

Stabilization of Soil using GGBS and Calcium Carbide Residue

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ABSTRACT: This study investigated the use of two kinds of industrial wastes Ground Granulated Blast Furnace Slag (GGBS) and Calcium Carbide Residue (CCR) in the stability of soil. These industrial wastes are generally dumped or thrown, which produce detrimental effect on the environment. The use of these wastes as soil stabilization improve the properties of soil which helps in various purposes such as designing of pavements, embankments, etc. and save the environment from the ill impact. The soil can be treated and stabilized well at a relatively low cost by using these additives.

From the experimental results, it has been observed that various properties of soil added with these stabilizers at certain percentage show remarkable positive changes as compared to the natural soil obtained. The permeability of the soil has reduced, which states that it can be used for the impervious core in Embankments. The value of Unconfined Compressive Strength has increased enabling increase in the bearing capacity of soil. The increased value of California Bearing Ratio in both soaked and unsoaked conditions indicates that the designing of flexible pavements becomes economical by reducing the thickness of base and sub-base courses.

KEYWORDS: Compaction, California Bearing Ratio, UCS, Permeability, Silty Clay soil, CCR, GGBS.

I. INTRODUCTION

1.1 General

There are various types of soils which show volume changes due to change in the moisture content. This causes major damage to property constructed on it. These soils contain minerals such as montmorillonite that are capable of absorbing water. When they absorb water their volume increases. One of the biggest necessities in the developing countries is to provide proper roadway network by conventional method. Hence it is necessary to go for suitable method of low cost road construction followed by a process of stage development of the roads, to meet the growing needs of road traffic. Good quality of subgrade soil is preferable for durable road but not always available for highway construction. The highway engineers designing a road pavement face weak or unsuitable subgrade. In this situation improvement in the properties of the existing soil by addition of some other materials can be adopted which is otherwise known as "soil stabilization".

Soil Stabilization: Soil stabilization means the improvement of the stability or bearing capacity of a poor soil by the use of compaction; proportioning and the addition of suitable stabilizers or admixtures. Soil stabilization includes chemical, mechanical, physio-chemical methods to make the soil stabilized. This process basically involve excavation of soil, this is an ideal technique for improving of soil in shallow depth, as in pavements. Stabilization method may be categorized as two main types: (a) improvement of soil properties of existing soil without using any type of admixture; and (b) improve the properties with the admixtures.

The greatest challenge before the processing and manufacturing industries is the disposal of the harmful residual waste products. Waste products which are generally toxic, ignitable, corrosive or reactive pose serious health and environmental consequences. Thus disposal of industrial waste is a major issue of the present generation. This major issue requires an effective, economic and environment friendly method to combat the disposal of the residual industrial

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waste products. Hence it is a common and feasible way to utilize these wastes in construction of roads, highways and embankments, so that the pollution problems caused by the industrial wastes can be greatly reduced. Huge amount of soil is used in the construction of roads and highways but sufficient amount of soil of required quality is not available easily. These industrial wastes which are used with natural soil in the construction not only solve the problems of disposal and environmental pollution but also help to preserve the natural soil.

1.2 Stabilizers used

1.2.1 Ground Granulated Blast Furnace Slag (GGBS)

GGBS is obtained by quenching molten iron slag which is 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. It has a cementitious property which acts as binding material for the soil. In general the presence of sufficient quantity of CaO results in enhanced slag basicity and compressive strength. This waste material is easily available and also cost efficient.

The physical characteristics of GGBS such as density, porosity and particle size are affected by the cooling rate (i.e. cooling method) of the slag and its chemical composition. Air-cooled GGBS is angular, roughly cubical and has textures ranging from rough, vesicular (porous) surfaces to glassy surfaces with conchoidal fractures. It has a rough surface texture giving good frictional properties and good adhesion to bituminous and cements binders, a low coefficient of thermal expansion and a high fire resistance.

