International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 05 | May-2016 www.irjet.net p-ISSN: 2395-0072

Comparative Study On Stabilization of Soil With Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash

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Abstract - *Stabilization is a broad sense for the various methods employed and modifying the properties of a soil to improve its engineering performance and used for a variety of engineering works. Soil stabilization has become the major issue in construction engineering and the researches regarding the effectiveness of using industrial wastes as a stabilizer are rapidly increasing. This study briefly describes the suitability of the local fly ash and ground granulated blast furnace slag (GGBS) to be used in the local construction industry in a way to minimize the amount of waste to be disposed to the environment causing environmental pollution. In this present study, different amount of fly ash and GGBS are added separately i.e. 5, 10, 15 and 20% by dry weight of soil are used to study the stabilization of soil. The performance of stabilized soil are evaluated using physical and strength performance tests like specific gravity, atterberg limits, standard proctor test and California Bearing Ratio (CBR) test at optimum moisture content. From the results, it was found that optimum value of fly ash is 15% and GGBS is 20% for stabilisation of given soil based on CBR value determined.*

Key Words: *Stabilization of soil, fly ash, GGBS, CBR values*

1. INTRODUCTION

In developing country like India due to the remarkable development in road infrastructure, Soil stabilization has become the major issue in construction activity. Stabilization is an unavoidable for the purpose of highway and runway construction, stabilization denotes improvement in both strength and durability which are related to performance. Stabilization is a method of processing available materials for the production of low-cost road design and construction, the emphasis is definitely placed upon the effective utilization of waste by products like ground granulated blast furnace slag GGBS and fly ash, with a view to decreasing the construction cost. In the present investigation is to evaluate the compaction and unconfined compressive strength of stabilized clayey soil using fine ground granulated blast furnace slag (GGBS) and fly ash. Characterization of clayey soil is to be carried out for grain distribution and soil classification. A series of compaction test are to be carried out using mini compaction mould for different combination of soil along with fine ground granulated blast furnace slag (GGBS) and flyash mixtures. For stabilization of clayey soil, the unconfined compressive strength and CBR test will be conducted in accordance with the standard procedures for different combinations of soil and additives.

Soil stabilization is any process which improves the physical properties of soil, such as increasing shear strength, bearing capacity etc. which can be done by use of controlled compaction or addition of suitable admixtures like cement, lime and waste materials like fly ash, GGBS, rice husk etc. The cost of introducing these additives has also increased in recent years which opened the door widely for the development of other kinds of soil additives such as plastics, bamboo etc. This new technique of soil stabilisation can be effectively used to meet the challenges of society, to reduce the quantities of waste, producing useful material from non-useful waste materials. Around 110 million tonnes of fly ash get accumulated every year at the thermal power stations in India. Internationally fly ash is considered as a byproduct which can be used for many applications. Fly Ash Mission was initiated in 1994 to promote gainful and environment friendly utilization of the material. One of the areas identified for its bulk utilization was in construction of roads and embankments.

1.1 Basic principles of soil stabilization:

a). Evaluating the properties of given soil.

b). Effective Utilization of locally available soils and other suitable stabilizing agents.

c). Encouraging the use of industrial wastage in building low cost construction of roads.

1.2 METHODS OF SOIL STABILIZATION:

1. Mechanical stabilization
2. Cement stabilization
3. Lime stabilization
4. Bitumen stabilization
5. Chemical stabilization

1.2.1 Mechanical Stabilisation:- The most basic form of mechanical stabilisation is compaction, which increases the performance of a natural material. The benefits of compaction however are well understood and so they will not be discussed further in this report. Mechanical stabilisation of a material is usually achieved by adding a different material in order to improve the grading or decrease the plasticity of the original material. The physical properties of the original material will be changed, but no chemical reaction is involved. For example, a material rich in fines could be added to a material deficient in fines and in order to produce a material nearer to an ideal particle size distribution curve. This will allow the level of density achieved by compaction to be increased and hence improve the stability of the material under traffic. The proportion of material added is usually from 10 to 50 per cent. Mechanical stabilisation is usually the most cost-effective process for improving poorly-graded materials. This process is usually used to increase the strength of poorly-graded granular material up to the well-graded granular material. The stiffness and strength will generally be lower than that achieved by chemical stabilisation and would often be insufficient for heavy traffic pavements. It may also be necessary to add a stabilising agent to improve the Final properties of the mixed material.

