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Stabilization of Marine Clay a Viable Means to Rain Harvesting

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Abstract*—Providing water to India's ever-increasing population is a growing problem. The quantity of water available is reducing yearby year. The challenge before us is to preserve the available free rain water to the maximum for future use. This is profoundly true because water is needed not only for the basic needs of human beings,and livestock but alsofor agriculture, power generation and all kinds of industry. In fact water is an unavoidablecommodity for all of creation.*

This study proposes to suggest economically viable solutions to this problem through thestorage of water in earthen structures—including reservoirs, canals and ground tanks. Maintaining surface storage of harvested rainwater with minimum or no loss is a major concern, although there are various methods to preserve harvested water. Most modern solutions are costly and unaffordable to the general public. Therefore,this study evaluates methods to maximize water storage on ground surface reservoirs. This calls for minimum, if not zero permeability, and good shear strength. Clayhas a detrimental effect on structures, especially when there is variation in moisture movement. Permeability and shear strength play an important role in determining the behavior of clayey soil under wet conditions; hence these are two major factors considered in this study. A sincere effort has gone into determining the optimum percentage of admixtureto reduce the permeability of soil usingthe commonest ingredients such as cement, lime and their combinations. This paper presents the findings of an experimental study.

Keywords*— *surface reservoirs, permeability, shear strength, detrimental effect, optimum percentage of admixture

I. INTRODUCTION

Water harvesting is the need of the hour. Drinking water is a basic necessity for the growing population. Studies conducted by various agencies prove this fact beyond doubt. Consider New Delhi, India's capital, for example: In 1961, New Delhi had a population of 26.6 lakhs, while its sources of raw water were from wells sunk along the Yamuna. There were 5 water treatment plants having a total capacity of 35 MGD and one sewage treatment plant having a capacity of 18 MGD. In 1981 the population was 62.22 lakhs, while the sources of raw water werewells sunk along the Yamuna, Bhakra, storage / Yamuna, upper Ganga canal and eight water treatment plants having a total capacity of 303 MGD and seven sewage treatment plants with a capacity of 122 MGD. In 2001, the population of Delhi was 138.5 lakhs, the sources of raw water were wells sunk along the Yamuna, Tehri, upper Ganga Canal, Bhakra, storage / Yamuna, upper Ganga Canal Ground water and 11 water treatment plants having a total capacity of 715 MGD and 11 sewage treatment plants having a capacity of 346 MGD (figures courtesy studies published by Centre for Science and Environment) The demand for water is growing in many cities. India's urban population has grown by almost five times in five decades. Till a few years ago, our cities were self-sufficient in meeting their water needs, thanks to the available water bodies. But the condition today is different: most water bodies have completely disappeared. The municipalities are under increasing strain to provide water to the multiplying urban population.

Currently, the people depend on the governments for management and distribution of water. Therefore, the governments are under pressure to launch new projects to meet the need. Rather than helping to provide solutions, the public continues to be a demanding group. Public participation in collecting and preserving water is now the need of the hour. We also need to revive traditional systems for collecting and distributing water.

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An old technology is now gaining popularity—it involves collecting and using rainfall from a catchment's surface. Rainwater harvesting in a large scale has existed for more than 4000 years in Palestine and Greece. In ancient Rome residences were built with individual cisterns and paved courtyards to capture rain water. Rain water harvesting is essential because surface water is inadequate to meet our demands. Rapid urbanization has resulted in decrease in infiltration of rain water into the sub-soil and recharge of ground water has diminished.

Rain water harvesting is done either through storage of water on the surface for future use or through recharge to ground water. The storage of rain water is a traditional technique and the structures used were underground tanks, ponds, check dams, weirs etc.Recharge of ground water is a new concept in rainwater harvesting and is done through pits, trenches, dug wells, hand pumps, recharge shafts, lateral shafts with bore wells, and spreading technique. There are various methods of water harvesting available but we need to choosecost-effective ones, depending on the catchment area available. One of the most effective methods is to store water in large open reservoirs,and preserve it with minimum or no loss. Stabilizing the interior of the pond with admixture is found to be a good and cheap solution.

Soilstabilization is the process of improving the engineering properties of the soil, and thus to make it more stable. It is required when the soil available for construction is not suitable for its intended purpose. In its broad sense, stabilization includes compaction, preconsolidation, and many other processes. However the term stabilization is generally restricted to the process which alters the soil material itself for modification of its properties.

