International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 01 | Jan 2022 www.irjet.net p-ISSN: 2395-0072

Stabilisation of Soft Soil using Ground Granulated Blast Furnace Slag (GGBS) and Lime

Gyanendra Kumar[1], Dr. Ran Vijay Singh[2]

[1]*M. Tech Student, Department of Civil Engineering, BIT Sindri, Dhanbad, India*
[2]*Professor & Head, Department of Civil Engineering, BIT Sindri, Dhanbad, India*

Abstract - *Now a days, Waste is the worldwide problem such as Industrial waste, plastics etc. As a civil engineer it is our responsibility to enhance the properties of soil by adding the wastes. In this paper, Industrial waste "Ground Granulated Blast Furnace Slag" (i.e., a by-product of steel and iron making) with Lime added in soil to enhance soil properties. A Soft soil has significant problem, most important the subsoil strength, shear strength, high compressibility etc. Due to rapid increase of urbanization, Land is required of good bearing strength and stability. Stabilization is the broad sense for the increasing the strength, bearing capacity and another physical property of soil. Stabilization can be done through chemical or mechanical methods. Now a days chemical method is highly used to enhance the properties of soil. In this paper, the soil is stabilised using GGBS and Lime. By using GGBS and lime, the construction cost is decreased & make economical. The influence of GGBS and lime mixture on the engineering property such as Atterberg limits, OMC, MDD, unconfined compressive strength, CBR test, has been investigated. GGBS was added from 0% to 20% by dry weight of soil with Lime of 7% by dry weight of soil and check the soil property by using various percentage and compare their property at different percentage. On adding GGBS and lime, the GGBS of 15% by dry weight of soil and lime of 7% by dry weight of soil is used as an optimum value to stabilize the soil.*

Key Words: Ground Granulated Blast Slag (GGBS), Lime, Soft soil, Soil stabilisation, Unconfined compressive strength, CBR etc.

1. INTRODUCTION

1.1 General

Urbanization and economic development of any country is mainly depending on highway and airport networks. As a result of rapid urbanization, it is necessary to stabilise the soft soil on which buildings and roads are built. Soft soil is one of the most problematic soils in civil engineering, the reason is that soft soil has high degree of compressibility, low compressive strength, low bearing strength, and potential to swell. At different value of moisture content, the volume of soil is also varied and result is that soil swell and shrinks. Any construction built on this soil will be felt. As a result, we blend industrial waste, such as ground granulated blast furnace slag, to offer stability. Cement is not used at this place because the cost of cement is very high at this place as compared to GGBS as well the in production of cement, carbon dioxide (CO_2) is emitted in the environment which harms our atmosphere. Some more wastes which are used to improve the strength of soil economically such as fly ash, lime, geotextile, plastics, rubber tyre etc.

1.2 Soil Stabilisation

Soil stabilisation is a process that improves the properties of soil by using a method that is appropriate for the soil. It has the ability to improve soil qualities or alter soil engineering properties. Soil stabilization is used to increase the strength of soil, bearing capacity, stability for the construction of buildings, roads, etc. Soil stabilization reduce the cost of construction and makes project economical and environment friendly. There are many methods to stabilize the soil.

1.3 Method of Soil Stabilisation

There are many methods of soil stabilization which have its own benefits and potential problems. Some of them are frequently used, these are following: -

1.3.1 Mechanical Stabilisation: -

The most basic form of the mechanical stabilization of soil is compaction method. By compaction method the property of soil enhances properly. In this method mechanical energy (by roller, plate compactors, tampers etc.) is used to improve the soil property. The method of compaction is well understood so that no further discussion of this in this report. Mechanical stabilization of material is usually achieved by adding the different material in order to improve the grading or decrease the plasticity of the material. By adding, the physical properties of soil are changed but no chemical reaction taken. The density of soil is increased and by compaction the strength and stability of soil increased. Generally, the strength & stiffness is less than that achieved by chemical stabilization.

