Effect of Tap Water and Sea Water on Fly Ash Mixed Swelling Soil- A Comparative Study

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Abstract – *Around 20% area of our country and also more or less of the world is covered by swelling soil. Researchers all over the world use one or more other type of admixtures to stabilize and to improve the engineering properties of swelling soil Fly ash is one of the most commonly used admixture used for controlling the swelling properties of expansive soil. It is very important to study how fly ash stabilized coastal roads behaves with respect to swelling, when they are saturated with sea water and ordinary tap water. Some important tests like Atterberg's limit test, free swell index tests, UCC tests and standard compaction test were conducted on fly ash mixed swelling soil treated with tap water and sea water. And from the result of comparative study using both types of water shows that fly ash mixed swelling soil treated with sea water is more economical.*

Key Words: Fly ash 1, Admixture 2, Swelling 3, Expansive soil 4, Sea water 5, Tap water 6,Atterberg's limit 7,Free swell index 8, UCC test 9, Compaction 10.

1. INTRODUCTION

Soil is one of the most commonly encountered materials in civil engineering. All the structures except some, which are founded on solid rock, rest ultimately on soil. Geotechnical engineers all over the world face enormous problems, when the soils founding those structures are expansive in nature. This expansiveness is imparted to such soils when they contain clay minerals such as montmorilonite, illite, kaolinite etc. in appreciable quantity. 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) on saturation during rainy season and settlement due to shrinkage during summer season. Due to this 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. On the contrary, during rainy season when the foundation soil swells it is restrained by the foundation to do so. As a result, an upward swelling pressure is exerted by the soil on the foundation. As 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 saturate the soils of those roads. During some period of the year those roads may also remains partially submerged with saline water. In saline condition, as the treating of lime to swelling soil has reported to be uneconomic and ineffective, in the present investigation fly ash has been chosen as a stabilizing swelling soil in coastal areas. There are other reasons behind the choice of fly ash as a stabilizer. They are fly ash is costless and abundantly available all over the country. As 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 fly ash mixed swelling soil. To it was mixed fly ash in different proportions by weight from 0% (virgin soil), 10%, 20%, 30% and 40% of fly ash content. Soil engineering tests like differential free swell test, Atterberg's limit, and compaction were conducted on virgin soil and soil-fly ash mix. It was also required to conduct shear or other strength tests in presence of water and saline water.

2. MATERIALS USED

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

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	120 %

Index	
UCC Strength KN/m^2	90.742
Coefficient Of Permeability	3.2x10^{-10} m/s

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 Thoothukudi thermal power plant.

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

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 (SO42-), magnesium (Mg2+), calcium (Ca2+), and potassium (k+).In this project the sea water is collected from St Andrews beach, kazhakuttom.

3. EXPERIMENTAL METHODS

Fly ash mixed bentonite clay treated with both tap water and sea water are tested to determine Atterberg limits, free swell index, maximum dry density, optimum water content and unconfined compressive strength. The testing program was conducted on different percentage of fly ash treated soil mixed with tap water as well as sea water according to the rules of Indian standard. All tests were conducted at the laboratories of Marian Engineering College Thiruvananthapuram.

4. RESULT AND ANALYSIS

Table -3: Properties of Bentonite clay on tap water and sea water.

SL NO	PROPERTIES	TAP WATER	SEA WATER
1	Liquid limit	336%	120%
2	Plastic limit	50%	50.81%
3	Plasticity index	286	69.19%
4	Shrinkage limit	12.4%	15.948%
5	Differential free swell index	120	100

4.1 Atterberg's limit

A fine grained soil can exist in any several states; which states depends on the amount of water in the soil system. When water is added to the dry soil, each particle is covered with a film of adsorbed water. If the addition of water is continued, the thickness of the water film on a particle increases. Increasing the thickness of the water films permits the particle to slide on another more easily. The behavior of the soil therefore is related to the amount of water in the system.

The graph given below shows Atterberg's limits, namely liquid limit, plastic limit, shrinkage limit, those were conducted on virgin soil and soil- fly ash mix in tap water and sea water separately. The liquid limit decreases with increasing fly ash and saline water content. The plastic limit and shrinkage limit increase with increasing fly ash content for both types of water. The plasticity index of fly ash mixed expansive soil in sea water is less than that in tap water. Factors that affect the swelling potential of the swelling soils, such as the clay fraction (F = % finer than 0.002 mm in soil diameter) and its mineralogy.