1.2.2 Cement Stabilisation: - Any cement can be used for stabilisation, but Ordinary Portland cement is the most widely used throughout the world. The addition of cement material, in the presence of moisture, produces hydrated calcium aluminate and silicate gels, which crystallize and bond the material particles together. Most of the strength of a cement-stabilized material comes from the hydrated cement. A chemical reaction also takes place between the material and lime, which is released as the cement hydrates leading to a further increase in strength. Granular materials can be improved by the addition of a small proportion of Portland cement, generally less than 10 per cent. The addition of more than 15 per cent cement usually results in conventional concrete. In general the strength of the material will steadily increase with a rise in the cement content.

1.2.3 Lime Stabilization:- The stabilisation of pavement materials is not new, with examples of lime stabilisation being recorded in the construction of early Roman roads. However, the invention of Portland cement in the 19th Century resulted in cement replacing lime as the main type of stabiliser. Lime stabilisation will only be effective with materials which contain enough clay for a positive reaction to take place. Lime is produced from chalk or limestone by heating and combining with water. Only quicklime and hydrated lime are used as stabilisers in road construction. They are usually added in solid form but can also be mixed with water and applied as slurry. It must be noted that there is a violent reaction between quicklime and water and consequently operatives exposed to quicklime can experience several external and internal burns, as well as blinding. Hydrated lime is used extensively for the stabilisation of soil, especially soil with a high clay content where its main advantage is in raising the plastic limit of the clayey soil. Very rapid stabilisation of water-logged sites has been achieved with the use of quicklime.

1.2.4 Bitumen or Tar stabilization:- Bitumen or tar are too viscous to use at ambient temperatures and must be made into either cut-back bitumen (a solution of bitumen in kerosene or diesel) or a bitumen emulsion (bitumen particles suspended in water). When the solvent evaporates or the emulsion „breaks" the bitumen is deposited on the material, the bitumen merely acts as a glue to stick the material particles together and prevent the ingress of water. In many cases the bituminous material acts as an impervious layer in the pavement, preventing the rise of capillary moisture. In a country where bitumen is relatively expensive compared to cement and where most expertise is in cement construction, it appears more reasonable to use a cement stabiliser rather than a bitumen/tar based product.

1.2.5 Chemical stabilisation:- Stabilization of moisture in soil and cementation of particles may be done by chemicals such as calcium chloride, sodium chloride etc. Although all the method is well versed for the soil stabilization but these all require money to spend. Hence to study the stabilization of soil "GROUD GRANULATED BALLAST FURNANCE SLAG (GGBS)" may be used as an admixture which is easily available. The general objectives of mixing chemical additive with soil are to improve or control volume stabilities, strength and stress-strain properties, permeability and durability. Volume stabilities namely control of swelling and shrinkage can be improved by replacement of high hydration of cations such as calcium, magnesium, aluminium or iron. It can also be improved by cementation and by water proofing chemicals. The development and maintenance of high strength and stiffness is achieved by elimination of large pores by bonding particles and aggregates together by maintenance of flocculent particle arrangement by prevention and swelling.

2. LITERATURE REVIEW

Ashish Kumar Pathak, et.al. (2014) investigated the effect of GGBS on the engineering property (optimum moisture content and maximum dry density, plastic limit, liquid limit, compaction, unconfined compressive strength, triaxial and California bearing ratio test) of the soil and determine the engineering properties of the stabilised. GGBS are added from 0% to 25% by dry weight of soil, first of all check the all soil property at 0 % (no GGBS) and then compare after addition of GGBS from 5% to 25%. The investigations showed that generally the engineering properties which improved with the addition of GGBS. The addition of GGBS resulted in a dramatic improvement within the test ranges covered in the programme. The maximum dry density increased and the optimum moisture content decreased with increasing GGBS content and at 25% we got the maximum value of dry density.

