A Study on The Assessment of Egg Shell Powdwer Activated GGBS In Improving Weak Marine Clay

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Abstract- *Marine clay is a type of clay found in coastal regions around the world. In the northern, deglaciated regions, it can sometimes be quick clay, which is notorious for being involved in landslides. Being a developing country for India has large area coming under coastal region and also it has been the habitat for considerable percentage of population. Structurally marine clay creates lot of damages to the structures which have construct over them. Problems of marine clay have appeared as cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, irrigation systems, water lines, and canal and reservoir linings. In now a days there is a lot of research work done on the stabilization of soil by using different waste materials produced from various sources like agriculture, industrial, transportation, textile and etc. The present study deals with testing of a typical Marine clay deposit of Kakinada with the aim to investigate its engineering properties and further stabilize it to be suitable for foundation constructions or as sub-grades by using proposed waste materials with different percentages. In the present work, compaction & strength properties of weak marine clay was determine by weak marine clay was replaced with GGBS from 0% to 25% with an increment of 5%, ESP was added to the optimum mix of GGBS-Clay from 0% to 12% with an increment of 3% in order to determine the optimum mix of ESP-GGBS-Clay. Also the various properties of ESP-GGBS-Clay planned to determine at various curing periods like 7, 14 & 28 Days.*

I. INTRODUCTION

India has large coastline exceeding 6000kms. In view of the developments on coastal areas in the recent past, large number of ports and industries are being built. In addition, the availability of land for the development of commercial, housing, industrial and transportation, infrastructure etc. are scarce particularly in urban areas. This necessitated the use of land, which has weak strata, wherein the geotechnical engineers are challenged by presence of different problematic soils with varied engineering characteristics. Many of these areas are covered with thick soft marine clay deposit, with very low shear strength and high compressibility.

Majority of the population in India depends on road-based transport. There are many deposits of fine clays on coastal corridor and those soils are suffering from high saturation, low density, low shear strength, sensitivity, and deformation problems and are normally consolidated. The marine clays, because of the specific physico-chemical make-up, are subjected to volume change with the changes in their ambient environment. These soils are widely occupied in costal corridor and not easy to avoid marine clay regions for the construction of pavements and foundations due to the population density.

These soils are generally found in the states of West Bengal, Orissa, Andhra Pradesh, Tamilnadu, Kerala, Karnataka, Maharashtra and some parts of Gujarat in India. So there is need to improve transportation and also the construction facilities in these coastal regions for easy access. Marine clays exist in these regions are weak and highly compressible in nature.

The marine clays are not suitable as pavement sub grade & foundation soil beds and pose problems due to their inability of strength criteria. More and more construction projects are encountering soft clays and hence there is a need to better quantifying the properties of marine clays.

Objective

- To find the approach of techniques to overcome the problems created by marine clays with a view to adopt suitable procedure through critical review of literature.
- Laboratory experimentations will conduct to study the impact of proposed additives and admixtures on the properties of marine clays.
- To evaluate the performance of marine clay when stabilized with proposed additives and admixtures and their suitability for fill material and sub grade material.
- To investigate the suitability and adoptability of Nylon Fibers (NF) as discrete reinforcement.

II. REVIEW OF LITERATURE

Weak marine soil deposits have been found both on the coast and in several offshore areas spread over many parts of the world. When clay particles precipitate in salt water, there is a tendency for the clay particles to flocculate and stick together giving rise to some sort of edge-to-face arrangement. As a result, clay, silt, and fine sand particles settle almost at the same rate and the final sediment formed consists of particles with a very loose card house-like structure. Hence the marine sediments can be considered as loose sediments, usually formed with high void ratios. Problems are associated with these fine-grained soils deposited at a soft consistency. Fine-grained soils are very sensitive to changes in the stress system, moisture content and system chemistry of the pore fluid.

The marine deposits are mainly confined along a narrow belt near the coast and generally derived from terrestrial sources. In the south-west coast of India, there are thick layers of sand above deep deposits of soft marine clays. These deposits are very soft to soft normally consolidated highly compressible clays. The sensitivity range is in the order of slight to medium sensitive and essentially inorganic in composition. The thickness of deposits varies from 5- 20mt.

