days	7 days	14 days
Bentonite	504.43	363.97	324.02	282.21
Bentonite + FA (20%) + S (5%)	181.06	339.44	451.75	951.80
Bentonite + FA (30%) + S (5%)	255.38	718.10	992.79	1189.76
Bentonite + FA (40%) + S (5%)	130.32	532.43	828.89	972.31
Bentonite + FA (20%) + S (10%)	157.76	296.07	643.27	1053.88
Bentonite + FA (30%) + S (10%)	184.49	623.61	1108.70	1469.20
Bentonite + FA (40%) + S (10%)	328.67	857.92	1386.74	1632.25
Bentonite + FA (20%) + S (15%)	180.09	137.21	163.99	114.30
Bentonite +FA (30%) + S (15%)	118.96	261.44	314.13	324.10
Bentonite +FA (40%) + S (15%)	117.18	294.37	299.17	294.19

Table 3: Comparison of resistance to loss in strengthforbentonite and alkali solution activated fly ash added withbentonite

Sample Name	UCS of control sample (UCSC) (kPa)	UCSof soaked sample (UCSS) (kPa)	Increase or decrease in strength from control sample (CS) to soaked sample (SS)	Resistance to loss in strength (RLS= UCSS/UCSC)
Bentonite	-	-	-	-
Bentonite + FA (20%) + S (5%)	111.05	143.35	Increase	+1.29
Bentonite + FA (30%) + S (5%)	127.41	175.84	Increase	+1.38
Bentonite + FA (40%) + S (5%)	625.92	980.22	Increase	+1.57
Bentonite + FA (20%) + S (10%)	342.25	605.73	Increase	+1.77
Bentonite + FA (30%) + S (10%)	571.23	1190.56	Increase	+2.08
Bentonite + FA (40%) + S (10%)	780.90	1694.56	Increase	+2.17
Bentonite + FA (20%) + S (15%)	787.72	452.43	Decrease	-0.57
Bentonite + FA (30%) + S (15%)	793.53	540.75	Decrease	-0.60
Bentonite + FA (40%) + S (15%)	794.49	522.46	Decrease	-0.66

Table 4: DFS of alkali solution activated fly ash added with bentonite

Sample Name	DFS (%)0 day (withoutcuring)	DFS (%)3 days
Bentonite+ FA (20%) + S (5%)	72.73	19.05
Bentonite+ FA (30%) + S (5%)	65.22	13.64

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Bentonite+ FA (40%) + S (5%)	56.52	9.09
Bentonite+ FA (20%) + S (10%)	65	14.29
Bentonite+ FA (30%) + S (10%)	59.09	9.52
Bentonite+ FA (40%) + S (10%)	52.38	-
Bentonite+ FA (20%) + S (15%)	57.14	-
Bentonite+ FA (30%) + S (15%)	54.55	-
Bentonite+ FA (40%) + S (15%)	47.62	-

Table 5: MFSI of alkali solution activated fly ash added with bentonite

Sample Name	MFSI (cm^3/g) 3 days	MFSI(cm^3/g) 7 days	MFSI(cm^3/g) 14 days
Bentonite + FA (20%) + S (5%)	-	1.48	1.30
Bentonite + FA (30%) + S (5%)	-	1.43	1.25
Bentonite + FA (40%) + S (5%)	-	1.38	1.18
Bentonite + FA (20%) + S (10%)	-	1.33	1.15
Bentonite + FA (30%) + S (10%)	-	1.25	1.05
Bentonite + FA (40%) + S (10%)	1.45	1.18	0.98
Bentonite + FA (20%) + S (15%)	1.35	1.10	0.90
Bentonite + FA (30%) + S (15%)	1.33	1.03	0.83
Bentonite + FA (40%) + S (15%)	1.30	0.98	0.73

Table 6: Comparison of SP of alkali activated fly ash added with bentonite (after curing period of 3 days)

Sample Name	SP (kN/m^2)
Bentonite + FA (20%) + S (5%)	113
Bentonite + FA (30%) + S (5%)	103
Bentonite + FA (40%) + S (5%)	93
Bentonite + FA (20%) + S (10%)	78
Bentonite + FA (30%) + S (10%)	74
Bentonite + FA (40%) + S (10%)	64
Bentonite + FA (20%) + S (15%)	49
Bentonite + FA (30%) + S (15%)	34
Bentonite + FA (40%) + S (15%)	20