1.3.2 Chemical Stabilisation: -

There are many chemicals is used as a soil stabilizer such are calcium chloride, sodium chloride etc. These chemicals are not used in general because of high costs of chemical. We use some other admixtures in place of these chemicals to minimize the cost of mixture. We can use admixture which is less in cost and easily available. Such are following:

Cement Stabilisation: -

Cement stabilization can be done by soil and cement and compacting the mixture of soil and cement to attain the strong material. For cement stabilization, we generally use ordinary Portland cement because of economical mix. Generally, the strength of cement stabilized are comes from the hydrated cement.

Lime Stabilisation: -

Lime stabilization is used from the romans time. It is not a new process to stabilize the soil. Before the invention of cement, lime was mostly is used to stabilize the soil [4]. Lime stabilization is used now a days for soil which contain high amount of clay because it is effective in clay due to positive reaction taken place.

Bitumen Stabilisation: -

In soil stabilization, bitumen is also used as a binder and this stabilization is called bitumen stabilization. Bitumen is too viscous to use at ambient temperatures. When the solvent evaporates, the bitumen is deposited on soil. This bitumen acts as a glue to stick the soil particle. Bituminous material acts as an impervious layer and prevents the capillary rise.

Blast furnace slag Stabilisation: -

In stabilization of soil, blast furnace slag is used as a granulated form, known as GGBS. GGBS is obtained from the Quenching molten iron slag (a by-product of iron & steel making) from blast furnace then dried and ground. Ground Granulated Ballast Furnace Slag (GGBS) is cost effective and easily available. These admixtures have some property such as volume stabilities, strength, permeability and durability etc.

Fly ash Stabilisation: -

In this stabilisation process, soil is stabilisaed by using the material fly ash. Fly ash is a coal combustion product that is composed of the particulates that are driven out of coal fired boilers together with the fuel gases.

2. EXPERIMENTAL SETUP

2.1 General

In this experimental work which has been performed to achieve the objective and scope of experiment. In this experimental work, firstly collect the soil from the Kamlapuri Muhalla, Garhwa, Lime from sindri shop and GGBS (Ground Granulated Blast Furnace Slag) from the ACC private limited, Sindri. Then the natural soil was left for natural drying. After that the various physical properties of the soil like Specific Gravity, Grain size distribution, Consistency, Optimum moisture content (OMC), Maximum dry density (MDD), Unconfined compressive strength (UCS) and California Bearing Ratio (CBR) values were found out in laboratory.
After that mix the GGBS with the different proportion (such as 5%, 10%, 15% and 20% of dry weight of soil) & Lime and found out the physical properties of GGBS mixed soil with lime and compare the observations that obtained.

2.2 Material used

Soil: -

The natural soil has been collected from the Kamlapuri muhalla, Garhwa by digging a pit of 3 feet to 5 feet and transported to soil laboratory of Civil engineering department, BIT Sindri, Dhanbad. The natural soil which contains some moisture has been spread over the floor and left for natural drying for some days. After some days the natural soil of big size was broken with the help of hammer in the smaller size and sieved in 4.75mm sieve for the use of various experiments.

Lime: -

The lime was purchased from the shop, Sindri. The lime was broken into the smaller size by the help of hammer.

GGBS (Ground Granulated Blast Furnace Slag): -

The GGBS has been collected from the ACC plant, Sindri. The sample are as shown below.

Fig 1: Ground Granulated Blast Furnace Slag

2.3 Methodology

In this, we will discuss about the various procedure through which we carried out the different laboratory test to found out various physical properties of soil.

2.3.1 Specific Gravity

Specific gravity of soil is defined as the ratio of mass of sample of given volume to the mass of the standard fluid (i.e., water) of the same volume at the same temperature. The

specific gravity test was carried out on the soil as per the procedure given in IS: 2720 – Part - 3 – 1980. The specific gravity test was performed by the help of pycnometer bottle.

Fig 2: Pycnometer Apparatus

2.3.2 Sieve Analysis

Grain size analysis test was carried out on soil as per procedure given in IS:2720 – Part - 4 – 1985. Grain size distribution is determined on the basis of the total weight of soil taken and the weight of soil retained on each sieve. The percentage of the total weight of soil passing through each sieve was calculated. Grain size is performed by passing the soil through a set of sieves arranged from larger sieve at the top to smaller sieve at the bottom. The sieves were arranged in sequence i.e., 4.75 mm, 2.0 mm, 1.0 mm, 600-micron, 425-micron, 212-micron, 150-micron, 75-micron.