PROBLEMS ASSOCIATED WITH MARINE CLAYS

- Damages to the Pavement Sub grades
  - Rutting
  - Longitudinal cracks
- Damages to the building foundations
- Damages to super structure
- Cracks in buildings

REMEDIAL MEASURES TO OVERCOME PROBLEMS OF MARINE CLAY

If soil has a high deformation, the preventive measures are required. These measures can be broadly classified into the following categories.

- Avoiding highly compressible soils
- Alterations to these soils

In case of foundations, Sand Cushion method, Stiffening the foundation by adopting Alterations, Mat Foundations, Heat treatment, Chemical stabilization, soil replacement technique are some of the remedial measures to overcome the problems of compressible marine clay soils.

In case of Pavement sub grades, stabilization techniques can be adopted using various industrial waste considering the economy and also chemical additives for easy mixing and early results. The reinforcement techniques also plays vital role in improving the load carrying capacity of the marine clay beds.

- Soil Replacement
- Sand Cushion Method
- Stiffening the Foundation and Super structure
- Mat Foundation
- Stone Columns
- Heat Treatment
- Stabilization

Figure1 *Marine Clay Showing Cracks*

STABILIZATION

Soil stabilization technology offers advantages in a wide variety of road stabilization applications from unpaved roads that will remain un-surfaced to roads that will receive running surface treatments. Roadbed stabilization treatments include native roadbed soils, old gravelled roads, or recycled roadway surface materials. We create a superior structure that maximizes potential road strength and extends the useful life of the road bed.

Stabilization alters the following engineering properties.

- Increases load bearing capacity and shear strength of the soil
- Decreases the permeability and compressibility

There are different types of stabilization. They are:

- Mechanical stabilization

- Cement stabilization
- Lime stabilization
- Bituminous stabilization
- Chemical stabilization
- Thermal stabilization

STUDIES ON MARINE CLAY

In general, the soils which are existing in the coastal corridors are Soft Marine Clays formed by the deposits and generally weak and possesses high deformation values in nature. It is essential to study the various techniques for the improvement of marine clays, especially in case of infra-structure development.

Shridharan A et.al (1989), reported the Engineering properties of Cochin and Mangalore Marine Clays. A research has been done on the Physico-Chemical effects on the engineering behavior of Indian marine clays by Rao, M.S et.al (1992)

Thiam-Soon et al (2002), reported on improving the strength of the marine clay by the stabilization technique. Chu, J et.al (2002), reported the consolidation and permeability properties of the Singapore marine clay based on the laboratory and field investigations.

Balasubramaniam, A.S et.al (2003), proved the effects of additives on Soft Clay behaviour and concluded that the strength characteristics of the soft clays are improved by using various additives.

Oh, E.Y.N et.al (2006), presented the engineering properties and the characterization of marine clay for road embankment design in coastal area and the engineering properties of the marine clay were improved using various stabilization techniques.

Matchala Suneel et.al (2008), represented the compressibility characteristics of Korean marine clay. W.L. Sing et.al (2008), reported an improvement in the engineering properties of peat soils stabilizing with cement and ground granulated blast furnace slag and proved a remarkable increase in the pH and unconfined compressive strength, significant reduction in linear shrinkage, compressibility and permeability of the stabilized peat soils.

Basack,S et.al (2009), reported that the Engineering characteristics of marine clay collected form Visakhapatnam, India and the physical, chemical and mineralogical properties were presented and the strength, stiffness of the soil water matrix were established.

D. Koteswara Rao et al.(2011) studied the efficiency of CaCl2,KCl,GBFS with marine clay and the test results concluded that load carrying capacity of the marine clay foundation soil bed has been improved.

D. Koteswara Rao et al.(2012) studied the efficiency of Rice Husk Ash & Lime with marine clay and the test results concluded that load carrying capacity of the marine clay foundation soil bed has been improved.

III. METHODOLOGY

In this we will discuss about the properties of different types of materials used during the laboratory experimentation were presented. And a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study are briefly presented.

Materials Used and Their Properties

The details of the various materials used in the laboratory experimentation are reported in the following sections.

