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Effect of Sea Water on Free Swell Index of Stabilized Swelling Soil

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***Abstract*: Around 20% of India and 8% of world land is covered by swelling soil. Hence we cannot avoid these soils for the construction of pavement and other construction activities. One way to improve Engineering properties of swelling soil is to blend it with other admixtures. Researchers all over the worlds use different type of chemical admixtures to improve engineering properties of swelling soil. In this study fly ash, lime and lime activated fly ash are used to stabilize swelling soil with the presence of sea water. The determination of free swell index of soil helps to identify the potential of a soil to swell. By conducting Free swell test on stabilized swelling soil shows better result in lime activated fly ash treated soil mixed with sea water.**

***Keywords*: Swelling soil, Admixture, Fly ash, Lime, Lime activated fly ash, Sea water, Free Swell Index.**

1. Introduction

Soil is one of the most commonly encountered materials for civil engineering construction. All the structures except some ultimately rest on soil. Geotechnical engineers all over the world face enormous problems, when the structures founding on those soils are swelling in nature. Swelling is imparted to such soils when they contain clay minerals such as montmorilonite, illite, kaolinite etc. The swelling soils expand on wetting and are subjected to shrinkage on drying. The problem of instability of structures constructed on such soil is mainly due to lifting up of the structures on heaving of soil mass under the foundation, due to saturation during rainy season and settlement due to shrinkage in summer season. Due to shrinkage, cavities are formed leading to loss of contact between the soil and structures at some points. This in turn leads to splitting of structure and failure due to loss of shear strength or unequal settlement. During rainy season when the foundation soil swells it is restrained by the foundation. As a result, an upward swelling pressure is exerted by the soil on the foundation. Since this pressure is not uniform everywhere, the net downward pressure becomes uneven. This also leads to unequal settlement, leading to progressive failure of structures.

In coastal areas there are long bay- roads near to the sea. Seasonally or during tidal surges in the sea, the saline water saturates the soils of those roads. During some period of the year those roads may also remain partially submerged with saline water. In saline condition, various chemical admixtures show different impacts on engineering properties of soil.

Free swell is the increase in volume of soil, without any external constraints, on submergence in water. The possibility of damage to structures due to swelling of expansive soil should be identified. Inferential testing is resorted to reflect the potential of the system to swell under different conditions. Actual magnitude of swelling pressures developed depends upon the dry density, initial water content, surcharge loading and several other environmental factors. The scope of free swell index test is to determine the free swell index of the soil which helps to identify the potential of a soil to swell which might need further detailed investigation regarding swelling and swelling pressures under different field conditions. In the present investigation fly ash, lime and lime activated fly ash were chosen for stabilizing swelling soil in coastal areas. There are other reasons behind the choice of these admixtures as a stabilizer. They are costless and abundantly available all over the country. Fly ash is a by-product of thermal power plants; land area required for its disposition is a great problem in a densely populated country like India. Utilization of fly ash solves the problem of air and water pollution. The objective of the present investigation is to study the effect of saline water on virgin swelling soil as well as stabilized swelling soil.

2. Materials Used

The materials adopted in this study are bentonite clay, fly ash, lime, lime activated fly ash, sea water and Tap water.

A. Bentonite clay

Bentonite is a form of clay which comprises of montmorillonite. Bentonite used in this study mainly comprises of sodium ions as their major constituent. The material was collected from Associate chemicals, Kochi, Kerala.

Fig. 1. Bentonite clay

Table 1
Properties of Bentonite clay

Properties	Value
Specific Gravity	2.57
Liquid Limit	336%
Plastic Limit	50%
Shrinkage Limit	12.4%
Plasticity Index	169.03%
Optimum Moisture Content	40%
Maximum Dry Density	1.19 g/cc
Soil Classification	CH
Percentage of clay content	98.6%
Percentage of silt content	1.4%
Differential Free Swell Index	120 %
UCC Strength KN/m^2	90.742
Coefficient Of Permeability	$3.2x10^{-10}$ m/s

B. Fly ash

Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. Fly ash is produced by coal-fired electric and steam generating plants. Class F ashes are typically derived from bituminous and anthracite coals and consist primarily of an alumino-silicate glass, with quartz, mullite, and magnetite also present. Class F, or low calcium fly ash has less than 10 percent CaO. In this project class F fly ash was used and it is collected from Tuticorin thermal power plant, Tamil Nadu.