Soil stabilization is generally used to:

Increase or reduce strength or reduce sensitivity to the environmental changes, especially moisture changes

Increase or reduce permeability

Reduce compressibility

Check frost susceptibility

The need for maximizing water storage in earth structures like reservoirs, canals, and ground tanks calls for a minimum, or zero permeability and good shear strength.

II. OBJECTIVES OF STUDY

The objective of this study is to evaluate the quality and sustainability of soil lining of ground water storage at Bhayander. Marine clay soil abounds in this place as in other parts of Mumbai. These soils are characterized by low strength, high compressibility and sensitivity to disturbances. These properties make such places unsuitable and problematic for civil engineering construction. Marine clay deposits exhibit very low shearing strength and great affinity towards water. So it is very difficult to use such soil for any type of structure without suitable treatment. This study will investigate the mechanical properties of Bhayander soil. The permeability characteristics of the soil is analyzed, along with the variation of SL, UCS & CBR on stabilization. Strength and shrinkage characteristics along with permeabilityisstudied. Though there are various methods available, stabilization by additives are preferred. The additives usually employed are cement, lime, fly-ash, asphalt, and other chemicals. Thecommonest stabilizers, cement and limehave been proved to be veryeffective and are preferred for soil selected.

III. DISCUSSION OF RESULTS

Results of the tests have been presented and discussed below for Bhyander soil. The results are super imposed for the comparison of the effect of differenttypes of stabilization on different properties like permeability, UCS and CBR

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TABLE

Bhayander soil

Coefficient permiability cm/sec X 10^{-7}				
total concentration of admixture	Cement	Lime	Cement + Lime	Cement + Cont. 2% Lime
0 Percentage	2.93	2.93	2.93	2.93
0.5 percent	2.81	-	2.6	-
2 percent	0.97	2.7	0.89	2.7
4 percent	2.2	3.6	1.07	1.07
8 percent	0.97	6	1.36	4.49
12 Perccent	0.53	-	0.95	3.53
16 Percent	0.14	9.4	0.53	2.56