Marine Clay

The marine clay used in this study and was typical soft clay. The marine clay used in this study was typical soft clay. The marine clay was collected from KSPL (Kakinada Sea Port Limited) Site, Kakinada Port Area and Andhra Pradesh State, India. The properties of soil are presented in the Table 1. All the tests carried on the soil are as per IS specifications.

Table 1: Properties of Marine Clay

S. No.	Property	Value
1	Specific gravity	2.61
2	Differential free swell Index (%)	29
	Atterberg's Limits	
3	Liquid limit (%)	71.5
	Plastic limit (%)	29.2
	Plasticity index (%)	42.3
	Grain Size Distribution	
4	Sand Size Particles (%)	11
	Silt & Clay Size Particles (%)	89
5	IS soil classification	CH
	Compaction Parameters	
6	Max. Dry Density (g/cc)	1.36
	Optimum Moisture Content (%)	29.9
	Penetration Parameters	
7	CBR - Unsoaked (%)	2.9
	CBR - Soaked (%)	1.4
	Shear Parameters at OMC & MDD	
8	UCS at OMC & MDD (kPa)	82

GGBS

Ground-granulated blast-furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Physical properties and chemical compositions are placed in Table 3.2 and 3.3 respectively. For the present work GGBS brought from VIZAG STEEL PLANT, Visakhapatnam.

Table 2: Properties of GGBS

S. N	Property	Value
1	Specific gravity	2.8
Atterberg's Limits		
2	Plasticity index (%)	NP
Grain Size Distribution		
3	Gravel Size Particles (%)	0
	Sand Size Particles (%)	29
	Silt & Clay Size Particles (%)	71
Compaction Parameters		
4	Max. Dry Density (g/cc)	1.47
	Optimum Moisture Content (%)	18.2
Penetration Parameters		
5	CBR - Unsoaked (%)	10.1
	CBR - Soaked (%)	3.5

Table 3: Chemicals Present in GGBS

S.No.	Chemical	Composition
1	CaO	30-50%
2	SiO_2	28-38%
3	Al_2O_3	8-24%
4	MgO	1-18%
5	MnO	0.68%
6	TiO_2	0.58%
7	K_2O	0.37%
8	N_2O	0.27%

Egg Shell Powder (ESP)

Eggshell known as a smooth surface that is desirable compared rough eggshells fracture more easily. Most good quality eggshells of commercial layers contain approximately 2.2 grams of calcium in the form of calcium carbonate. About 95% of the dry eggshell is calcium carbonate weighing 5.5 grams. The average eggshell contains about 0.3% of magnesium, phosphorous, and traces of sodium, zinc, potassium, iron, copper and manganese. Properties and chemicals present in the Egg Shell Powder (ESP) were given in the table 3.4.

Table 3.4: Chemicals Present in ESP

S.No.	Chemical	Composition
1	CaO	45-50%
2	SiO_2	0.1-0.5%
3	Al_2O_3	Nill
4	MgO	Nill
5	Fe_2O_3	Traces
6	SO_3	1-2%
7	K_2O	Nill
8	N_2O	0.1-0.5%

List of Laboratory Tests

- The grain size distribution
- Specific gravity
- Swell Tests- Differential Free swell
- Index properties –Liquid Limit, Plastic Limit
- Compaction tests
- Penetration tests- California bearing ratio tests.
- UCS – Unconfined Compressive Strength

SAMPLE PREPARATION

The soil was initially air dried, pulverized and then was sieved through 4.75mm sieve, prior to the testing. The samples were prepared by mixing the pulverized and sieved soil with the needed stabilizing agents in dry condition and then required amount of water is added to make a consistent mix by thorough mixing. The following tests were conducted as per IS Codes of practice to assess the influence of GGBS, Egg Shell Powder (ESP) on the Soft Marine Clay. Also strength and penetration tests were planned at different curing periods.Compaction tests

i. Penetration tests- California Bearing Ratio test.
ii. Strength tests- UCS test

The following table lists the different variables and their respective contents used in the present study.

Table 4 Different variables studied

S.No.	Stabilizing Agent	% Content
1	GGBS	0, 5, 10, 15, 20 & 25
2	Egg Shell Powder (ESP)	0, 3, 6, 9 & 12
3	Curing Period in Days for Optimum Mix	7, 14 & 28

IV. RESULTS AND DISCUSSIONS

Details of the laboratory experimentation carried-out with different combinations of materials have been discussed in the previous chapter including the laboratory proctor's test and strength tests on untreated and treated marine clay.