Table 7: OMC and MDD of white soil and biopolymer modified white soil

Sample Name	OMC (%)	MDD (KN/m^3)
WS	15.19	17.18

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WS+ XG (1%)	17.18	17.04
WS+ XG (2%)	17.79	16.30
WS+ XG (3%)	18.38	15.78
WS+ GG (0.5%)	17.28	16.95
WS+ GG (1%)	17.35	16.84
WS+ GG (2%)	17.88	16.17

Table 8: UCS of white soil and biopolymer modified white soil without and with curing period of 3 and 7 days

Sample Name	**UCS (kPa)0 day (without curing)**	**UCS (kPa) 3 days**	**UCS (kPa) 7 days**
WS	95.86	115.86	113.10
WS+ XG (1%)	105.77	114.08	109.62
WS+ XG (2%)	113.18	116.79	91.39
WS+ XG (3%)	122.91	120.13	72.19
WS+ GG (0.5%)	129.37	115.58	137.08
WS+ GG (1%)	131.78	118.89	125.66
WS+ GG (2%)	133.16	121.59	89.94

Table 9: UCS of white soil and biopolymer modified white soil kept for sundried with curing (3 days)

Sample Name	**UCS (kPa) (sundried 3 days)**
WS	300.93
WS+XG (1%)	2521.77
WS+XG (2%)	3030.25
WS+XG (3%)	3041.00
WS+GG (0.5%)	2557.66
WS+GG (1%)	2656.95
WS+GG (2%)	3481.28

Table 10: Comparison of resistance to loss in strength for white soil and biopolymer modified white soil

Sample Name	UCS ofcontrolledsample (UCSC)(kPa)	UCS ofsoakedsample(UCSS)(kPa)	Increase or decrease in strength from control sample (CS) to soaked	Resistance to loss in strength (RLS= UCSS/UCSC)

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			sample (SS)	
WS+XG (1%)	50.37	109.73	Increase	+2.18
WS+XG (2%)	42.20	83.40	Increase	+1.98
WS+XG (3%)	37.71	69.90	Increase	+1.85
WS+GG (0.5%)	54.06	116.02	Increase	+2.15
WS+GG (1%)	53.68	125.27	Increase	+2.33
WS+GG (2%)	44.21	90.98	Increase	+2.06

Table 11: OMC and MDD of pond ash and biopolymer modified pond ash

Pond ash	Pond ash+ XG/GG (%)	OMC (%)	MDD (kN/m^3)
RSP1	Pond ash	40.93	10.8
	Pond ash+ XG (2%)	55.69	9.11
	Pond ash+ GG (2%)	48.34	9.58
RSP2	Pond ash	38.13	11.57
	Pond ash + XG (1%)	44.79	10.36
	Pond ash + XG (2%)	42.86	10.33
	Pond ash+ XG (3%)	43.55	9.86
	Pond ash + GG (0.5%)	43.83	10.47
	Pond ash + GG (1%)	46.95	10.34
	Pond ash+ GG (2%)	41.4	10.59
AND	Pond ash	38.66	11.3
	Pond ash + XG (2%)	44.79	10.11
	Pond ash+ GG (2%)	42.35	9.31

Table 12: UCS of pond ash samples and biopolymer modified pond ash

Pond Ash	Pond ash + XG/GG (%)	UCS (kPa) 0 day	UCS (kPa) 7 days	UCS (kPa) (sundried 1 day)
RSP1	Pond ash	76.59	-	-
	Pond ash + XG (2%)	86.07		
	Pond ash + GG (2%)	156.14	-	
RSP2	Pond ash	102	28	126
	Pond ash + XG (1%)	140	87	210
	Pond ash + XG (2%)	149	91	216
	Pond ash + XG (3%)	154	99	221

	Pond ash + GG (0.5%)	98	92	199
	Pond ash + GG (1%)	160	147	202
	Pond ash + GG (2%)	169	149	204
AND	Pond ash	91	-	-
	Pond ash + XG (2%)	129	-	-
	Pond ash + GG (2%)	131	-	-

V. CONCLUSION

- 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%).
- 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.
- 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.
- 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.
- 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.
- It was observed that with addition of biopolymer, OMC increased and MDD decreased for dispersive soil. However, The UCS value increased with addition of biopolymer.
- With same percentage of gum, it was observed that dispersive soil stabilized with guar gum has better strength compared to that of Xanthan gum.
- 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%.
- Based on crumb test and double hydrometer test it was seen that white soil was extremely dispersive (89.57%) and became non-dispersive with addition of biopolymer.
- 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.
- With same percentage of gum, it was observed that pond ash stabilized with Guar gum had better strength compared to that of Xanthan gum.
- 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 expansive and dispersive soil. IT was also observed that geopolymer is more effective

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than biopolymer in terms of stabilization

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