Fig. 2. Fly ash

Table 2
Properties of Fly ash

Properties	Value
Specific gravity	2.18
Liquid limit (%)	28.3
Plastic limit (%)	Non plastic
Shrinkage limit (%)	11
Plasticity index	Non plastic
OMC (%)	31.3
MDD (g/cc)	1.6
Clay (%)	16.25
Silt (%)	29.75
Sand (%)	46
UCS (kN/m^2)	168.67
Class	F

C. Lime

The lime used was commercial hydrated lime ($Ca(OH)_2$). It was collected from local market of Trivandrum.

Fig. 3. Hydrated lime

Table 3
Properties of Lime

Properties	Calcium Hydroxide
Physical appearance	Dry white powder
Specific gravity	1.2-1.5
Bulk density (Kg/m^3)	Max 500
Boiling temperature(^{0}C)	100
pH	12.4

D. Sea water

Sea water can be defined as a weak solution of almost everything. Ocean water is indeed a complex solution of minerals salts and of decayed biological matter. Sea water that makes up the oceans and seas covers more than 70% percent of earth's surface. Sea water is a complex mixture of 96.5 percent water, 2.5 percent salts, and smaller amounts of other substances, including dissolved inorganic and organic materials, particulates, and a few atmospheric gases. The six most abundant ions of sea water are chloride (Cl^-), sodium (Na^+), sulfate (SO_4^{2-}), magnesium (Mg^{2+}), calcium (Ca^{2+}), and potassium (K^+). In this project the sea water is collected from St Andrews beach, kazhakuttom, Kerala, India.

3. Experimental method

Fly ash treated with bentonite clay mixed with both tap water and sea water are tested to determine free swell index. Also lime and lime activated fly ash were used instead of fly ash to determine free swell index. The testing program was conducted on different percentage of additive treated soil mixed with tap water as well as sea water according to Indian standard method. All tests were conducted at the laboratories of Marian Engineering College Thiruvananthapuram, Kerala.

5g Bentonite clay mixed with (0%, 10%, 20%, 30%, and 40%) fly ash. Another set of samples are made by mixing bentonite clay with (0%, 2%, 4%, 6%, 8%, 10%) lime. Finally, another set of sample taken as bentonite mixed with 20% fly ash and by adding different percentage of lime. (20% fly ash +0% lime, 20% fly ash +2% lime, 20% fly ash +4% lime, 20% fly ash +6% lime, 20% fly ash +8% lime, 20% fly ash +10% lime).

Each soil specimen was poured in each of the two graduated glass cylinders of 100 ml capacity. One cylinder was filled with kerosene oil and the other with distilled water up to the 100 ml mark. Also another cylinder filled with sea water. After removal of entrapped air, the soils in the cylinders were allowed to settle sufficient time not less than 24 hours for the soil sample to attain equilibrium state of volume. The final volume of each soil

sample was taken and free swell index was calculated by following equation,

$$\text{Free swell index} = \frac{Vd - Vk}{Vk} \text{ x } 100$$

Where,

V_d = the volume of soil specimen read from the graduated cylinder containing distilled water.

V_k = the volume of soil specimen read from the graduated cylinder containing kerosene.

4. Result and discussion

A. *Free swell index on fly ash mixed bentonite clay*

Table 4
Free swell index on fly ash treated bentonite clay mixed with both sea water and tap water

S. no.	% of fly ash	Tap water	Sea water
1	0	120	100
2	10	100	50
3	20	80	40
4	30	50	25
5	40	33.33	16.67

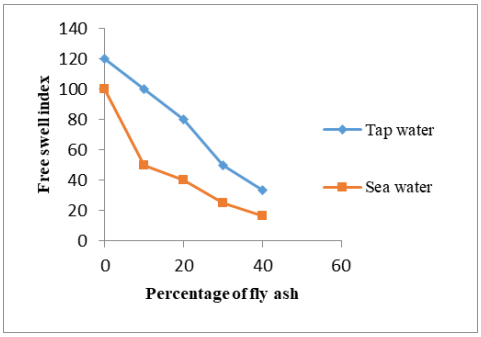

Fig. 4. Variation of free swell index in fly ash mixed bentonite clay in both tap water and sea water

The graph shown above shows that the free swell percent decreases with increasing fly ash content in presence of both tap water and sea water. The differential free swell percent in saline water is lower than that in tap water, indicating reduction in swelling potential in saline water. Free swell values of virgin bentonite clay in saline water are lesser than those in tap water. These reductions may be due to the fact that at higher salt content, cation concentration increases which resulted in depressed double layer thickness due to cation exchange reaction. This result could be supported by the double layer thickness is depressed with cation exchange and along with increased electrolyte concentration.

