Effect on Geotechnical Properties of Clayey Soil Stabilised with Iron Ore Mine Tailing and Ground Granulated Blast Furnace Slag

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Abstract – Soil Stabilisation in a broad sense, incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance. Stabilisation is being used for a variety of engineering works, the most common application being in the construction of road and air-field pavements, where the main objective is to increase the strength or stability of soil and to reduce the construction cost by making best use of the locally available waste materials. Methods of stabilisation may be grouped under two main types:

- **Modification or improvement of a soil property of the existing soil without any admixture.**
- **Modification of the properties with the help of admixtures.**

Compaction and drainage are the examples of the first type, which improves the inherent shear strength of soil. Examples of the first type are mechanical stabilisation and stabilisation with cement, lime, bitumen and chemicals or other additives belongs to second type.

In this investigation, industrial waste Iron ore mine tailing and Ground granulated blast furnace slag were used to improve the engineering properties of soil. This investigation involves the determination of the various properties of soil i.e. Particle size distribution, Atteberg's limits, OMC, MDD and CBR were determined for the prepared samples. The various tests were performed in natural soil sample as well as when mixed with different proportion of IRON ORE mine tailing and GGBFS from 3 to 15% at interval of 3% and 5 to 25% at the interval of 5% respectively.

Index Terms – Soil Stabilisation, Iron ore mine tailing, Ground Granulated Blast Furnace Slag, Particle size distribution, Consistency Indices, OMC, MDD and CBR.

1. INTRODUCTION

Clay, common name for a number of fine-grained, earthy materials that become plastic when wet. Chemically, clays are hydrous aluminium silicates, ordinarily containing impurities, e.g., potassium, sodium, calcium, magnesium, or iron, in small amounts. Clay is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. Clays are plastic due to their water content and become hard, brittle and non–plastic upon drying or firing. The main problem with clay soil is that, the clay soil gets swell when comes in contact with moisture and loses its strength. This property causes uneven settlement. Uneven settlement is dangerous for all kind of structures i.e. pavement, building etc. Stabilisation is the best solution for improving bearing capacity and reduce the shrinkage and swell of soil. There are various admixture used in the process of stabilisation. Cement and lime are very popular admixture for soil stabilisation. In present study we are investigate the effect of industrial waste material in the various properties of soil. Industrial waste is the waste produced by industrial activity which includes any material that is rendered useless during a manufacturing process such as that of factories, industries, mills, and mining operations. The most effective aspect in this study is to reduce the cost of stabilisation and disposal of industrial waste.

2. NECESSITY OF STABILIZATION

Soil stabilisation is a modern and efficient method of recycling and strengthening inert and contaminated soils and other construction materials for foundation to buildings and vehicular paving, offering substantial benefits to the developer and contractor alike. Most cohesive and granular sub - soils can be stabilised. Natural soils as well as made ground and recycled materials can be utilised. Soil Stabilisation converts weak and unsuitable soils into viable construction materials. Stabilisation is the best solutions for light, dry and structurally weak soil that is geo-technically unsuitable for construction.

3. MATERIALS

The various material used in carrying out this project are natural soil, Iron ore mine tailing and Ground granulated blast furnace slag.

1) NATURAL SOIL: The clay soil was procured from NH-7 Shihora, JABALPUR District, MADHYA PRADESH, INDIA at a depth of 100 cm below

natural ground level. Manual excavation method was used for the procurement of the soil.

2) IRON ORE MINE TAILING: Mine tailing is a waste material of Iron industries. Iron ore mine tailing was procured from an open dump from Jain mines and minerals India Pvt. Ltd. HARGARH INDUSTRIAL AREA, JABALPUR District, MADHYA PRADESH, INDIA. After removing the vegetation and other matter on the surface of mine dump, it was air dried, pulverized and passing through 425 micron BIS sieve was used in different proportion from 3% to 15% at the interval or 3% in the present investigation.

3) GROUND GRANULATED BLAST FURNACE SLAG: GGBFS is a by-product of Iron making industries. The granulated blast-furnace slag is sand-type slag manufactured by spraying high-pressure water jets on a blast-furnace molten slag. GGBFS was obtained in an open dump from UTTAM GALVA STEEL INDUSTRY, MAHARASTRA, INDIA. After removing the impurities and other matter on the surface of dump the GGBFS was collected and then it was oven dried, and passing through 425 micron BIS sieve was used in different proportion from 5% to 25% at the interval of 5% in the present investigation

Fig 1. Collection of natural soil sample

Fig 2 Iron ore mine tailing dump

Fig 3 Ground Granulated Blast furnace Slag

4. METHODS OF TESTING

The various tests were carried out on the natural soil as well as the sample prepared i.e. replace with different proportion of Iron ore mine tailing and GGBFS.