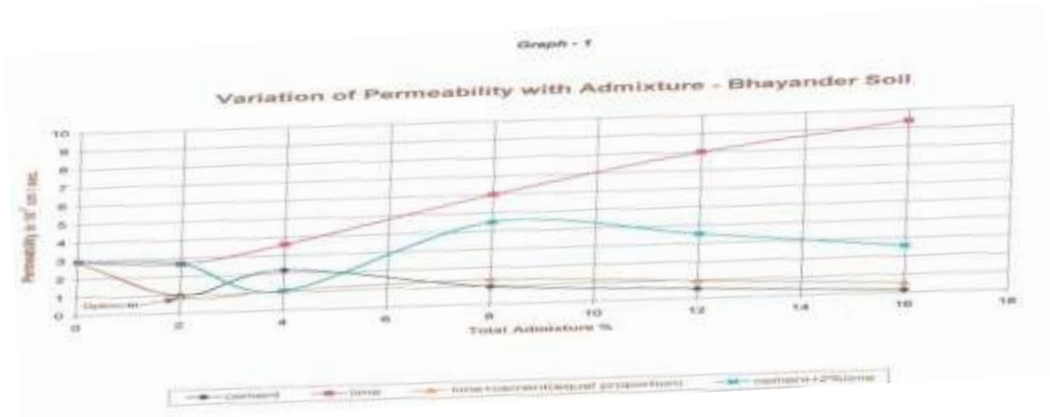

FIGURE 1:Variation of permeability with admixture-Bhayander soil

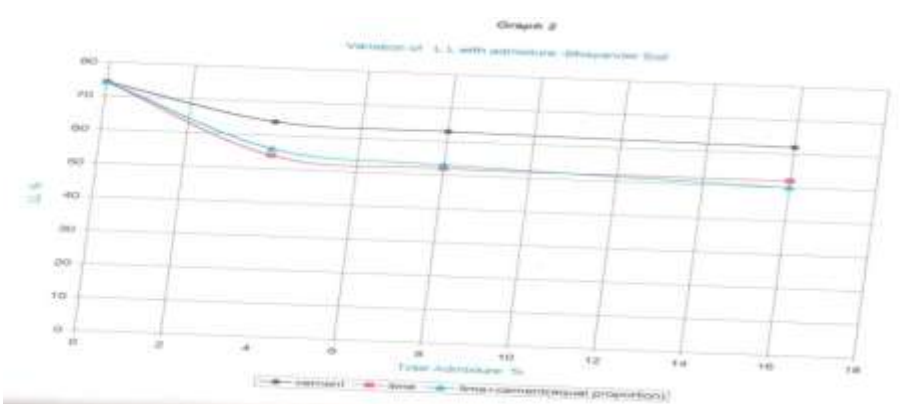

FIGURE 2:Variation of LL with admixture-Bhayander soil

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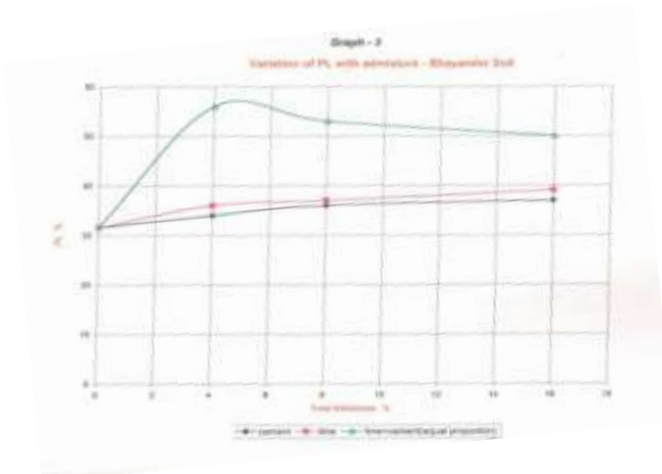
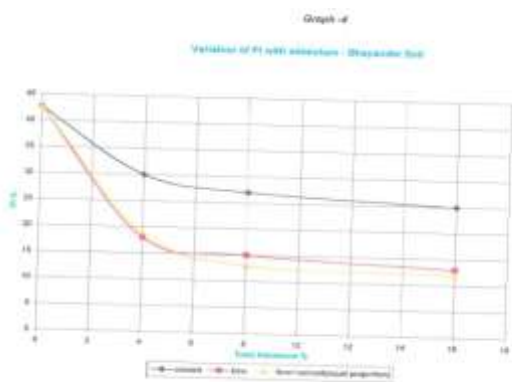


FIGURE 3:Variation of PL with admixture-Bhayander soil



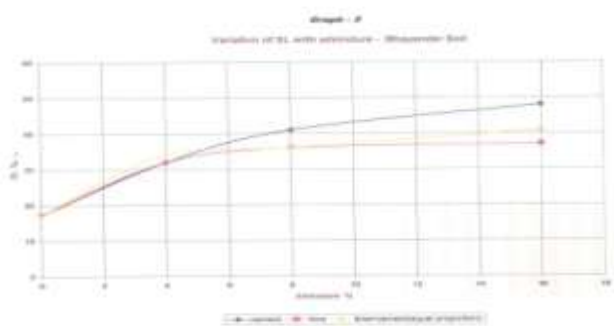


FIGURE 4:Variation of PI with admixture-Bhayander soil

FIGURE 5:Variation of SL with admixture-Bhayander soil

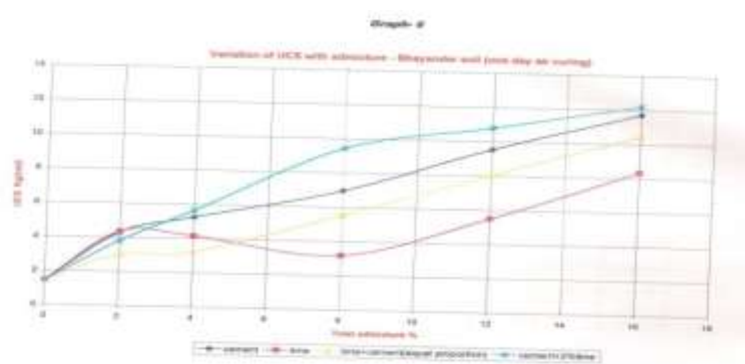


FIGURE 6:Variation of UCS with admixture-Bhayander soil

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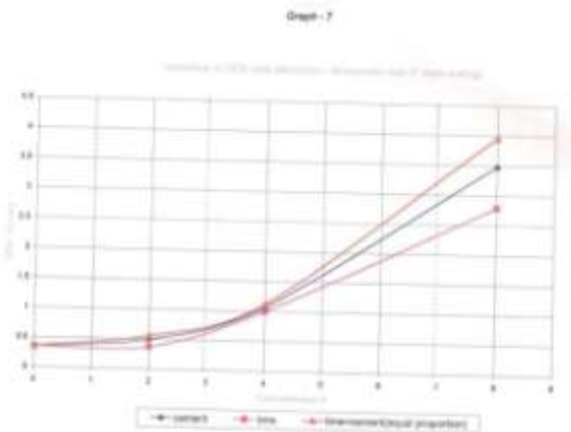