Oormila.T.R. et.al.(2014), proved that the utilization of industrial waste materials in the improvement of soils is a cost efficient and environmental friendly method. Stabilisation of the soil is studied by using flyash and ground granulated blast furnace slag. This paper includes the evaluation of soil properties like unconfined compressive strength test and California bearing ratio test. The soil sample was collected from Palur, Tamil Nadu and addition to that, different percentages of flyash (5, 10%, 15% and 20%) and GGBS (15%, 20%, 25%) was added to find the variation in its original strength. Based on these results CBR test was performed with the optimum flyash, optimum GGBS and combination of optimum flyash with varying GGBS percentages (15%, 20%, and 25%). From these results, it was found that optimum GGBS (20%) gives the maximum increment in the CBR value compared with all the other combinations.

Laximanth Yadu (2013) evaluated the potential of granulated blast furnace slag (GBS) with fly ash to stabilize a soft soil. Soft soil samples were collected from Tatibandh-Atari, rural road of Raipur, Chhattisgarh. This soil was classified as CI-MI as per Indian Standard Classification system (ISCS). Different amounts of GBS, i.e. 3, 6, and 9% with different amount of fly ash i.e 3%, 6%, 9% and 12% were used to stabilize the soft soil. The performance of GBS with fly ash modified soils was evaluated using compaction and california bearing ratio (CBR) test. Based on these performance tests, optimum amount of GBS with fly ash was determined as 3% fly ash + 6% GBS. Reasonable improvement has been observed for unsoaked and soaked CBR value of soils with this optimum amount.

DVS Prasad (2008) describes the attempts made to investigate the stabilization process with model test tracks over expansive sub grade. Shear, CBR, and loading-unloading tests were carried out on the tracks with different reinforcement materials, namely waste plastics and waste tire rubber introduced in gravel sub base course laid on expansive sub grade. Test results show that enhanced load carrying capacity is obtained for reinforced gravel sub base as compared to unreinforced gravel sub base in the flexible pavement system.

Aanjan kumar & Prasada raju (2008) Attempts are made to investigate the stabilization process with model test tracks over expansive sub-grade. Cyclic plate load tests were carried out on the tracks with chemicals like lime and cement introduced in fly ash sub–base laid on expansive sub-grade. Test results show that maximum load carrying capacity is obtained for stabilized fly ash sub-base compared to untreated fly ash sub-base.

T.K.ROY &Dr B.C.CHATTOPADHYAY (2008) has undertaken an experimental program to explore the possibility of utilization of the alternative materials like rice husk ash and pond ash by mixing these with soil for the construction of road sub-grade as cost effective mix.

BHUVANESHWARI, ROBINSON, GANDHI (2005) described the study carried out to check the improvements in the properties of expansive soil with fly ash in varying percentages. Both laboratory trials and field tests have been carried out and results are reported in this paper. One of the major difficulties in field application is thorough mixing of the two materials (expansive soil and fly ash) in required proportion to form a homogeneous mass.

A Study carried out by **Phanikumar and Sharma (2004)** on the effect of fly ash on engineering properties of expansive soil through an experimental programme. The effect on parameters like free swell index (FSI), swell potential, swelling pressure, plasticity, compaction, strength and hydraulic conductivity of expansive soil were studied. The ash blended expansive soil with Fly ash contents of 0, 5, 10, 15 and 20% on a dry weight basis and they inferred that increase in Fly ash content reduces plasticity characteristics and the FSI was reduced by about 50% by the addition of 20% fly ash. When the fly ash content increases there is a decrease in the optimum moisture content and the maximum dry unit weight increases. The effect of fly ash is akin to the increased compactive effort. Hence the expansive soil is rendered more stable. The undrained shear strength of the expansive soil blended with fly ash increases with the increase in the ash content.

3. OBJECTIVES

- To investigate the effect of fly ash and GGBS on engineering properties of clayey soil by adding them in varying percentages.
- To improve the strength of soil by stabilizing using industrial wastes like fly ash and GGBS
- To improve the soil strength by using additives in order to use as a base or sub base courses and carry the expected traffic and pavement loads.

4. METHODOLOGY

The properties of natural soil and compaction and strength properties of blended mixes (fly ash alone and GBS alone) will be evaluated in the laboratory and results will be compared.The following laboratory tests are to be carried out as per **IS: 2720** for both the normal soil and stabilized soil.

1. Specific gravity test
2. Grain size analysis
3. Atterbegs limits
4. Proctor compaction test
5. California Bearing Ratio value (CBR) test

The fly ash and GGBS are added separately as mentioned in table

Table No.1 Different mix proportion

Sample	Fly ash (%)	GGBS (%)
1	5	5
2	10	10
3	15	15
4	20	20
5	25	25

The CBR tests will be conducted for the soil sample blended with optimum percentage of fly ash and GGBS.