Oxide compound	Calcium oxide (CaO)	Silicon dioxide (SiO ₂)	Aluminium oxide (Al ₂ O ₃)	Magnesium oxide (MgO)	Magnesium oxide (MgO)	Sulphur (S)	Manganese oxide (MnO)
Mass percentage	34% – 43 %	27% – 38%	27% – 38%	7% – 15 %	0.2% – 1.6%	1.0% – 1.9%	0.15% – 0.76%

Table 1: Typical chemical composition of GGBS

Ground Granulated Blast Furnace Slag (GGBS) was obtained from A.C.C. Plant, Sindri which they use as raw material for the production of slag cement.

The specifications of the GGBS obtained are (as per A.C.C. Plant) :

Moisture content – 0.1%

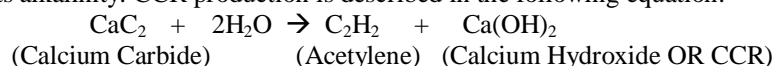
Specific Gravity – 2.95

Size of particles – 45 micron sieve residue = 5%

Fineness (Blain's air permeability) – 320 m²/kg

1.2.2 Calcium Carbide Residue (CCR)

CCR is by-product of Acetylene gas Production Process which is a slurry that mainly contains Calcium Hydroxide (Ca(OH)₂) along with SiO₂, CaCO₃ and other metal oxides. In India, there are many Acetylene Gas factories and PVC Chemical Plants which produces CCR in large amount which is mainly dumped in the landfills causing environmental pollutions due to its alkalinity. CCR production is described in the following equation:



Due to its high base, the CCR was hardly utilized in any work and dumped into disposal area in slurry form. After being sun-dried for a few days, the slurry form is changed to dry form. The dissociation of Ca(OH)₂ leads to an increase in the ph values of the pore water. Strong bases dissolve the silica and alumina from the clay particles (a natural pozzolanic material), in a manner similar to the reaction between a weak acid and a strong base. The hydrous silica and alumina then gradually react with the calcium ions (pozzolanic reaction), which hardens with time.

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CHEMICAL COMPOSITION	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃	K ₂ O	LOI
% PRESENCE IN CCR	70.78	6.49	2.55	3.25	0.69	0.66	7.93	1.35

Table 2: Chemical Composition of CCR

II. EXPERIMENTAL INVESTIGATIONS

2.1 General

Various laboratory tests have been performed to determine the properties of the natural soil. The necessary specifications of the additives have also been obtained. In order to study the modified properties of stabilized soil, the different tests have been conducted. Those tests are Proctor test, Atterberg's test, Unconfined compressive strength test, CBR test, Permeability test.

2.2 Preparation of Test Samples

For experimental study different nomenclatures have been prepared with different proportions of ingredients, which have been shown below:

S.N.	Nomenclature	Description of the additives added with the soil		
		Soil (%)	GGBS by (%) of weight of soil	CCR by (%) of weight of soil
1.	S	100	0	0
2.	S1	99.50	0	0.5
3.	S2	99.30	0	0.70
4.	S3	99.20	0	0.80
5.	S4	99.00	0	1.00
6.	S5	99.25	0	0.75
7.	S6	94.25	5.0	0.75
8.	S7	89.25	10.0	0.75
9.	S8	84.25	15.0	0.75
10.	S9	79.25	20.0	0.75
11.	S10	74.25	25.0	0.75

Table 3: Description of Samples

2.3 Specifications of Soil

The soil sample for this study has been collected from B.I.T. Sindri campus from a depth of 1.0 m below the natural ground surface by open excavation. The soil was dried and pulverised to perform the various experimental studies. Water content of the natural soil was obtained to be 6.69%.

2.3.1 Grain Size Distribution of Soil

The wet sieve analysis tests were conducted as per IS-2720 (part IV) 1985 (Reaffirmed 1995). The particle size distribution of soil is tested are given in "Fig." 1.

