World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 5.218

EFFICACY OF CBR ON COPPER AND STEEL SLAG IN EXPANSIVE SOILS

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Article Received on 06/07/2018 Article Revised on 26/07/2018 Article Accepted on 16/08/2018

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ABSTRACT

A large part of Central India and a portion of South India are covered with black cotton soils. These soils have high swelling and shrinkage characteristics and extremely low CBR value and shear strength. Hence, there is need for improvement of these properties. The present study is aimed at determining the behavior of black cotton soil reinforced with steel slag and copper slag in a random manner. The soil used is a type of black cotton soil collected from Vempalli, Kadapa District, at a depth of 1.5 m from the natural ground level. The soil samples were prepared at four different percentages of steel slag (5, 10, 15 & 20% by weight of soil) and keeping 20% copper slag as constant. CBR test for 4 days soaking period for both treated and untreated soil samples.

KEYWORDS: Copper Slag, Steel Slag, Expansive Soil, Compaction and CBR.

1.0 INTRODUCTION

Expansive soil is a term generally applied to any soil that has a potential for shrinking or swelling under changing moisture conditions. Expansiveness is a phenomenon that affects clay soils, those that contain significant quantities of Montmorillonite mineral. The problem that arises with expansive soils is that deformations are significantly greater, cannot be predicted. Movement is usually in uneven pattern and of such a magnitude as to cause severe damage to the structures and pavements lying on them. Damages sustained by structures include: distortion and cracking of pavements and on-grade floor slabs; cracks in grade beams, walls, and drilled shafts; jammed or misaligned doors and windows; and failure of steel or concrete plinths (or blocks) are supporting grade beams. The magnitude of damages to structures can be extensive, impair the usefulness of the structure, and detract aesthetically from the environment. Maintenance and repair requirements can be extensive, and the expenses can grossly exceed the original cost of the foundation. Soil stabilization refers to the procedures employed with a view to altering one or more properties of soil so as to improve its engineering performance. The main objective of soil stabilization is to increase the strength or stability of the soil and to reduce its sensitivity to moisture changes.

The stabilization techniques may be grouped under the following two major heads:

- Stabilization without additives.
- Stabilization with additives.

Stabilization without additives may be mechanical rearrangement of particles through compaction or addition or removal of soil particles. Soil stabilization can also be achieved through drainage. The drainage can be achieved by application of external load, electro-osmosis, or by application of thermal gradient i.e., heating or cooling.

Stabilization with additives may be with the use of cement, bitumen or chemical stabilizers. Chemicals may be fly ash, lime, calcium or sodium chloride, physico-chemical alterations involving ion exchange in clay minerals or stabilization by grouting with cement or chemicals. In the present work Copper slag and Steel slag are used as stabilizing agents. The aim of this research work was to use copper slag and steel slag in the stabilization of black cotton soil. The specific objectives of this study include, Determination of the index and engineering properties of the soil samples; Determination of the index, strength and CBR values of the black cotton soil-copper slag and black cotton soil-steel slag mixtures and their combinations, Determination of the optimum % of copper slag and steel-slag content required. The study was limited to the determination of the effect of adding up to 20 % of copper slag and various percentage of steel slag up to 20% on the properties of black cotton soil using Modified Proctor compaction energy with respect to compaction characteristics and CBR values. All tests were carried out in accordance with the procedures outlined in BS 1498 (1970) for the natural and treated soils, respectively.

2.0 LITERATURE REVIEW

Expansive soils are considered to be the most problematic soil all over the world due to their swelling and shrinkage behaviour. The deformations produced are significantly greater than elastic deformations. These soils causes damage to structures because of their heaving during rainy season and shrinkage during summer, due to which buildings crack, canal linings slide, beds of canal heave, roads get rutted etc. the degree of swell/shrink capacity is related to clay mineralogy or more specifically to active clay minerals such as montmorillonite. Swelling of pure montmorillonite clay can affect the volume changes as much as 2000 percent and generate swelling pressure in excess of 30000 pounds per square foot. Expansion is chiefly caused by the hydration or attraction and absorption of water molecules into expansible crystal lattice of the clay mineral. Soil shrinkage occurs when the process is reversed and the water is removed or extracted from the clay crystal lattice.