GRAIN SIZE DISTRIBUTION: Grain size distribution or the percentage of various size of soil grains present in a given dry sample, is an important soil grain property. Grain size analysis of soils is carried out by sieve analysis. Sieves are wire screens having square openings. The set of I.S. sieves for fine sieve analysis consist of 4.75 mm, 2 mm, 1 mm, 600 µ, 425 µ, 300 µ, 212 µ, 150 µ and 75 µ sieves. In the dry sieve analysis, a suitable quantity of pulverised dry soil of known weight about 500gms is taken and is sieved through a selected set of sieves arranged according to their sizes, with the largest aperture sieve at the top and the smallest aperture sieve at the bottom. A receiver is kept at the bottom and a lid is placed on the topmost sieve of the stack. The amount of shaking depends upon the shape and number of particles. However, ten minutes of shaking by a mechanical shaker is usually sufficient. The amount of soil retained on each sieve is weighed to the nearest 0.1g. On the basis of total weight of sample of sample taken and the weight of soil retained on each sieve, the percentage of the total weight of soil passing through each sieve also termed as percent finer than can be calculated as below:

% retained on a particular sieve = Weight of soil retained on that sieve X 100 / total weight of soil taken

Cumulative % retained = Sum of % retained on all sieve of larger sizes and the % retained on that particular sieve

Percentage finer than the sieve under reference = 100% - cumulative % retained

Fig 4 Sieve Analysis

CONSISTENCY OF CLAYS – ATTERBERG LIMITS: Consistency is a term which is used to describe the degree of

firmness of a soil in a quantitative manner by using description such as soft, medium, firm, stiff or hard.

Indicates the relative ease with which a soil can be deformed. In practice, the property of consistency is associated only with fine-grained soils, especially in clays. The physical properties of clays are considerably influenced by the amount of water present in them. The boundary water contents at which the soil undergoes a change from one state to another are called consistency limits.

1) **LIQUID LIMIT:** Liquid limit is 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 standardised procedure. With reference to one such standard procedure, the liquid limit is defined as the water content at which a groove cut in a pat of soil by a grooving tool of standard dimensions will flow together for a distance of 13 mm under the impact of 25 blows in a standard liquid limit device.
2) **PLASTIC LIMIT:** Plastic limit is defined as the water content at which a soil would just begin to crumble when rolled into a thread of approximately 3 mm diameter.
3) **PLASTICITY INDEX:** Plasticity index is the range of moisture content over which a soil exhibits plasticity. It is the numerical difference between the liquid limit and the plastic limit.

PROCTOR'S COMPACTION TEST: The modified proctor test was developed during World War II to better simulate the compaction required for airfields to support heavier aircraft. The test employs a heavier hammer 4054kg or 10 lb with a height of 457.2 mm and 5 layers tamped 25 times into a standard proctors mould.

The Indian standard equivalent of the standard proctor test is called Light compaction test (IS: 2720, part VII-1974). The volume of the mould is 1000 cc, the weight of hammer 2.6 kg and the drop 310 mm.

The Indian standard equivalent of the Modified proctor test is called Heavy compaction test (IS: 2720, part VII-1983). The weight of hammer is 4.9 kg and the drop 450 mm. The soil is compacted in 5 layers. Each layer tamped in 25 times.

Fig 5 Compaction mould

CALIFORNIA BEARING RATIO: The California Bearing Ratio (CBR) test yields relative strength of laboratory-compacted or in–situ soils and base course materials. The test is performed in the laboratory or field with different equipment and is based on penetration resistance of a soil to a standard-sized piston. In the lab, soils at specific moisture contents are compacted into moulds. Sample preparation prior to testing may include soaking and addition of surcharge weights to the moulded specimens. The penetration test is carried out in a load frame outfitted with CBR test components. The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

This instruction sheet covers the laboratory method for the determination of C.B.R. of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

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.

C.B.R. = Test load/Standard load x 100

5. RESULT

Table-1 Properties of the natural soil sample

Sr. NO.	Characteristics	Unit	Value
1.	Natural Moisture Content	%	15.36
2.	Liquid Limit	%	46.84
3.	Plastic Limit	%	24.68
4.	Plasticity Index	%	22.16
5.	Optimum Moisture Content	%	23.5
6.	Maximum Dry Density	gm/cc	1.66
7.	California Bearing Ratio	%	1.23

Where,

% indicates the value of particular characteristic in percentage.