4.1 Materials Used

4.1.1 Soil

The soil sample for this study was collected from nearby locality of Doddballapura, Benguluru in India. The soil was dried and pulverized to perform the various experimental studies.

4.1.2 Fly Ash

Fly ash is fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. When mixed with water, the fly ash forms a cementitious compound with properties very similar to that of Portland cement.

4.1.3 Granulated Blast Furnace Slag (GGBS)

Blast furnace slag is produced as a by-product during the manufacture of iron in a blast furnace. Molten blast furnace slag has a temperature of 1300-1600°C and is chilled very rapidly to prevent crystallization. The granulated material thus produced is known as granulated blast furnace slag. Blast furnace slag has a glassy, disordered, crystalline structure which can be seen by microscopic examination which is responsible for producing a cementing effect.

4.2 METHODS OF TESTING

The laboratory tests carried out on the natural soil include Sieve analysis, Atterberg limits, Specific gravity, Free swell test, Standard Proctor test and California Bearing Ratio test.

Specific Gravity Test : The appropriate method for determining the specific gravity of the soil is the pycnometer test. Specific gravity of the soil particles is the ratio of weight of given volume of soil solids to the weight of an equal volume of water at 4°c. i.e G = $_{\gamma}s$ /$_{\gamma}w$. Specific gravity as such does not indicate the behavior of a soil mass under external load, but it is an important factor which is used in computing other soil properties. For example soil particle size determination by means of the hydrometer method .It is also used in consolidation studies of clay in calculating the degree of saturation of a soil and in other calculation.

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 limit.

Soil Compaction Test (standard proctor test): There are many situations in engineering practice when the soil itself used as construction material. In the construction of engineering structure such as highway embankment or earth dams for example: - loose fills required to be compacted to increase the soil density and improving their strength characteristics in order to enhance the engineering performance of the soil compaction is must for the appropriate compaction of the soil we need to require optimum moisture content. This optimum moisture content corresponding to the max Compaction can be found by Standard Procter Compaction Test. Compaction is the densification of the soil by the application of the mechanical energy. It is the process by which the soils grains get arrange more closely, the volume of air void get reduced and the density of soil increase. For the heavier standard compaction for airfield construction the optimum moisture content corresponding to maximum compaction is derived by the Modified Procter Compaction Test.

California Bearing Ratio test (CBR): The California bearing ratio is a penetration test for evaluation of the mechanical strength of road subgrades and base-courses. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. This test was performed as per IS 2720(Part 16): 1979.

5. RESULTS AND DISCUSSION

5.1. Specific gravity test

The variation of specific gravity of soil with varying amounts of fly ash and GGBS added to by 0 to 25% by dry weight of soil is shown in Table.2

Table.2: Variation of Specific gravity

Sl.No.	% of additives	Specific Gravity (with Fly Ash)	Specific Gravity (with GGBS)
1	0	2.7	2.7
2	5	2.8	2.8
3	10	2.7	2.7
4	15	2.6	2.6
5	20	2.7	2.7
6	25	2.7	2.6

5.2 Atterberg's limits:

The atterberg's limits of the blended soil was determined as per IS 2720 (part5)-1985. Both the values of liquid limit and plastic limit decreases with increasing percentage of GGBS and fly ash and the variation of plasticity index is tabulated in table 3 and Table.4 respectively.

The variation of plasticity index with varying percentages of GGBS is shown in Table.4, it is inferred that the plasticity index decreases with increase in percentage of GGBS. The comparison of plasticity index for varying percentages of flyash alone and GGBS alone are shown in figure1.