B. *Free swell index on lime mixed bentonite clay*

Table 5
Free swell index on lime treated bentonite clay mixed with both sea water and tap water

S. no.	% of lime	Tap water	Sea water
1	0	120	100
2	2	100	80
3	4	55	29
4	6	33.33	20
5	8	24	15.5
6	10	14.28	10.5

Test results showed that there is significant reduction in swelling of bentonite clay treated with lime and using sea water instead of ordinary tap water as mixing water. An increase in concentration of the medium surrounding soil causes a decrease in swelling potential of bentonite clay. A salty medium leads to a dramatic reduction in the swelling behaviour.

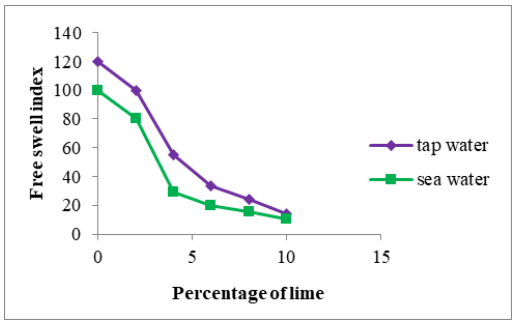

Fig. 5. Variation of free swell index in lime mixed bentonite clay in both tap water and sea water

C. *Free swell index on lime activated fly ash mixed bentonite clay*

Table 6
Free swell index on lime activated fly ash treated bentonite clay mixed with both tap water and sea water

S. no.	% of fly ash	% of lime	Tap water	Sea water
1	20	0	80	40
2	20	2	66.67	35
3	20	4	50	20
4	20	6	26	13
5	20	8	13	9.5
6	20	10	8.5	6

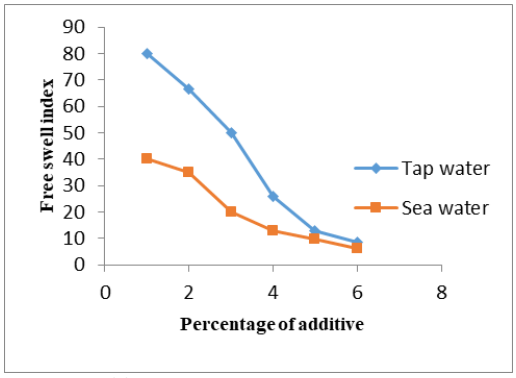

Fig. 6. Variation of free swell index in lime mixed bentonite clay in both tap water and sea water

Free swell index on lime activated fly ash treated bentonite clay mixed with both tap water and sea water. The reduction in free swell index of bentonite clay is more in lime activated fly ash compared to lime and fly ash. Also the reduction is more in sea water used as mixing water instead of ordinary tap water. The reason behind this was due to the adsorption of Ca2+ ions onto the clay particle surface decreases the repulsion between successive diffused double layers and this increases edge-to-face contacts between successive clay sheets. Thus, clay particles flocculate into larger clusters. The free swell index

decreased considerably with an increase in percentage of lime activated fly ash content.

5. Conclusion

Using fly ash, lime and lime activated fly ash as a stabilizer gives better results in presence of sea water. Lime activated fly ash-treated soil mixed with sea water is most economic method. In case of fly ash stabilization, by adding different percentage of fly ash leads to decrease in free swell index. Reduction in free swell index is more in case of sea water. This reduction may due to cation exchange and with the presence of strong electrolyte. It is also similar by using lime as an additive. By increasing different percentage of lime, free swell index gets reduced. Reduction was more in sea water as mixing water.

The presence of sea water as mixing water in the lime activated fly ash treated soil has formed a new fabric structure. By keeping 20% of fly ash as constant and by varying percentage of lime, the free swell index gets decreased with increase in percentage of lime. By using sea water instead of tap water index properties of the soil get improved due to flocculation and cation exchange, where positively charged ions in solution are substituted for other species of ions which are attached to the clay mineral crystals. The positive charged ions react with negative charged particles and allows the clay particles to clump together to form large particles.

It is clear that as fly ash and lime content increases the free swell index decreases. Reduction is more in case of sea water compared to tap water. Due to flocculation process, the thickness of double layer and repulsive force decreases. Hence it leads to reduction in swelling of soil. Economic impact on the projects of different structures or of roads network was gained via using the lime activated fly ash treated soil. There is no need for borrowing any materials to be used as base or sub-base courses of roads or as replaced soil for foundations of the structures. The materials are available at the site even if it was swelling soil. The sea water is available at the site as well. So, the lime activated fly ash-treated soil mixed with sea water is most economic method which saves borrowing the materials from outside of the project site. Sea water can be used instead of ordinary tap water. Environmental benefits are going to be gained from this process

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