Table 5 Variation of LL, PL & PI with % of GGBS

S.No	% GGBS	LL (%)	PL (%)	PI (%)
1	0	71.5	29.2	42.3
2	5	70.1	30	40.1
3	10	68.7	31.5	37.2
4	15	66.3	33.8	32.5
5	20	63.8	36.1	27.7
6	25	61.2	37.9	23.3

Table 6 Variation Compaction Parameters with % of GGBS

S.No	% GGBS	MDD (g/cc)	OMC (%)
1	0	1.36	29.9
2	5	1.37	27.5
3	10	1.39	25.2
4	15	1.41	22.7
5	20	1.44	20.1
6	25	1.45	19.8

Table 7 Variation of CBR with % of GGBS

S.No	% GGBS	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
1	0	2.9	1.4	82
2	5	3.6	2.3	95
3	10	5.5	3.6	109
4	15	6.7	4.9	123
5	20	7.8	5.7	141
6	25	7.3	5.1	136

Table 8 Variation of LL, PL & PI with % of ESP

S.No	ESP (%)	LL (%)	PL (%)	PI (%)
1	0	63.8	36.1	27.7
2	3	60.1	38.2	21.9
3	6	57.6	39.5	18.1
4	9	55	40.7	14.3
5	12	53.3	41.9	11.4

Table 9 Variation Compaction Parameters with % of ESP

S.No	ESP (%)	MDD (g/cc)	OMC (%)
1	0	1.44	20.1
2	3	1.47	19.5
3	6	1.5	18.8
4	9	1.54	18.2
5	12	1.52	18

Table 10 Variation CBR with % of ESP

S.No	ESP (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
1	0	7.8	5.7	141
2	3	8.5	6.4	165
3	6	9.7	7.2	196
4	9	10.9	8.1	229
5	12	10.4	7.7	217

Table 11 *Variation of Strength Characteristics with Curing Period*

S.No.	Curing Period (Days)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
1	0	10.9	8.1	229
2	7	11.6	8.5	246
3	14	12.5	9	263
4	28	13.8	9.7	295