2.3.3 Atterberg's Limit test

Consistency is a term which used to describe the degree of fineness of a soil is in a qualitative manner by using descriptions such as soft, medium, firm, stiff or hard. It indicates the relative is with which a soil can be deformed generally the properties of consistency associated only with fine grained soil especially clay. The engineering properties of clay are considerably influence by the amount of water present in them depending upon the water content the four stage and stages namely liquid stage, plastic stage, semi-solid stage and solid stage of the consistency are used to describe consistency of a clay soil. The boundary water content at which the soil undergoes a change from one state to another is called consistency or Atterberg's limits. In 1911 a Swedish soil scientist Atterberg's first demonstrate the significance of these limit on the basis of change of state there are mainly three consistency limits.

Liquid limit

It is defined as the water content at which a soil is practically in a liquid state, but has infinitesimal resistance against flow which can be measured by any standard liquid limit device. The liquid limit test was carried out on clayey soil as per the procedure given in IS:2720 Part 5-1985. Liquid limit test was done by using Casagrande apparatus.

Plastic Limit

It is defined as the minimum water content at which a soil is just begins to crumble when rolled into the thread of approximately 3mm diameter. This test was carried out in clayey soil as per the procedure given in IS: 2720 Part 5-1985.

2.3.4 Standard Proctor test

In this test, the water content corresponding to the maximum dry unit weight is known as the optimum moisture content (OMC). OMC&MDD test was carried out on the clayey soil as per procedure given in IS:2720, Part7-1974. This test is also called as light compaction test.

Fig 3: Mould and Hammer for OMC & MDD

2.3.5 Unconfined Compressive Strength test

This is a special case of the tri-axial test in which confining and cell pressure is zero. This test is an undrained test or quick test and is often used to determine the in-situ strength of soft, saturated fine grained soil deposits. The test was carried out on clayey soil as per procedure given in IS: 2720 Part 10-1991. UCS test was done using unconfined compression testing machine.

2.3.6 California Bearing Ratio test

CBR is a penetration test for evaluation of the mechanical strength of natural ground, sub-grades and base courses beneath new carriage way. CBR values are usually calculated for penetration of 2.5mm and 5.0mm. Corresponding to the penetration value at which the CBR values is desired, corrected load value shall be taken from the load penetration curve and the CBR value is calculated. CBR test was carried out as per procedure given in IS: 2720 Part 16-1987.

2.4 Properties of Soft Soil

Table 2.1: Properties of soft soil

Sl. No.	PARAMETERS	VALUE
1.	Specific Gravity	2.544
2.	Liquid Limit	38.44%

3.	Plastic Limit	22.93%
5.	Plasticity Index	15.51%
7.	OMC	15.82%
8.	MDD	1.92 g/cc
9.	UCS	1.049 Kg/cm^2
10.	Soaked CBR	2.17%
11.	Un-Soaked CBR	4.18%
12.	% finer than 75-micron (Clay +Silt)	62.40%
13.	% of clay	14.85%

2.5 Optimum Amount of Lime

For fixing the lime percentage in the soil and GGBS, add the lime in natural soil with varying percentage that is 3%, 5%, 7%, 9% of the dry weight of soil and find out the OMC-MDD for different percentages. At 7% amount of lime the OMC and MDD have been found maximum.

Table 2.2: OMC & MDD test

Sl. No.	Soil (%)	Lime (%)	OMC (%)	MDD (g/cc)
1.	100	0	15.82	1.92
2.	97	3	16.97	1.97
3.	95	5	18.31	2.03
4.	93	7	19.83	2.11
5.	91	9	18.69	2.06

2.6 Preparing Soil Sample

The soft soil has been mixed and replaced with varying percentage of GGBS (5%, 10%, 15% & 20%) and fixed percentage of lime (7%) as shown in fig. The dried soil was taken and sieved in the IS sieve 4.75mm. The sieved soil has been taken and mixed with lime of constant percentages (7% by the weight of soil) and different percentages of GGBS (5%, 10%, 15%, & 20%by the weight of dry soil) for finding the various physical properties.