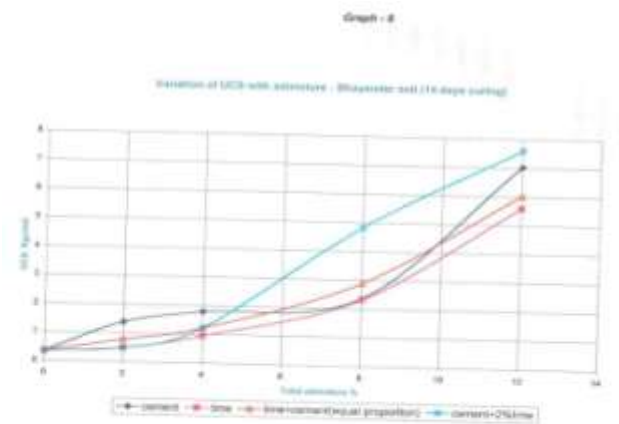

FIGURE 7:Variation of UCS with admixture-

Bhayander soilFIGURE 8:Variation of UCS with admixture-Bhayander soil

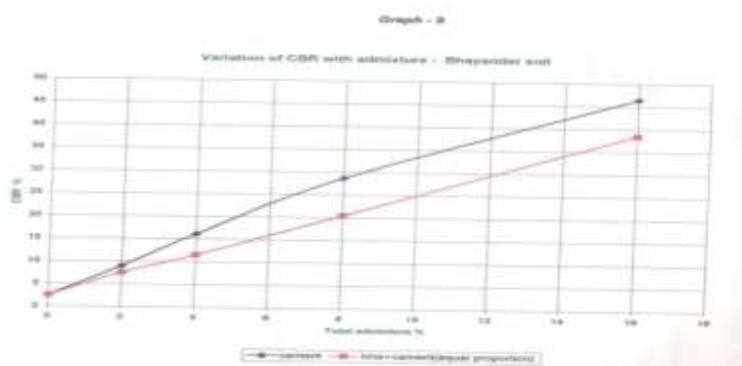

FIGURE 9:Variation of CBR with admixture-Bhayander soil

The variation of permeability on stabilization of Bhayandersoilis shown in **Graph 1, Graph 2,3,4,5** give LL, PL, PI and SL respectively of the stabilized soil. The variation on UCS on stabilization of Bhayander Soil is shown in **Graph 6, 7, 8**. The Variation on CBR on stabilization of Bhayander soil is shown in Graph 9.

This particular soil is predominantly clay of about 96% as per particle size analysis. Differential free swell index of 17.9 % indicates that the soil is a non-swelling soil. Shrinkage limit is also quite high as 17.3% confirming the non-swelling character. Therefore detrimentaleffects due to swelling arenegligible

Keeping permeability as the first and foremost important property to be considered for lining of ponds, reservoirs, canals etc., the variation in permeability is discussed first. Permeability for this soil is found out as 2.93 X 10^{-7} cm/sec, which is generally a low value of permeability. Stabilization further reduced the permeability to a great extent.

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Graph1indicates that, when lime is used as an admixture, till 2% lime, permeability decreased slightly due to the introduction of fines into the soil and afterwards it increased continuously as the percentage lime is increased. This is due to decrease in the LL and PI due to addition of lime. By adding lime the CaO reacts with aluminia, silicate and calciumions and reduced the plasticity of cohesive soils. Increase in effective grain size distribution is observed by adding lime to clay soil. This increased the permeability. Similar trend is reported for sandy clay. Hence it is not advisable to use lime for reducing the permeability of the soiland can be used where better drainage is required.

In the case of cement, effects of decrease in LL, PI and gelling or pozzolanic reactions are seen. The permeability depends on which reaction is predominant. When cement is used as an admixture, till 2%, permeability decreased as in case of lime due to introduction of fines. It is understood that the quantity of cement used is small (2% to 4%) though it reacts with clay particles together into coherent mass. Effect of decrease in LL and PI is predominant compared to pozzolanic action of cement. That is why at a particular range i.e between 2 to 4 % in this case there is a slight increase in permeability. A further increase in cement decreased the permeability continuously to a lower value since pozzolanicreaction is predominant. This decrease in permeability of the cement-stabilised soil is due to interlocking network throughout the soil mass and due to the hydration of cement and the gelling action.

When equal amounts of cement and lime were added initially there is a decrease in permeability till 2% (cement + lime) as in the above two cases, then increased slowly up to 8%. Further addition did not yield an appreciable change giving a compensating behavior.