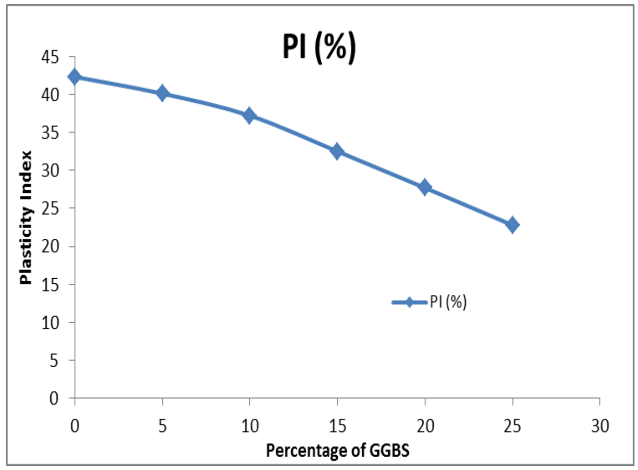

Figure 2: *Variation of P.I with % RHA*

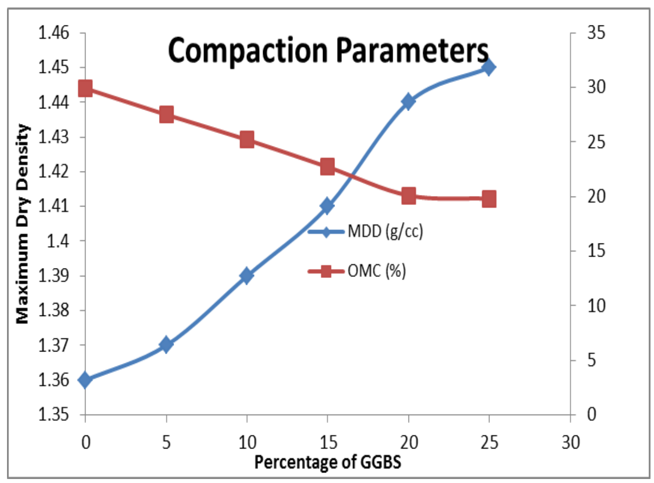

Figure 3: *Variation of Compaction Parameters with % RHA*

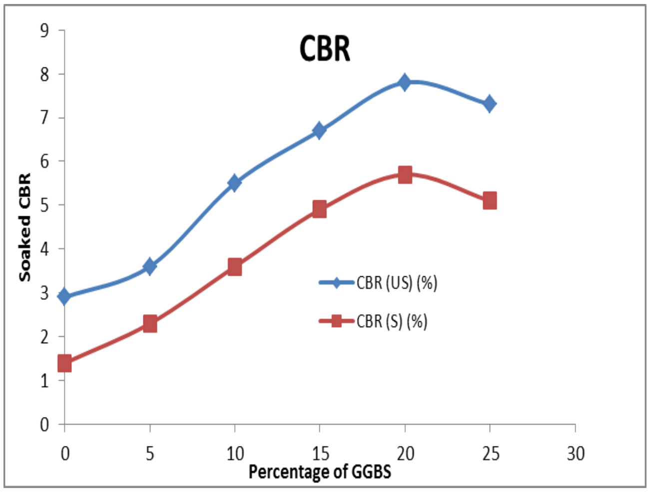

Figure 4: *Variation of Soaked CBR with % RHA*

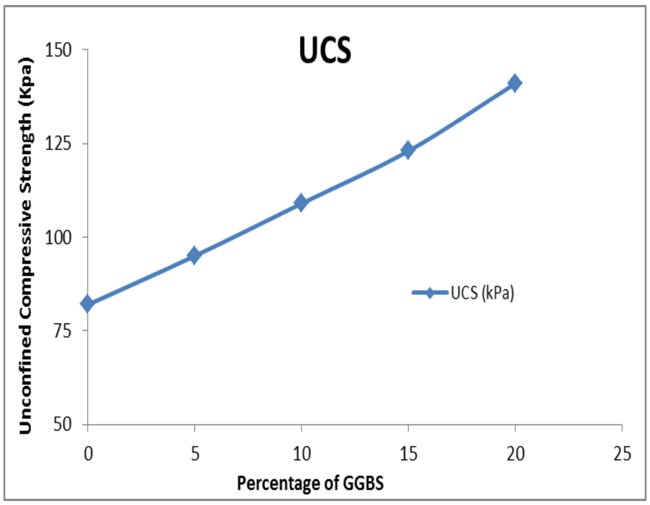

Figure 5: *Variation of UCS (kPa) with % RHA*

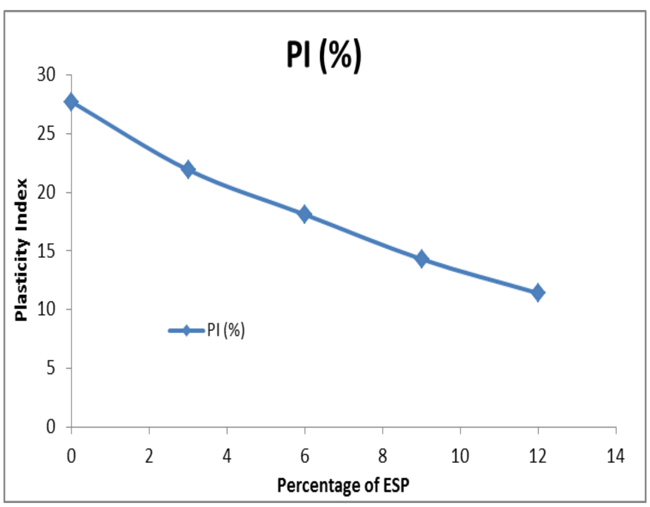

Figure 6: *Variation of P.I with % SL*

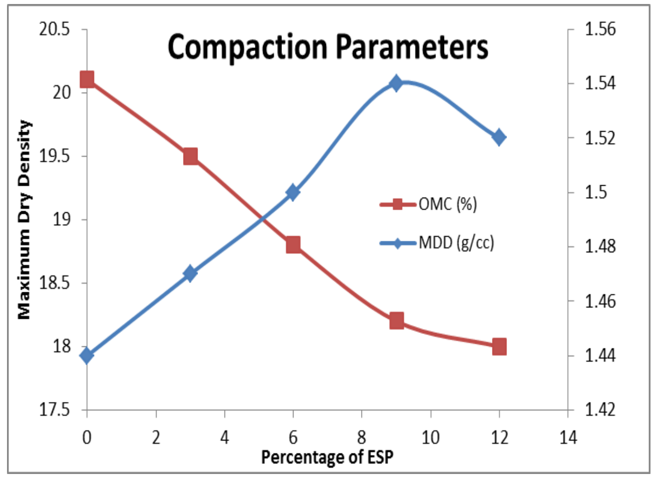

Figure 7: *Variation of Compaction Parameters P.I with % SL*

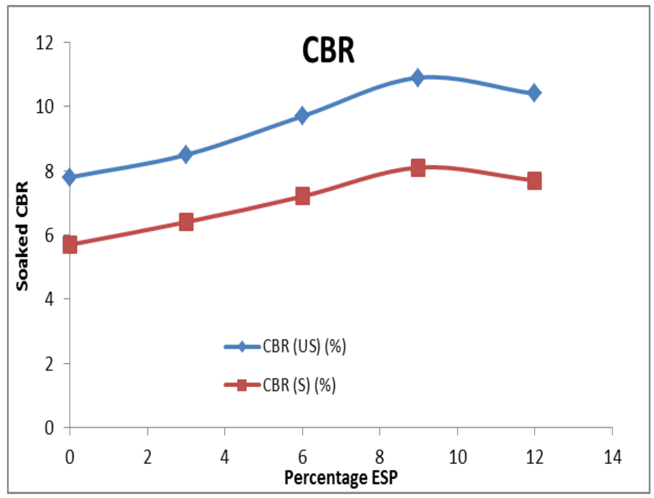

Figure 8: *Variation of Soaked CBR with % SL*

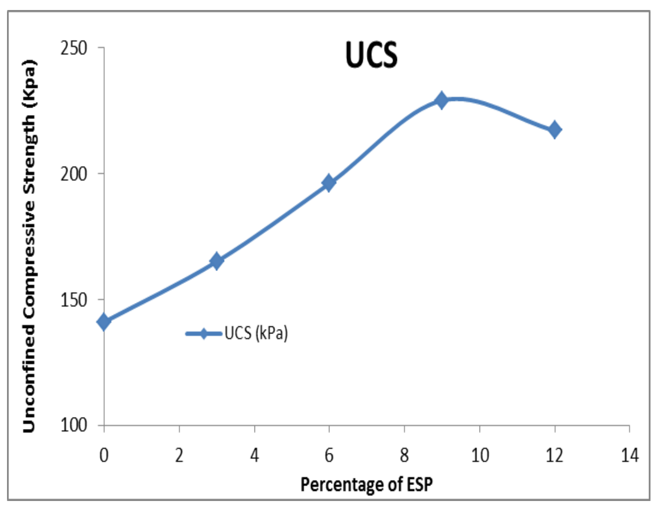

Figure 9: *Variation of UCS (kPa) with % SL*

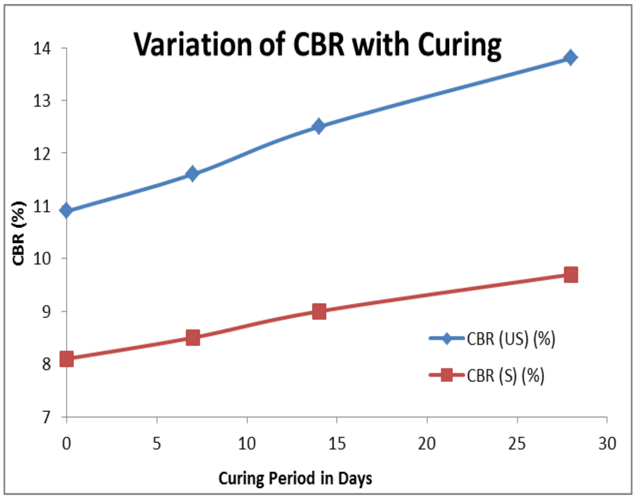

Figure 10: *Variation of Soaked CBR with different Curing Periods*

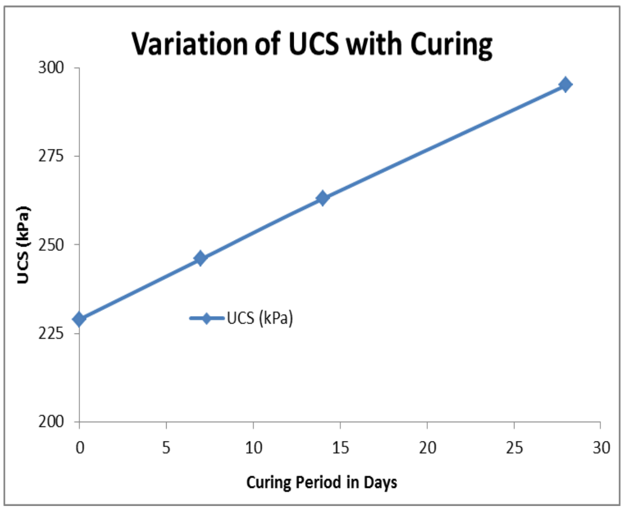

Figure 11: *Variation of Soaked UCS (kPa) with different Curing Periods*

EFFECT OF GGBS AND EGG SHELL POWDER ON THE BEHAVIOUR OF MARINE CLAY