Table 2.3: Nomenclature of mixed soil

Sl. No.	Sample ID	Sample Notation	Composition by Weight
1.	S100L0G0	S1	100%Soil, 0%Lime, 0%GGBS
2.	S93L7G0	S2	93%Soil, 7%Lime, 0%GGBS
3.	S88L7G5	S3	88%Soil, 7%Lime, 5%GGBS
4.	S83L7G10	S4	83%Soil, 7%Lime, 10%GGBS
5.	S78L7G15	S5	78%Soil, 7%Lime, 15%GGBS
6.	S73L7G20	S6	73%Soil, 7%Lime, 20%GGBS

3. RESULTS AND DISCUSSION

3.1 Specific Gravity test

The result obtained from the laboratory for Specific gravity of the mixed soil with different percentage of GGBS and a fixed 7% of lime has been given below.

Table 3.1: Specific Gravity test result

Sample Notation	Soil (%)	Lime (%)	GGBS (%)	Specific Gravity (G)
S1	100	0	0	2.544
S2	93	7	0	2.56
S3	88	7	5	2.60
S4	83	7	10	2.63
S5	78	7	15	2.65
S6	73	7	20	2.67

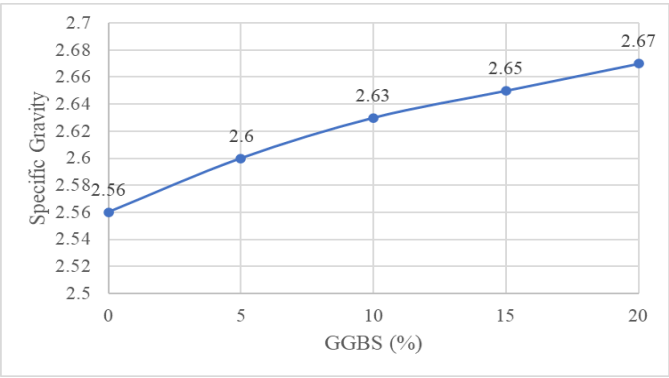

Fig 3.1: Effect of GGBS on Specific Gravity

3.2 Standard Proctor test

In laboratory, the standard proctor test result of a mixed soil with different percentage of GGBS and a fixed 7% of lime is given below.

Table 3.2: Standard Proctor test result

Sample Notation	Soil (%)	Lime (%)	GGBS (%)	OMC (%)	MDD (g/cc)
S1	100	0	0	15.82	1.92
S2	93	7	0	19.83	2.11
S3	88	7	5	19.69	2.36
S4	83	7	10	19.52	2.49
S5	78	7	15	19.38	2.63
S6	73	7	20	19.23	2.68