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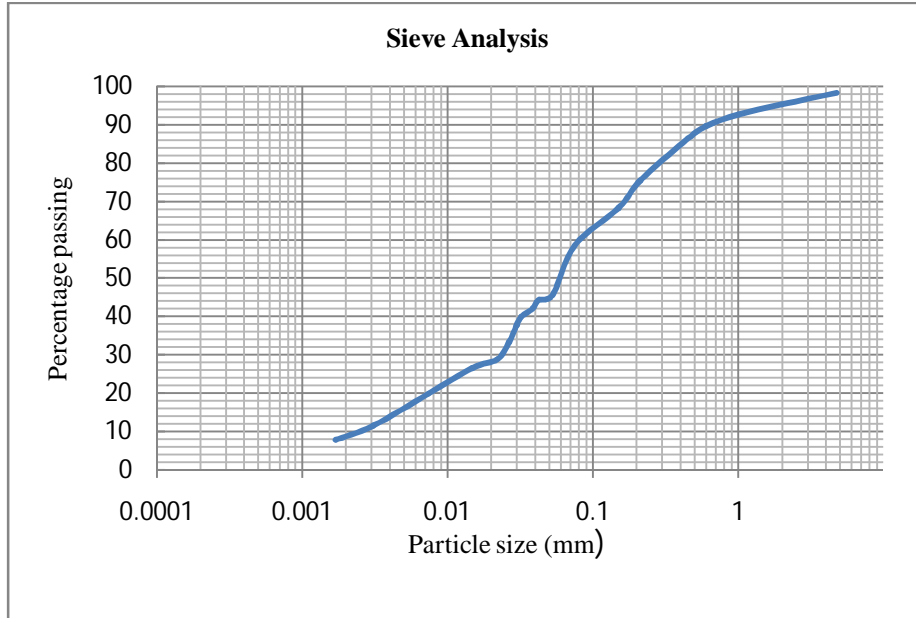


Fig 1. Gradation of soil

Fig 1. shows the S-curve obtained by gradation of the soil

Following table shows specifications of the natural soil:

S. No.	Parameters	Values
1.	Type of Soil	Silty Clay
2.	Coefficient of Curvature (Cc)	2.7
3.	Uniformity Coefficient (Cu)	28.57
4.	Specific Gravity	2.581
5.	Permeability	6.147×10^{-6} cm/sec
6.	OMC	16.20%
7.	MDD	1.812 g/cc
8.	Liquid limit	39.20%
9.	Plastic limit	18.79%
10.	Plasticity index	20.41%
11.	UCS	2.541 kg/cm ²
12.	Soaked CBR	2.25%
13.	Unsoaked CBR	3.85%

Table 4: Properties of Natural Soil (at a glance)

III. RESULTS AND DISCUSSION

3.1 Test Results of the Modified Soil

Detailed experimental study has been undertaken to investigate the characteristics and behaviour of locally available soil mixed with CCR and GGBS at different percentage. Initially only CCR was added to the soil to find its optimum percentage regarding the strength parameters. After fixing this percentage of CCR, GGBS was added to the mixture of soil and CCR.

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3.2 Mixing CCR to the natural soil to determine the optimum quantity of CCR

Following test results has shown in tabular form:

S. No.	Sample Type	OMC	MDD (g/cc)	Liquid Limit	Plastic Limit	Plasticity Index	UCS (kg/cm ²)	Unsoaked CBR
1.	S1	16.50 %	1.802	38.60 %	18.51 %	20.09 %	2.611	3.93%
2.	S2	16.80 %	1.794	37.60 %	18.45 %	19.15 %	2.923	4.09%
3.	S3	17.20 %	1.772	36.90 %	18.21 %	18.69 %	2.766	4.01%
4.	S4	17.60 %	1.752	36.50 %	18.13 %	18.37 %	2.693	3.93%
5.	S5	16.90 %	1.784	37.30 %	18.32 %	18.98 %	3.042	4.18%

Table 5: Test Results of Soil-CCR Mix

3.3 Remarks

- From above results, it is found that with the increasing percentage of CCR, OMC of the soil increases and MDD decreases, which shows CCR is a drying agent and acts as a desiccating agent.
- The liquid limit, plastic limit and plasticity index decreases as the percentage of CCR increases.
- The maximum value of UCS is 3.042 kg/cm² at 0.75% CCR by weight of soil, it means the strength of the soil is maximum when the percentage of CCR added to the soil is 0.75%.
- The value of CBR is 4.18% at 0.75% of CCR by weight of soil which is maximum.
- Hence from these results it is justified that the optimum values are observed in sample S5, where the percentage of CCR is 0.75% by weight of soil.