Table.3 Variation of Liquid limit and plastic limit with Fly ash

Sl.No	% of GGBS	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	0	34.5	16	18.5
2	5	31.33	15.2	16.13
3	10	30.48	17	13.48
4	15	33.5	21.2	12.3
5	20	34.2	24.22	9.98
6	25	33.2	21	12.2

Table.4 Variation of Liquid limit and plastic limit with GGBS

Sl.No.	% of FA	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	0	33	24.4	10.6
2	5	31	24	7
3	10	28	20	10
4	15	26	18	8
5	20	24	16	8
6	25	22	15	7

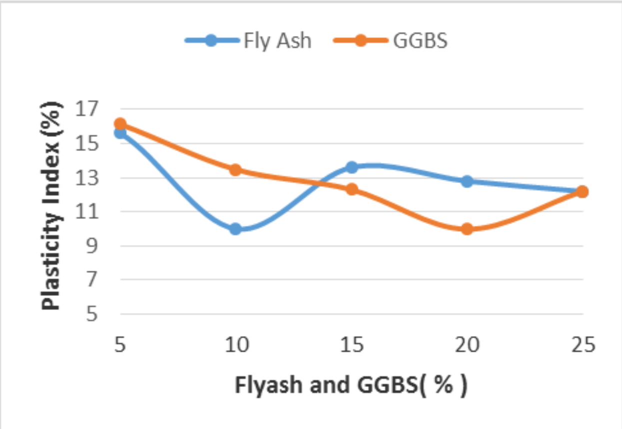

Fig.1. Variation of plasticity Index

5.3 Effect on Compaction Properties:

The variation of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) with varying percentages of fly ash is given in Table. Compaction properties i.e. maximum dry density (MDD) and optimum moisture content (OMC) were determined in the laboratory of all trial mixture in accordance with IS: 2720 (Part 8) - 1983. Variations of MDD and OMC of the mixes are shown in figs 2 and 3 respectively. It is conferred that OMC increased and MDD decreased with increasing percentage of fly ash - GBS mixtures. The decrease in the MDD can be attributed to the replacement of soil by the fly ash in the mixture which has relatively lower specific gravity (2.6) compared to that of the raw soil which is 2.7. The MDD increases by increasing the content of GBS in fly ash–GBS mixtures. This increase in MDD may be explained by considering the GBS as filler with higher specific gravity in the soil-fly ash voids. The increase in OMC due to addition of fly ash may be caused by the absorption of water by fly ash. This implies more water is needed in order to compact the soil with fly ash mixtures.

Table 5. Effect of OMC and MMD on Fly ash

Sl.No	Fly Ash (%)	OMC (%)	MMD (kN/cum)
1	0	12.2	1.76
2	5	14.3	1.68
3	10	14.8	1.84
4	15	13.6	1.745
5	20	12.8	1.76
6	25	12.7	1.75

Table 6. Effect of OMC and MMD on GGBS

Sl.No	GGBS (%)	OMC (%)	MMD (kN/cum)
1	0	13.88	1.72
2	5	13.2	1.68
3	10	13.7	1.82
4	15	12.48	1.71
5	20	12.9	1.69
6	25	12.42	1.65