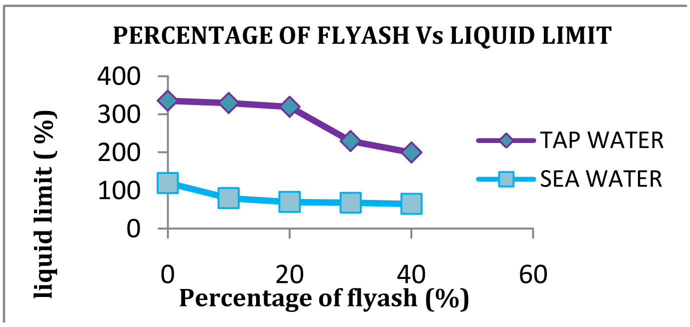

Chart -1: Variation of liquid limit with percentage of fly ash

As the clay fraction increases, the swelling potential increases. There is great effect on the activity of soil on the swelling behavior of soil. As the soil activity increases, the swelling behavior increases. It is known that the addition of fly ash can reduce the thickness of the diffuse double layer clay particles and cause flocculation of clay particles. Also it can increase the coarser particles content by substitute finer soil particles with coarser fly ash particles. These reasons all together cause the decrease in liquid limit and plasticity index and the increase in plastic limit. Plasticity index is a good indicator of swell potential. As the plasticity index reduces, the swell potential decrease. Addition of fly ash decreased the plasticity index of expansive soil significantly. This implies a reduction in swell potential with increasing in the addition of fly ash. The activity of soils is defined as the ratio of PI to the clay size fraction. Activity is an index of the surface activity of the clay fraction. Soils that are more active tend to have a greater quantity of minerals that have more chemically active surface. Above table shows that activity of soil decreases with increase of fly ash and saline water content. The decrease in activity represents the lower water affinity and consequently the lower liquid limit. The smaller particle size had higher surface activity. An increase in concentration of the medium surrounding the swelling soil causes a decrease in swelling potential. A salty medium leads to a dramatic reduction in the expansion.