3.4 Mixing GGBS to the soil sample fixing the value of CCR as 0.75%

As the value of CCR has been fixed by performing the tests where OMC, MDD; Liquid limit; Plastic limit; UCS and CBR were obtained. Now fixing the percentage of CCR as 0.75%, GGBS was added varying in a definite proportion and soil was tested. The optimum condition has to be obtained where the soil gives maximum strength and other enhanced properties. Now all the tests are performed adding both the stabilizers to the soil and the results and comparison are obtained.

3.4.1 Permeability Test

To know the value of coefficient of permeability of the mix of soil sample with the CCR and GGBS :

S. No.	Sample Type	Coefficient of Permeability (cm/sec)	Variation of coeff. of permeability with respect to Natural Soil (S)
1.	S	6.147×10^{-6}	
2.	S6	6.107×10^{-6}	0.65% (decrease)
3.	S7	6.051×10^{-6}	1.56% (decrease)
4.	S8	5.996×10^{-6}	2.46% (decrease)
5.	S9	5.937×10^{-6}	3.42% (decrease)
6.	S10	5.881×10^{-6}	4.33% (decrease)

Table 6: Values of Permeability test results

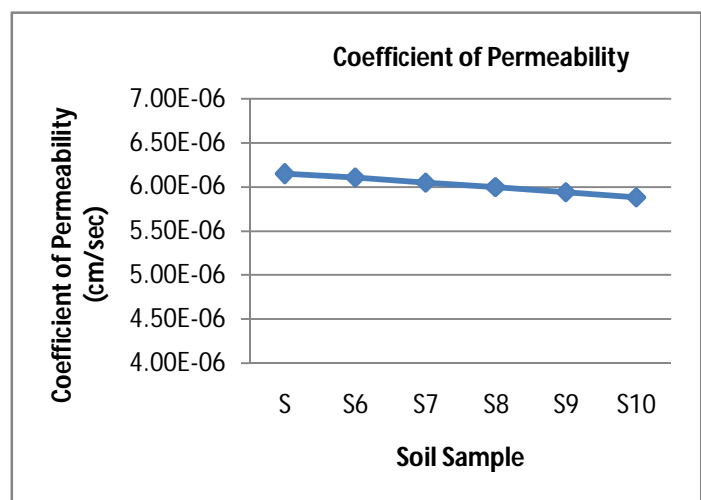


Fig 2. Permeability Comparison Graph

Fig 2. shows comparison in the values of Permeability for different samples

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3.4.2 OMC & MDD Test

To know the compaction characteristics, OMC and MDD test has been performed on different mix proportions of soil & CCR with GGBS :

S No.	Soil Sample	OMC (%)	MDD (g/cc)
1.	S	16.20	1.812
2.	S5	16.90	1.784
3.	S6	16.00	1.804
4.	S7	15.80	1.822
5.	S8	15.70	1.846
6.	S9	15.50	1.852
7.	S10	15.40	1.862