Table-2 Sample Nomenclature

S No.	Soil Sample	Nomenclature
1.	Simple Soil	S_1
2.	Soil + 3% MT + 5% GGBFS	S_2
3.	Soil + 6% MT + 10% GGBFS	S_3
4.	Soil + 9% MT + 15% GGBFS	S_4
5.	Soil + 12% MT + 20% GGBFS	S_5
6.	Soil + 15% MT + 25% GGBFS	S_6

Table-3 Index Properties of the soil sample

Sample Nomenclature	MT % + GGBFS %	L.L.	P.L.	P.I.
S_1	0% MT + 0% GGBFS	46.84	24.68	22.16
S_2	3% MT + 5% GGBFS	37.21	21.72	15.49
S_3	6% MT + 10% GGBFS	33.25	19.45	13.8
S_4	9% MT + 15% GGBFS	28.61	16.33	12.28
S_5	12% MT + 20% GGBFS	24.88	12.65	12.23
S_6	15% MT + 25% GGBFS	NP	NP	NP

Table-4 Engineering Properties of the soil sample

Sample Nomenclature	MT % + GGBFS %	MODIFIED PROCTOR		CBR	
		OMC	MDD	CBR VALUE	% CBR IMPROVED
S_1	0% MT + 0% GGBFS	23.5	1.66	1.17	-
S_2	3% MT + 5% GGBFS	17.76	1.81	2.95	148.78
S_3	6% MT + 10% GGBFS	16.33	1.86	3.11	152.14
S_4	9% MT + 15% GGBFS	14.79	1.91	3.48	197.44
S_5	12% MT + 20% GGBFS	13.46	1.96	3.88	231.62
S_6	15% MT + 25% GGBFS	12.09	2.01	4.17	256.41