When (cement + 2 % lime) were added permeability decreased up to 4% due to the introduction of fines into soil. The increase in permeability up to 8% is due to decrease in LL and PI and inadequate cement content for pozzolanic reaction.Above8% permeability continuously reduced, though marginally, as the percentage of admixture is increased due to pozzolanic reaction being predominant

Out of the four typeof combination tried;equal amount of (cement + lime) is found to give the least permeability at the earliest trial; that is at 2%(cement +lime)as shown in the Graph. Hence a combination of 2% (cement + lime) takenequally is considered as the optimum combination for the soil-lining. The least permeability 0.89 x 10^{-7}cm/ sec is considered as the optimum permeability. A percentage reduction in permeability with reference to original permeability 2.93 x 10^{-7}cm/sec is about 70% or reduction is approximately one third of the original permeability.

Graphs 2,3&4 indicates that on stabilization, in all types of combination of admixture, the liquid limit decreased and the plastic limit increase thereby reducing plasticity index as the percentage of admixture is increased indicating a reduction inswellingpotential as the percentage admixture is increased . The Graph 5 shows that the shrinkage limit of the soil increased indicating a reduction in swelling potential as the percentage admixture is increased.Stabilizationchanged the failure mode of the soil from plastic to brittle and developed a high tensile stress of the soil causing tensile stress of the soil causing high shrinkage. Itis found that cracks started appearing in the shrinkage limit soil pat 4%of admixture in all combination and the cracks widened as the percentage is increased. These cracks are due to thehydration reaction and not due to swelling properties. Sincethese shrinkage cracks are very much undesirable and cause further loss of water, these higher proportion of admixture shouldbeavoided in stabilization work. Though higher percentage (above 4%) of admixture gave low permeability, due to adverse effect of shrinkage these cannot be recommended for soil lining.

Unconfined compressive strength test is carried out with one-day air curing because the tests on cement and lime revealed that minimum three hours' time is required for cement and lime for its final setting. **Graph 6** shows that in three types of combinations like cement, equal (cement + lime) and (cement + 2 % lime), the strength increased as the % of admixture is increased. However the test results are obtained with (cement + 2% lime) where strength increased to 1.21Kg/cm2 from 1.46 Kg / cm2. In case of lime also there is an increase in strengthup to 2 % then it reduced up to 8% then continuously increased. This change in the increasing trend of strength in case of lime could be due toabad specimen.

The optimum combination defined earlier with reference to the permeability criteria and shrinkage criteria is 2 % (lime + cement). At this proportion the corresponding UCS is 3.01 Kg/cm^2 and is sufficient for the lining of canals, ponds etc. The percentage of improvement in UCS with reference to the natural soil of 1.46 Kg/cm^2 is 106 % or the increase is approximately two times the original value.

UCS Tests were also conducted with 7 days curing, covering the specimens with wet sackcloth; the specimens with lower percentage of cement gave very low strength after curing. Table 13 shows that the cured strength of natural soil is less than that of the uncured, due to softening of the soil after curing. 7 days as well as 14 dayscured strength of natural soil is reduced to0.35 Kg /$cm^2$with respect to the uncured strength of 1.46 Kg/cm^2. Curing reduced the strength in stabilized soil also. **Graph 7&8**

shows the increasing trend of cured UCS in stabilized soil. The value of cured UCS at optimum proportion is 0.56 Kg/cm^2 and 0.78 kg/cm^2 for 7 days and 14 days respectively.

CBR tests were conducted and the effect of stabilization is very good on CBR. Two types of combinations, cement and equal (cement + lime) were carried out.**Graph9** shows rapid increase in CBR. At optimum proportion of 2% (cement + lime), the CBR increased to 7.5% with reference to 2.48% of natural soil. The percentage increase is 204%.

Thus stabilizingBhayander soil, which is non-swelling type with proper combination of cement and lime showed the required reduction in permeability while strength characteristics of the soil were improved

IV. CONCLUSION

Studies on the stabilization effect of inorganic chemicals like cement and lime in Mumbai Marine clay revealed that these soils are very responsive to stabilization in reducing their permeability and increasing their strength characteristics. The shrinkage characteristics played a very important role in deciding the extent of stabilization for a particular soil. The optimum proportion based on permeability and strength criteria for Marine clay from Bhayander is 1% cement + 1% lime. Hence soil stabilization by admixtures would be a viable and economic solution for storage of harvested water on surface reservoirs in marine clays.

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