Table 7: OMC & MDD test results

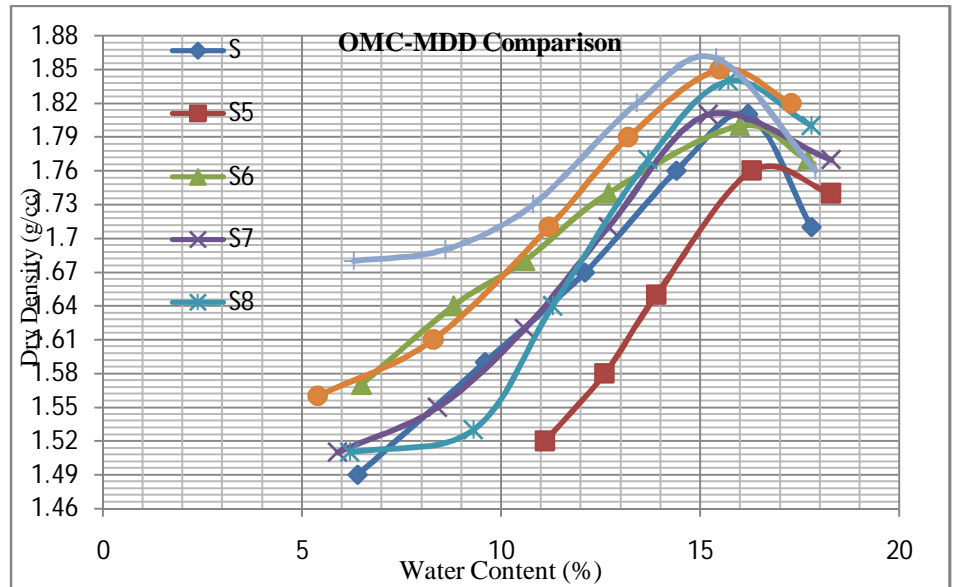


Fig 3. OMC – MDD Comparison Graph
Fig 3. shows comparison in the values of OMC & MDD for different samples

3.4.3 Liquid limit, Plastic limit & Plasticity index

To know the Atterberg’s limits characteristics, this test has been performed on different mix proportions of Soil & CCR with GGBS :

S. No.	Sample Type	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
1.	S	39.20	18.79	20.41
2.	S6	36.10	18.08	18.02
3.	S7	35.80	18.01	17.79
4.	S8	34.90	17.97	16.93
5.	S9	34.50	17.86	16.64
6..	S10	34.10	17.71	16.39

Table 8: LL, PL & PI test results

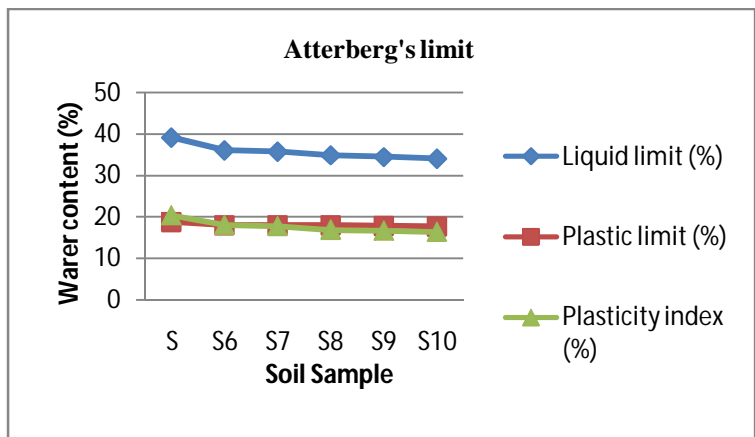


Fig 4. Atterberg’s Limit Comparison Graph
Fig 4. shows comparison in the values of LL, PL & PI for different samples

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3.4.4 UCS Test

The unconfined compressive strength of the mix of soil CCR and GGBS was known. Following table shows the results :

S. No.	Sample Type	UCS (kg/cm ²)	Variation of UCS w.r.t Natural Soil
1.	S	2.541	
2.	S6	3.081	21.25% (increase)
3.	S7	3.684	44.98% (increase)
4.	S8	4.051	59.42% (increase)
5.	S9	4.513	77.60% (increase)
6.	S10	4.582	80.32% (increase)