Where,

MT (%) = Iron Ore Mine Tailing

GGBFS (%) = Ground Granulated Blast Furnace Slag

L.L. = Liquid Limit

P.L. = Plastic Limit

P.I. = Plasticity Index

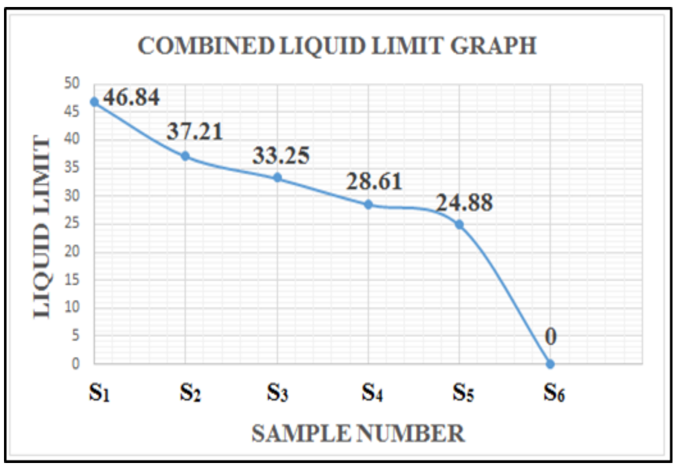
OMC = Optimum Moisture Content

MDD = Maximum Dry Density

CBR = California Bearing Ratio

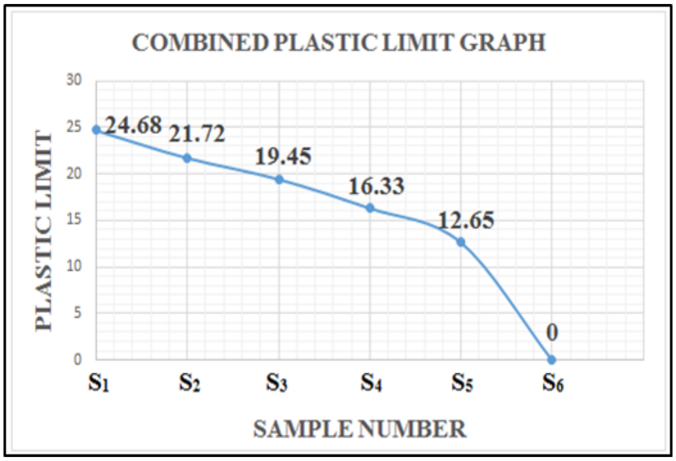
6. GRAPHICAL REPRESENTATION OF TEST RESULT

LIQUID LIMIT



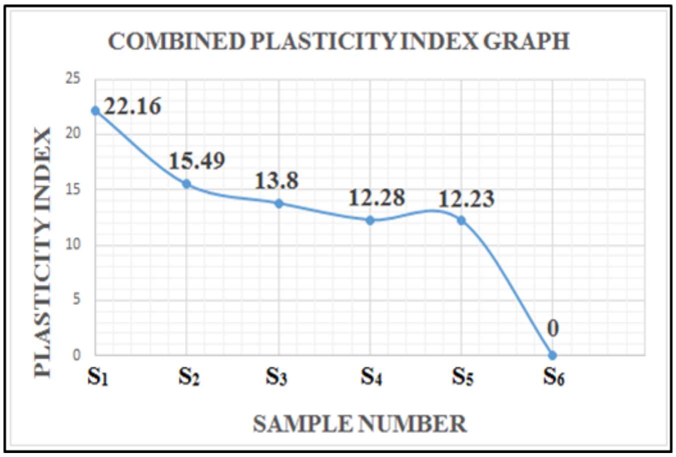
Graph 1: Variation in Liquid Limit

PLASTIC LIMIT



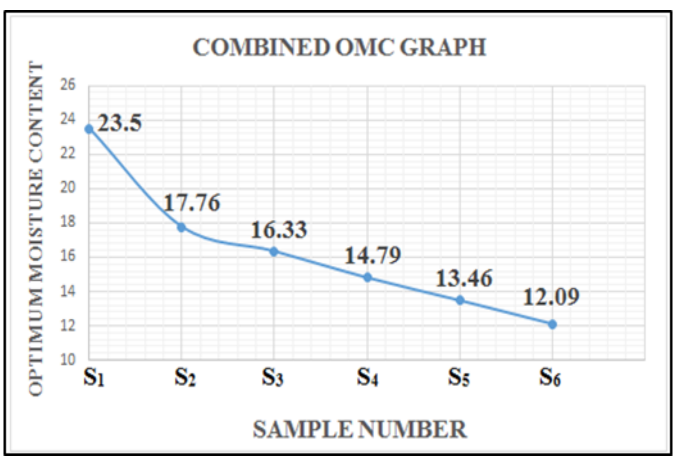
Graph 2: Variation in Plastic Limit

PLASTICITY INDEX



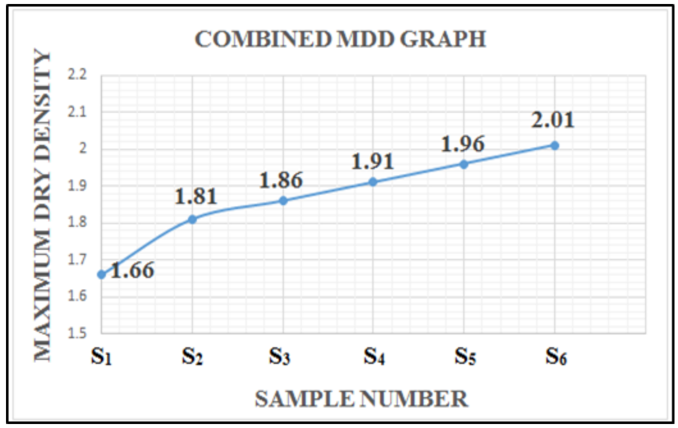
Graph 3: Variation in Plasticity Index

OPTIMUM MOISTURE CONTENT



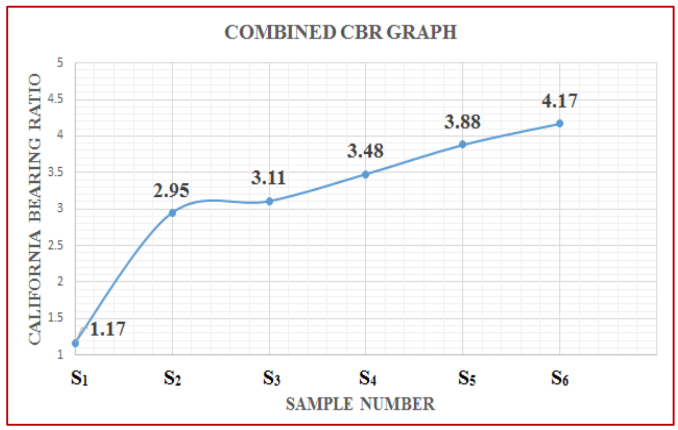
Graph 4: Variation in OMC

MAXIMUM DRY DENSITY



Graph 5: Variation in MDD

CALIFORNIA BEARING RATIO



Graph 6: Variation in CBR

7. CONCLUSION

In present investigation the clay soil is effectively stabilised while adding Iron ore mine tailing and GGBFS mixes in different proportion. With increasing the percentage of mixes Plasticity index of soil decreases. The other properties of soil are also improved with Iron ore mine tailing and GGBFS mixes. The OMC of soil decreases with increase the percentage of admixture, also the MDD increases with increase the percentage of admixture. The value of CBR effectively increased with increasing the percentage of admixture. The iron ore mine tailing and GGBFS is an industrial waste material so stabilise the soil with mine tailing is cost effective stabilisation also it is best way to dispose the industrial waste.

There is a good hike in the value of soaked CBR of soil with the mixes of Mine tailing and furnace slag. With the increase of percentage of additive mixes i.e. Iron ore mine tailing and Ground granulated blast furnace slag the CBR value enhanced in very good rate. The percentage of CBR increased are 148.78 to 256.41% with the increase in percentage of additive mixes.

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