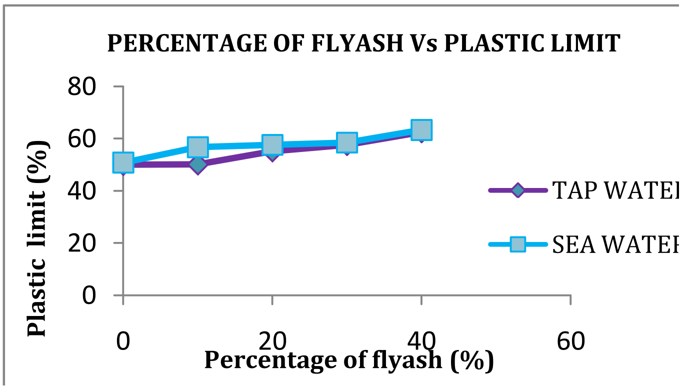

Chart -2: Variation of Plastic limit with percentage of fly ash

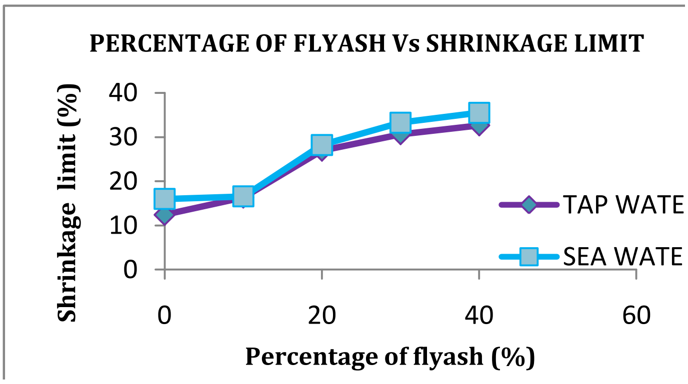

Chart -3: Variation of Shrinkage limit with percentage of fly ash

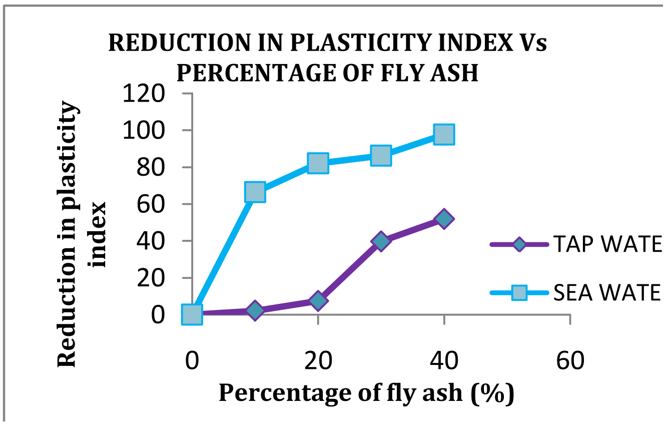

Chart -4: Variation of Plasticity index with percentage of fly ash

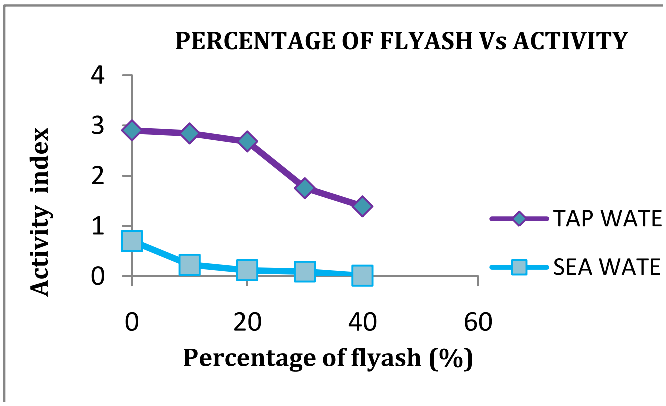

Chart -5: Variation of Activity with percentage of fly ash

4.2 Effect on differential free swell index

The free swell index is obtained by conducting Free Swell Index Test as per IS 2720 (Part XL). The free swell index obtained for control sample in both tap water and sea water. A comparison plot of free swell in sea water and tap water is shown in chart.

The graph shown below shows that the differential free swell percent decreases with increasing fly ash content in presence of both tap water and saline water. The differential free swell percent in saline water is lower than that in tap water, indicating reduction in swelling potential in saline water. Differential free swell values of virgin swelling soil 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 with aluminum, ferric and ammonium ions and with increased electrolyte concentration

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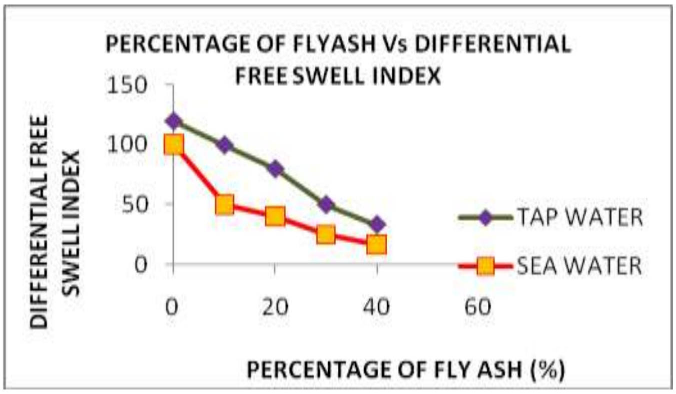

Chart -6: variation of differential free swell index with percentage of fly ash.

4.3 Effect on compaction

Proctor compaction test is a laboratory method of test is to define the optimal moisture content at which a given soil type will specifically. To determine the optimum water content at which soil be able to get to its maximum dry density. The optimum moisture content decreases and the maximum dry unit weight increases with an increase in fly ash content. This result indicates that swelling soil is stabilized by the addition of fly ash even at low water contents. The addition of fly ash increased compaction effort. Hence, expansive soil is rendered more stable. The optimum moisture content decreases by 25.17% and maximum dry unit weight increases by 1.480g/cc at 20% fly ash content in tap water. In case of fly ash mixed expansive soil treated with sea water reduces optimum moisture content by 23% and maximum dry unit weight increased by 2.9g/cc at 10% fly ash content. Addition of sea water and fly ash brings in an improvement in the compaction parameters of the steady soils by increasing the maximum dry density of soil, with decrease in the corresponding values of optimum moisture content. Furthermore, at given water content, the dry unit weight increases as the fly ash content increases. This indicates that the fly ash-blended expansive soil is rendered stable and this makes it a suitable material for sub grade, embankment and back-fill.