Table 9: Values of UCS test results

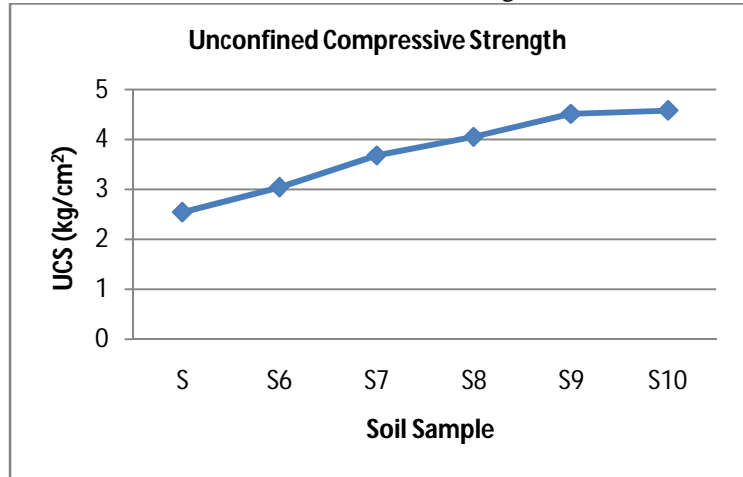


Fig 5. UCS Comparison Graph

Fig 5. shows comparison in the values of UCS for different samples

3.4.5 CBR Test

To know the soaked and unsoaked CBR value of the all the mix of soil, CCR and GGBS this test was done. Results are given in following table :

S. N o.	Sample Type	Soaked CBR Value (%)	Variation of Soaked CBR w.r.t Natural soil	Unsoaked CBR Value (%)	Variation of Unsoaked CBR w.r.t Natural soil
1.	S	2.25		3.85	
2.	S6	3.61	60.44% (increase)	4.26	10.65% (increase)
3.	S7	3.93	74.66% (increase)	5.38	39.74% (increase)
4.	S8	4.17	85.33% (increase)	6.10	58.44% (increase)
5.	S9	4.34	92.89% (increase)	6.50	68.83% (increase)
6.	S10	4.74	110.67% (increase)	6.74	75.06% (increase)

Table 10: Values of CBR test results

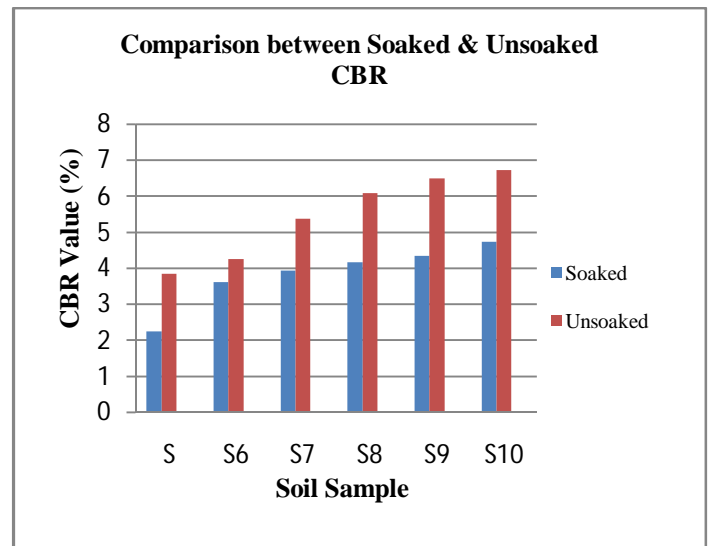


Fig 6. CBR Comparison Graph

Fig 6. shows comparison in the values of CBR for different samples

IV. CONCLUSIONS

1. With the increase of CCR (0.5%, 0.7%, 0.75%, 0.8% & 1.0% of the weight of soil), OMC increases and MDD decreases which is due to the water absorbing nature of CCR.

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2. The UCS value increases when CCR percentage changes from 0.5% to 0.7% but started decreasing at 0.8% and 1.0%, hence it was tested for 0.75% and found that the value of UCS was 3.042 kg/cm² which was maximum.
3. Similar result was obtained for CBR test, maximum value of CBR in unsoaked condition was found to be 4.18% when soil sample was added with 0.75% CCR by weight.
4. Based on above two results, optimum quantity of CCR was fixed to 0.75% by weight of soil.
5. With the addition of GGBS (5%,10%, 15%, 20%, 25% by weight of soil) to the mixture of soil and CCR (0.75%), OMC goes on decreasing and simultaneously MDD goes on increasing which conclude that compactness of the soil increases with the increase of GGBS and makes the soil denser.
6. With the increase of percentage of GGBS, liquid limit, plastic limit and plasticity index decreases, hence the soil sample becomes less plastic and less compressible.
7. The results from UCS test show that UCS value increases as the percentage of GGBS increases. The maximum value obtained was 4.582 kg/cm² for 25% of GGBS by weight of soil. With the increase of GGBS percentage, percentage finer goes on decreasing which decreases the voids, hence strengthens the soil.
8. As the percentage of GGBS increases to the mixture of soil and CCR, both soaked and unsoaked CBR increases which show the densification of soil and hence the requirement of greater thickness of pavement can be avoided. Maximum value of CBR was obtained 6.74%, when percentage of GGBS was 25% by weight of soil.
9. Hence from strength analysis, use of 25% GGBS and 0.75% CCR by weight of soil is advisable.