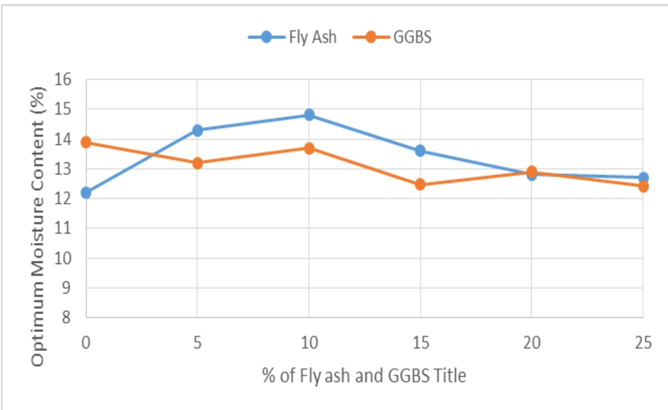

Fig.2. Comparison of Variation of OMC with fly ash and GGBS

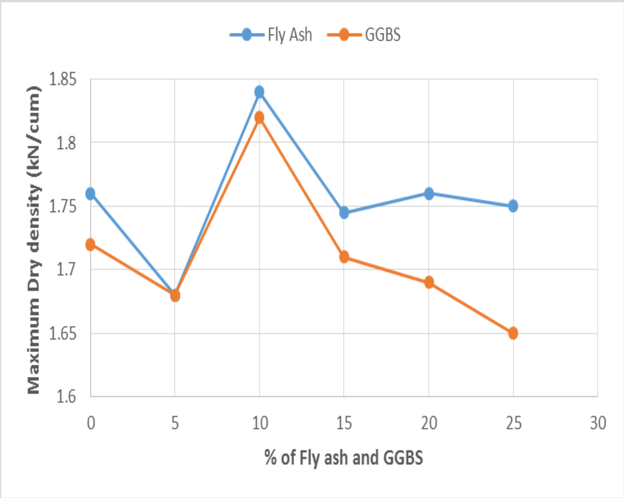

Fig.3. Comparison of Variation of MDD with fly ash and GGBS

5.4 California Bearing Ratio (CBR) :

CBR value is widely used in the design of base and sub base material for the pavement as an indicator of compacted soil strength and bearing capacity. The soaked CBR tests were conducted on samples compacted at OMC (10% fly ash and 10% of GGBS), and soaked for 96 hours in accordance with IS: 2720 (Part 16) – 1987. The variation in CBR value with addition of fly ash-GBS mixtures is shown in table.7 & 8 respectively. The CBR value increase with increase in amount of fly ash and attained maximum value at 15% and again decreases. The same trend is also observed in GGBS in which the maximum CBR value (8.6 %) is attained at 15% of GGBS. The initial increase in the CBR is expected because of gradual formation of cementitious compounds between the fly ash and CaOH present in the soil.

Table.7 Effect of Flyash on CBR values

Sl.No.	% of Fly Ash	CBR (%)
1	0	4
2	5	4.82
3	10	5.21
4	15	6.28
5	20	5.6
6	25	4.4

Table.8 Effect of GGBS on CBR values

Sl.No.	% of GGBS	CBR (%)
1	0	2.2
2	5	3.4
3	10	4.8
4	15	6.8
5	20	7.1
6	25	6.6

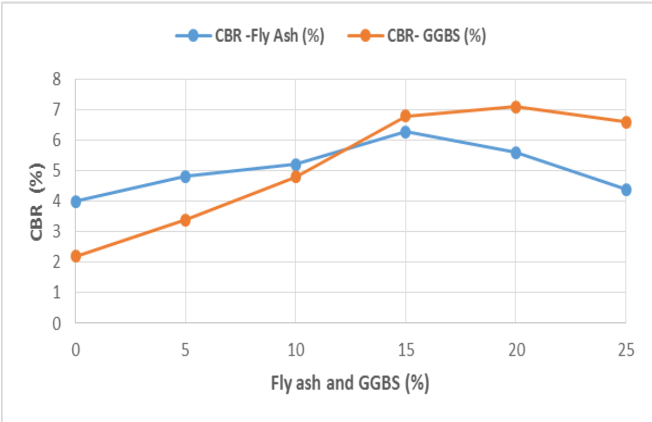

Fig.4 CBR values for different amounts of fly ash and GGBS

5.5 Optimum amount of flyash and GGBS:

The CBR test results are widely used to determine the optimum amount of additives (i.e. fly ash and GGBS) of blended soil. It can be inferred from fig 6 and 7, the CBR value increased from 4% of unstabilised soil to maximum value of 6.28% at 15% fly ash. Similarly CBR value is increased from 2.2% to maximum value of 7.1% at 20% GGBS. Hence the optimum value for fly ash is 15% and GGBS is 20% respectively.

6. CONCLUSIONS

The study has been conducted to assess the potential of fly ash and GGBS for stabilization of the same nature of soil and detailed comparison has been presented based on various properties of soil.

1. It is observed that with the increases of fly ash and GGBS percentage, optimum moisture content goes on decreasing while maximum dry density goes on increasing, hence compact ability of soil increases and making the soil more dense and hard.

2. The maximum optimum moisture content of 14.8% is reached at 10% of flyash and of 13.7% is reached at 10% of GGBS. This showed that the optimum value based on OMC is 10%.

3. The CBR value increase with increase in amount of fly ash and attained maximum value at 15% and again decreases. The same trend is also observed in GGBS in

which the maximum CBR value (8.6 %) is attained at 15% of GGBS. The initial increase in the CBR is expected because of gradual formation of cementitious compounds between the fly ash and CaOH present in the soil.

4. It is concluded that the optimum value for fly ash is 15% and GGBS is 20% respectively.

Based on the results of this study, it appears that the selected soil can be effectively stabilised with the addition of fly ash at 15 % or 20% GGBS by dry weight of soil. Fly ash- GBS mixtures are suitable for use in rural roads, embankments and it be used as provide fill materials of comparable strength.

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