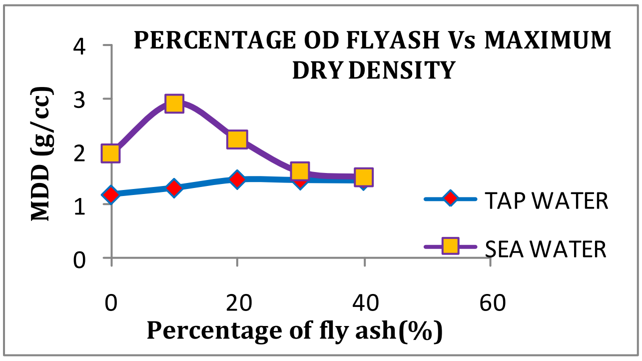

Chart -7: Variation of MDD with percent of fly ash in both tap water and sea water.

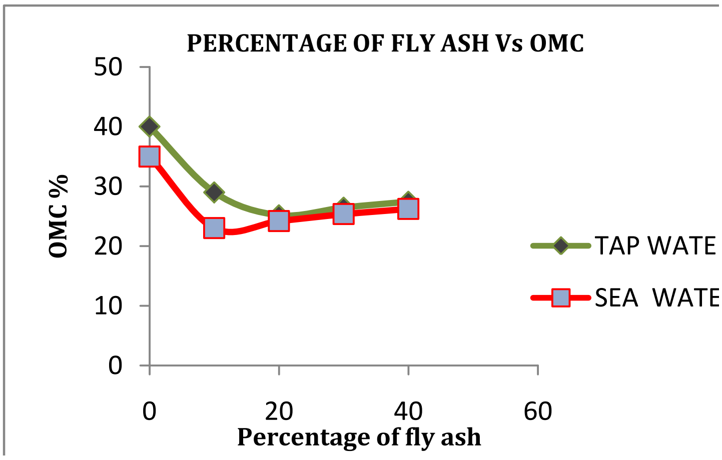

Chart -8: variation of OMC with percent of fly ash in both tap water and sea water.

4.4Effect on UCC test

Unconfined compressive strength ~IS 2720 PART 10 was determined by conducting unconfined compression tests at as compacted Proctor densities that corresponded to oven-dried water contents 40, 29, 25.17, 26.45, 27.44% of tap water and 35, 23, 24.2, 25.35, 26.23% of sea water. No curing period was allowed for the samples.

The UCC strength increases with an increase in fly ash content. At tap water content of 20% the increase in UCC strength is about 1.542Kg/cm^2 when the fly ash content is 20%. But in case of saline water, at sea water content of 10% the increased UCC value is 2.40Kg/cm^2 when the fly ash content is 10%. The increase in UCC results from the increase in dry unit weight with increased fly ash content for a given water content. The trend in variation of measured UCC value with water content is shown in Fig. It shows a steep decrease in UCC value with addition of more water for a given fly ash content. The unconfined compressive strength of the soil increase with the addition of sea water and fly ash.

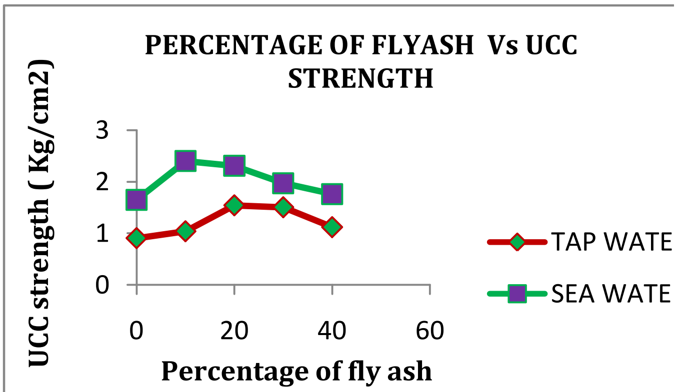

Chart -9: Variation of UCC strength with percent of fly ash in both tap water and sea water.

5. CONCLUSION

Using fly ash as a stabilizer gives better results in presence of sea water. Fly ash-treated soil mixed with sea water is most economic method. The presence of sea water as mixing water in the fly ash treated soil has formed a new fabric structure of high rigidity as well as of high shear strength. Accordingly, the new fabric structure became capable to resist the compression process. 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 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 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 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. This method leads to saving the costs of transportation. The delay of project execution due to scarcity of water or transportation problems can be avoided as all materials are available at the site. As a result, the overall construction duration and costs are going to be dramatically reduced. Environmental benefits are going to be gained from this process.

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