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REFERENCES

1. Kumrawat Neeraj, Ahirwar. S.K.,(2014), "Performance Analysis of Black Cotton Soil Treated with Calcium Carbide Residue and Stone Dust", International Journal of Engineering and Science & Technology, ISSN 2319-5991. Vol. 3, No. 4 Nov 2014
2. Pathak, A.K. 2014, "Soil Stabilization using Ground Granulated Blast Furnace Slag". IJERA ISSN:2248-9622,Vol.4, Issue 5 2014,pp.164-171
3. Laxmikant Yadu, Tripathi, R.K. (2013), "Stabilization of soft soil with granulated blast furnace slag and flyash", International Journal of Research in Engineering and Technology, vol.2, Issue 2, pp115-119.
4. Horpibulsuk. S., Phetchuay, C., and Chinkulkijniwat..A. (2013) "Strength development in silty clay stabilized with calcium carbide residue and flyash", Soils and Foundation, 53, issue4, pp477-486.
5. Gyanen. Takhelmayum, Savitha. A.L, Krishna Gudi (2013), "Laboratory Study on Soil Using Flyash Mixture", International Journal of Engineering Science and Innovative Technology (IJESIT), ISSN:2319-5967.
6. Dr. D. Koteswara Rao. And G.V.V. Rameswara Rao, P.R.T. Pranav, (2012), "A Laboratory Study on the affect of Rice Husk Ash & Lime on the Properties of Marine Clay" International Journal of Engineering and Innovative Technology (IJEIT) vol 2, ISSN:2277-3754.
7. Horpibulsuk. S., Phetchuay, C., and Chinkulkijniwat..A. (2012). "Soil stabilization by calcium carbide residue and flyash", Journal of Materials in Civil Engineering, ASCE, 24, Issue 2, pp184-193.
8. Anil Kumar Sharma, Sivapullaiah, P.V., (2011) "Soil stabilization with waste materials based binder." Proceedings of Indian Geotechnical Conference.
9. Erdal cokca,(2009). "Stabilization of Expansive clays using Granulated Blast Furnace Slag and GBFS cement". Geotech Geol Eng 27:489-499.
10. Andres M. Arvelo Guerrero. (2004), "Effects of the soil properties on the Maximum Dry Density Obtained from the Standard Proctor Test" 2004 Andres Arvelo.
11. Akinmusuru, J.O. (1991), "Potential Beneficial Uses of Steel Slag Wastes for Civil Engineering Purposes", Resources Conservation and Recycling, Vol. 5, PT1, pp. 73-80.
12. Gupta, S., and Seehra, S.S. (1989), "Studies on Lime-Granulated Blast Furnace Slag as an Alternative Binder to Cement", Highways Research Board, Bulletin, No. 38. Pp.81-97.
13. IS: 2720-Part III-1980, Determination of Specific gravity.
14. IS:2720-Part 4-1980, Grain Size Distribution.
15. IS:2720-Part 5-1980, Determination of Liquid limit and Plastic limit.
16. IS:2720-Part 6-1980, Determination of Shrinkage factors
17. IS:2720-Part 7-1980, Determination of water content-dry density relation using light compaction.
18. IS:2720-Part 10-1980, Determination of unconfined compressive strength.
19. IS:2720-Part 16-1980, Laboratory determination of CBR.