Table 5 to Table 11 shows the summarized results of the behaviour of marine clay stabilized with GGBS, GGBS+ESP in tabulated form and from fig 2 to fig 11 shows the same in graphical representation. There is decrease in liquid limit and plasticity index with increase in GGBS content from 0% to 25% and increase in plastic limit with increase in GGBS content. At 25% replacement of GGBS the reduction in LL and PI are 10.7% and 34.5% of respectively when compared with LL and PI values of virgin marine clay, also PL value increased by 23.63%. The reduction in the plasticity index indicates that plasticity characteristics of the GGBS-Soil mix were improved. There is an increase in MDD also observed with increase in the GGBS as a replacement to the virgin marine clay from 0% to the 25%. At 25% of GGBS + 75% Marine soil the MDD is improved by 6.62% compared to the Maximum Dry Density of untreated marine clay.

The density of combination of GGBS + Soil was increased with increase in the percentage of GGBS as a replacement to the soil from 0% to 25%, which leads to improve in the MDD of the combined GGBS-Soil Mix. Decrease in the Optimum Moisture Content (OMC) and Increase in the Maximum Dry Density (MDD) will indicates that there is an improvement in the compaction parameters of the GGBS-Soil mix, compared to the untreated marine clay.

Improvement in Unsoaked and soaked CBR of 168% and 307% respectively when compared with pure marine clay at 20% of GGBS + 80% Marine soil. For 25% replacement of GGBS to the virgin marine clay there is an improvement of Unsoaked and soaked CBR compared to the untreated marine clay, but which are less compared to 20% GGBS replacement. From above discussion we can declare that 20% GGBS as a replacement to the marine clay is an optimum. The Unconfined Compressive Strength of 71.9% when compared with pure marine clay at 20% of GGBS + 80% Marine soil. For 25% replacement of GGBS to the virgin marine clay there is an improvement of UCS is 65.8% which are less compared to 20% GGBS replacement. From above discussion we can declare that 20% GGBS as a replacement to the marine clay is an optimum.

The influence of different percentage variations of ESP on Soil-GGBS of 20% as a replacement mix was discussed in this article. The CBR values of the untreated and treated marine clay were determined at the respective OMC of the various mixes obtained from IS proctor's compaction test, also Atterberg limit values determine.