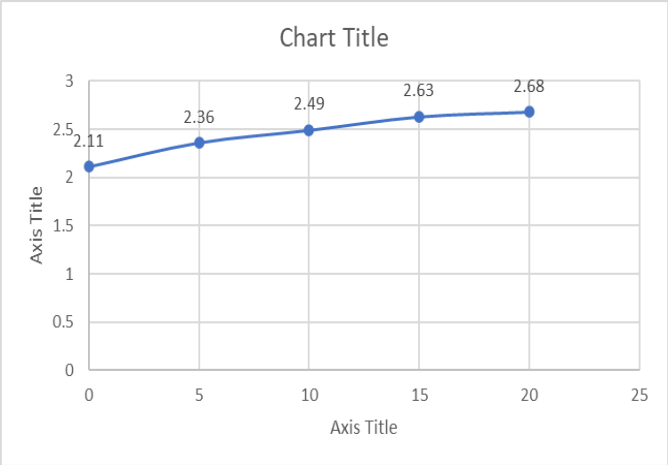

Fig 3.2: Effect of GGBS on MDD

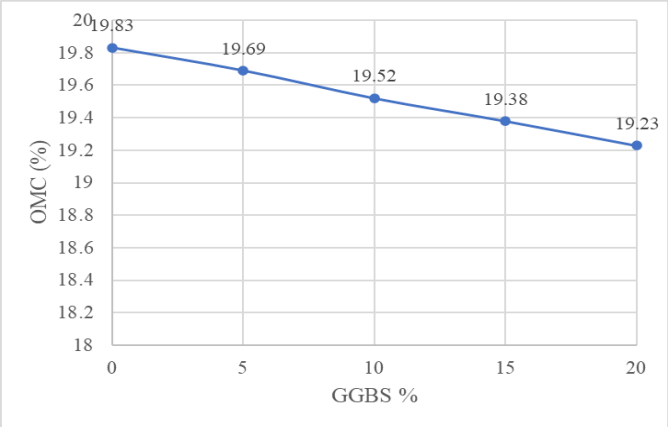

Fig 3.3: Effect of GGBS on OMC

3.3 Atterberg's Limit test

The result obtained from the Atterberg's Limit test on soil with different percentage of GGBS and a constant percentage of lime has given below.

Table 3.3: Atterberg's Limit test result

Sample Notation	Soil (%)	Lime (%)	GGBS (%)	W_L (%)	W_P (%)
S1	100	0	0	38.44	22.93
S2	93	7	0	38.49	24.79
S3	88	7	5	38.28	24.89
S4	83	7	10	38.03	24.97
S5	78	7	15	37.74	25.08
S6	73	7	20	37.61	25.17

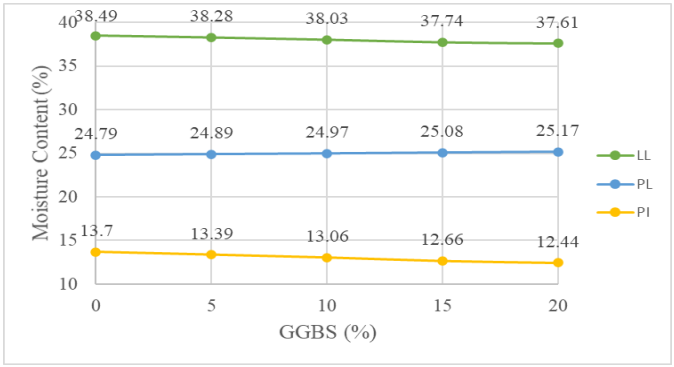

Fig 3.4: Effect of GGBS on Consistency Limit

3.4 Unconfined Compressive Strength test

The results obtained from laboratory tests for UCS mixed with different percentage of GGBS and fix percentage of lime has been given below.

Table 3.4: UCS test result

Sample Notation	Soil (%)	Lime (%)	GGBS (%)	UCS (Kg/cm^2)
S1	100	0	0	1.049
S2	93	7	0	1.596
S3	88	7	5	1.689
S4	83	7	10	1.825
S5	78	7	15	1.968
S6	73	7	20	2.007

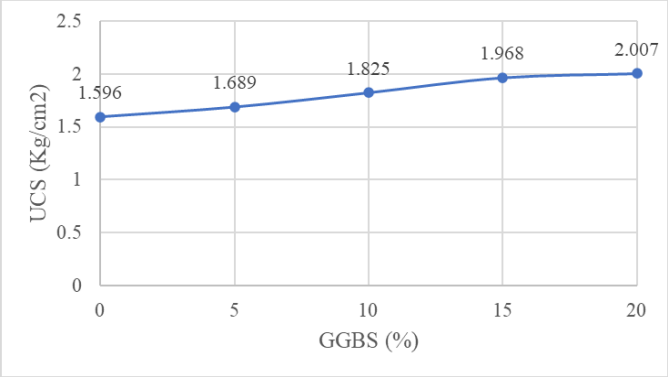

Fig 3.5: Effect of GGBS on UCS

3.5 California Bearing Ratio test

For Soaked Soil

A series of Soaked California Bearing Ratio Tests are conducted on natural soil with different % of GGBS (0%, 5%, 10%, 15% & 20%) and Constant percentage of lime (7%). CBR value with different percentage of GGBS & a fixed 7% of lime under soaked condition is given below.