There is decrease in liquid limit and plasticity index with increase in ESP and increase in plastic limit with increase in ESP. Decrease in the plasticity index with increase in the Egg Shell Powder (ESP) to the mix of 25% GGBS + 75% Soil is indicates that improvement in the plastic characteristics of the ESP-GGBS-Soil Mix. There is an increase in MDD with increase in Egg Shell Powder (ESP) from 0% to 9% to the 80% Soil + 20% GGBS which is optimum for GGBS variation. At 20% of GGBS + 80% Marine soil + 9% ESP the MDD is improved by 6.94% compared to 20% of GGBS + 80% Marine soil and 13.24% compared to virgin soil. Further increase in Egg Shell Powder (ESP) i.e for 12% the MDD observed to be decrease. From above discussion we can declare that 9% Lime is optimum for 20% of GGBS + 80% Marine soil. Decrease in the Optimum Moisture Content (OMC) and Increase in the Maximum Dry Density (MDD) will indicates that there is an improvement in the compaction parameters of the GGBS-Soil mix, compared to the untreated marine clay.

An improvement in Unsoaked and soaked CBR of 39% and 42.1% respectively when compared with 20% of GGBS + 80% Marine soil and 275.8% and 478.5% respectively when compared with virgin marine clay. From above discussion we can declare that 9% Egg Shell Powder (ESP) is optimum for 20% of GGBS + 80% Marine soil. Egg Shell Powder (ESP) as an addition to the 20% of GGBS + 80% Marine soil. There is increase in UCS with increase in Egg Shell Powder (ESP) from 0% to 9%.

There is an improvement in Unconfined Compressive Strength of 62.41% when compared with 30% of GGBS + 70% Marine soil and 179.27% compared with pure marine clay. From above discussion we can declare that 9% Egg Shell Powder (ESP) is optimum for 20% of GGBS + 80% Marine soil. Unconfined strength was getting decrease when the Egg Shell Powder (ESP) was increased to 12% to the optimum mix of 20% of GGBS + 80% Marine soil.

For the optimum mix combination of ESP-GGBS-Soil was 9% ESP + 20% GGBS + 80% soil. After the gently mix of the above proposed optimum mix of 9% ESP + 20% GGBS + 80% soil was subjected to curing by maintaining moisture content for 7, 14 & 28 Days. Unconfined Compressive Strength (UCS) was improved by 28.82% at 28 days of curing compared to 0 days of curing. Also the UCS at 9% ESP + 20% GGBS + 80% Soil mix with 28 days curing was improved by 109.22% compared to 20% GGBS + 80% Soil mix and 259.76% compared to untreated marine clay.

V. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

- The strength and index properties of soft marine clay were improved due to treating with GGBS, Egg Shell Powder (ESP).
- There is a decrease in Liquid Limit with increase in GGBS content as a replacement to the marine clay.
- With increase in GGBS content there is an increase in Plastic Limit and decrease in Plasticity index were observed.
- At 20% of GGBS as a replacement to the virgin soil the Plasticity Index decreased by 34.52%. Later there is a decrease with ESP content, at 9% of ESP the PI decreased by 66.19%.
- Due to addition of GGBS compaction parameters like Maximum Dry Density and Optimum Moisture Content also improved considerably. At 20% replacement of GGBS to the untreated marine clay the MDD was improved by an amount of 5.88% and OMC decrease by 32.78%.
- Further for the 20% GGBS + 80% Soil when the ESP was added at 9% addition of ESP to the GGBS-Soil mix the MDD was improved by 6.94% and 13.24% when compared with the untreated marine clay. Also the OMC was decreased considerably which indicates that improvement in the compaction parameters was achieved.
- At 20% replacement of GGBS unsoaked and soaked CBR are Improved by 168% and 307% respectively. Also there is 71.95% improvement in Unconfined Compressive Strength. Further when 9% ESP added the unsoaked and soaked CBR were improved by an amount of 275.86% and 478.57% respectively, also the Unconfined Compressive Strength increased by 179.27% when compared with the untreated marine clay.
- From the above points we can say that the 20% GGBS + 9% ESP + 80% Soil is the optimum mix proportion. The strength properties of the optimum mix was improved further when the mix kept for the curing under 7, 14 & 28 Days. The strength properties were increased with increase in the curing period.
- The unsoaked and soaked CBR were improved by 375.86% and 592.86% respectively at 28 days of curing when compared with untreated marine clay, also the Unconfined Compressive Strength at 28 days curing was improved by 259.76% compared to virgin marine clay.
- Finally we can conclude that the considered waste materials i.e GGBS & ESP were very effectively work in improving the characteristics of weak marine clay, which gives two fold advantage of improving the soil and solution to the waste disposal for such a waste materials.

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