Table 3.5: Soaked CBR test result

Sample Notation	Soil (%)	Lime (%)	GGBS (%)	CBR (%)	
				2.5 mm penetration	5.0 mm penetration
S1	100	0	0	2.17	2.09
S2	93	7	0	2.79	2.68
S3	88	7	5	3.28	3.21
S4	83	7	10	4.19	4.11
S5	78	7	15	5.16	5.08
S6	73	7	20	5.97	5.86

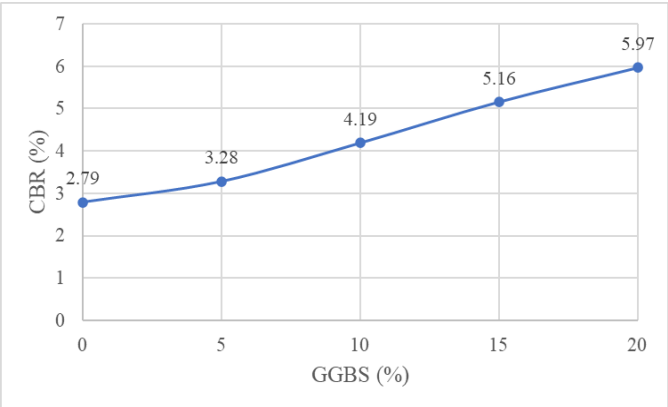

Fig 3.6: Effect of GGBS on Soaked CBR

For Un-Soaked CBR

A series of un-soaked California Bearing Ratio Tests are conducted on natural soil with different % of GGBS (0%, 5%, 10%, 15% & 20%) and Constant percentage of lime (7%). CBR value with different percentage of GGBS and a fixed 7% of lime under un-soaked condition is given below.

Table 3.6: Un-Soaked CBR test result

Sample Notation	Soil (%)	Lime (%)	GGBS (%)	CBR (%)	
				2.5mm penetration	5.0mm penetration
S1	100	0	0	4.18	3.64
S2	93	7	0	4.62	3.96
S3	88	7	5	5.25	4.59
S4	83	7	10	6.58	5.07
S5	78	7	15	7.79	5.73
S6	73	7	20	8.92	6.35

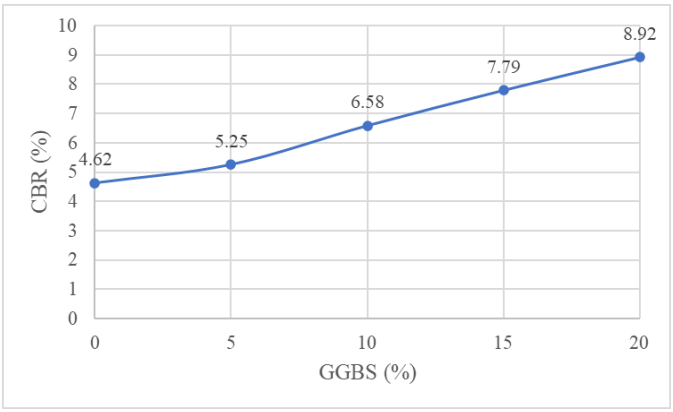

Fig 3.7: Effect of GGBS on Un-Soaked CBR

4. CONCLUSIONS

As per the data and results obtained from the experimental work on soil stability investigation with Ground Granulated Blast Furnace Slag (GGBS) using lime. On discussion following conclusion comes: -

1. The Specific Gravity test of mixed soil with increasing the percentage of GGBS (5%, 10%, 15% & 20% by weight of dry soil) and a constant percentage of lime (7%), the Specific Gravity of mixed soil increases.
2. The MDD is increases and OMC is decreases with the increasing the percentage of GGBS & a constant percentage of lime (7%). It is clearly seen that after the mixing of 15% of GGBS and 7% of lime by weight of dry soil, the increase in MDD is very less or slightly, so we

consider 15% of GGBS and 7% of lime by weight of dry soil is the optimum value.

3. Liquid limit decreases, plastic limit increases slightly, so that the plasticity index of mixed soil decreases with the increase in percentage of GGBS.
4. The unconfined compressive strength (UCS) test, it is found that on the increasing of GGBS and a constant percentage of lime, the UCS value of mixed soil is increases. It is also found that up to 15% of GGBS by weight of dry soil, the UCS value increases with some major difference percentage but after further mixing of GGBS, the UCS value increases very slightly. So, from this, it is concluded that the optimum value of mixing of GGBS in soil is 15% of its dry weight of soil.
5. On increasing the percentage of GGBS with the constant percentage of lime (7%), the CBR value increases.

REFERENCES

[1] Pathak AK, Pandey V, Murari K, Singh JP. "Soil stabilisation using ground granulated blast furnace slag." Int. J. Eng. Res. Appl. 2014 May; 4:164-71.

[2] Kumar Krishna and Sneha Gupta. "Stabilization of soft soil using industrial waste." Int. J. Adv. Res. Sci. & Eng. 2018 April; 7: 514-18.

[3] Joe, M. Adams, and A. Maria Rajesh. "Soil stabilization using industrial waste and lime." International Journal of Scientific Research Engineering & Technology (IJSRET) 4, no. 7 (2015).

[4] Zahraa Jwaida, W. Atherton, Anmar Dulaimi, Hassnen M. Jafer, Ruqayah Al- Khafaji, "Soft soil stabilisation using ground granulated blast furnace slag", May 2017.

[5] Yadu, Laxmikant, and R. K. Tripathi. "Effects of granulated blast furnace slag in the engineering behaviour of stabilized soft soil." Procedia Engineering 51 (2013): 125-131.

[6] Oormila, T. R., and T. V. Preethi. "Effect of stabilization using flyash and GGBS in soil characteristics." Int J Eng Trends Technol 11, no. 6 (2014): 284-289.

[7] Tyagi, Arshad, and D. K. Soni. "Effects of granulated ground blast furnace slag and fly ash on stabilization of soil." Recycled waste materials. Springer, Singapore, 2019. 79-90.

[8] Sharma, Anil Kumar, and P. V. Sivapullaiah. "Ground granulated blast furnace slag amended fly ash as an expansive soil stabilizer." Soils and Foundations 56, no. 2 (2016): 205-212.

[9] Manimaran, A., S. Seenu, and P. T. Ravichandran. "Stimulation behaviour study on clay treated with ground granulated blast slag and groundnutshell ash." International Journal of Engineering 32, no. 5 (2019): 673-678.

[10] Kavak, A., and G. Bilgen. "Reuse of ground granulated blast furnace slag (GGBFS) in lime stabilized embankment materials." International Journal of Engineering and Technology 8, no. 1 (2016): 11.

[11] Jiang, Ning-Jun, Yan-Jun Du, and Kai Liu. "Durability of lightweight alkali-activated ground granulated blast furnace slag (GGBS) stabilized clayey soils subjected to sulphate attack." Applied Clay Science 161 (2018): 70-75.

[12] Higgins, D. D., J. M. Kinuthia, and S. Wild. "Soil stabilization using lime-activated ground granulated blast furnace slag." Special Publication 178 (1998): 1057-1074.

[13] Cokca, Erdal, Veysel Yazici, and Vehbi Ozaydin. "Stabilization of expansive clays using granulated blast furnace slag (GBFS) and GBFS-cement." Geotechnical and geological engineering 27, no. 4 (2009): 489-499.

[14] Celik, Ece, and Zalihe Nalbantoglu. "Effects of ground granulated blastfurnace slag (GGBS) on the swelling properties of lime-stabilized sulfate-bearing soils." Engineering Geology 163 (2013): 20-25.

[15] Takhelmayum, Gyanen, A. L. Savitha, and G. Krishna. "Laboratory study on soil stabilization using fly ash mixtures." International Journal of Engineering Science and Innovative Technology (IJESIT) 2, no. 1 (2013): 477-482.

[16] IS: 2720-Part 4-1985, Bureau of Indian Standards New Delhi, January (1986). Laboratory method for Grain Size Analysis.

[17] IS: 2720-Part 5-1985, Bureau of Indian Standards New Delhi, August (1985). Laboratory method for determination of LL and PL of soil.

[18] IS: 2720-Part 7-1980, Bureau of Indian Standards New Delhi, December (1980). Laboratory method for Standard proctor test.

[19] IS: 2720-Part 16-1987, Bureau of Indian Standards New Delhi, May (1988). Laboratory Determination of CBR Value.

[20] IS: 2720-Part 3-1980, Bureau of Indian Standards New Delhi, Feb (1981). Determination of Specific Gravity of Soil Solids.