Prof. Jinka Chandrshekhar and Timir A Chokshi (2015) examined that Mine squanders are one of the perpetual waste concerns. Akshaya Kumar Sabat and Subasis Pati (2014) says that Expansive soil is a problematic soil for civil engineers because of its low strength and cyclic swell shrink behaviour. Stabilization using solid wastes like copper slag, blast furnace slag, mines waste etc., is one of the different methods of treatment, to improve the engineering properties and make it suitable for construction. The beneficial effects of some prominent solid wastes as obtained in laboratory studies, in stabilization of expansive soils. R C Gupta, Blessen Skariah Thomas, Prachi Gupta, Lintu Rajan and Dayanand Thagriya (2009) studied that Copper Slag is one of the waste byproduct produced by 'Hindustan Copper limited', Khetri, Rajasthan, India. The production of Copper Slag is 120-130 lakh ton per annum. Expansive soils are a worldwide problem that creates challenges for Civil Engineers. Isaac Ibukun Akinwumi(2012) talked about that Elemental and compound examination of the steel slag was resolved utilizing x-beam fluorescence spectroscopy. Tests were completed to decide the record and building properties of the common and treated soil. Kiran B. Biradar, U. Arun kumar, Dr.PVV Satyanarayana (2014) conducted studies on the effect of length of Steel slag on Clayey soil with the addition of Fly ash and Steel slag.

3.0 MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Black Cotton Soil

In the present study black cotton soil was collected from Vempalli, near kadapa, Telangana, India, at a depth of 1.5m from the natural ground level. The soil obtained is air dried and pulverized manually. All the tests were conducted as per IS-2720 standards. The physical and chemical properties of the soil are shown in Table 3.1and Table 1.

Table 1: Properties Black Cotton Soil.

Specific Gravity	2.52
Grain Size Distribution	
Fine sand fraction (%)	2.4
Silt size (%)	22.5
Clay size (%)	75
Atterberg‘S Limit	
Liquid Limit (%)	80.56
Plastic Limit (%)	21.26
Plasticity Index (%)	59.3
Free Swell Index	140
Classification of soil	CH
Compaction Characteristics	
Maximum Dry Density (g/cc)	1.46
Optimum Moisture Content (%)	26.4
Unconfined Compressive Strength(Kg/cm^2)	0.85
California Bearing Ratio	
Soaked	2.11
Unsoaked	1.4

3.1.2 Copper Slag

For the present study, Copper slag obtained from Apple insulated wires P.LTD at Hyderabad, Andhrapradesh, India is used in this investigation. Copper slag is a by-item shaped amid the copper purifying procedure. The countermined copper slag must be appropriately treated or washed to meet certain reusing criteria before it can be further utilized. The creation of one ton Copper produces, roughly 2-3 tons of Copper Slag. Copper Slag is lethal to environment since it contains substantial measure of overwhelming metals in their oxides. It can tackle an imperative issue for environment by use of Copper Slag in soil adjustment.

3.1.3 Steel Slag

For the present study, Steel slag was obtained from Lanco Industries, Srikalahasthi, Andhra Pradesh; India. Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations. The slag randomly mixed with soil in varying percentages (5%, 10%, 15% and 20%) by dry weight of soil.

3.2 METHODOLOGY

3.2.1 Preparation of the CBR Specimen

The test may be performed on undisturbed specimens or on remolded specimens which support from the sides of the mould during the penetration test. The density of the may be compacted either statically or dynamically. Undisturbed specimens shall be obtained by fitting to the mould, the steel cutting edge of 150 mm internal diameter and pushing the mould as gently as possible into the ground. When the mould is sufficiently full of soil, it shall be removed by under digging. The top and bottom undersurfaces are then trimmed to give the desired length to the specimen. If the specimen is loose in the mould, the annular cavity shall be filled with paraffin wax thus ensuring that the soil receives proper soil and the water content of the soil must be determined by one of the available standard methods. Remolded specimens must be prepared in such a way that the dry density and water content correspond to those values at which the CBR value is desired. The material shall pass a 20-mm IS sieve. Allowance for larger material shall be made by replacing it by an equal amount of material which passes a 20 mm IS sieve but is retained on 4.75 mm IS Sieve.

Statically compacted specimens may be obtained by placing the calculated mass of soil in the mould and pressing in the displacer disc, a filter paper being placed between the disc and the soil. The pressing may be stopped when the top of the displacer disc is flush with the rim of the mould.

Dynamically compacted specimens may be obtained by using the standard metal rammer in accordance with ‘‘IS: 2720 (Part VII)—1983—Determination of water content—dry density relation using light compaction’’ or ‘‘IS: 2720 (Part VIII)-1983—Determination of water content— dry density relation using heavy compaction’’. The mould with the extension collar attached shall be clamped to the base plate. The spacer disc shall be inserted over the base plate and a disc of coarse filter paper placed on the top of the spacer disc. After compacting the soil into the mould, the extension collar shall be removed and the top of the sample struck off level with the rim of the mould by means of a straight edge. The perforated base plate and spacer disc shall be removed for recording the mass of the mould and the compacted soil. A disc of coarse filter paper shall be placed on the perforated base plate, the mould and the compacted soil shall be inverted, and the perforated base plate clamped to the mould with the compacted soil in contact with the filter paper.

In both cases of compaction, if soaking of the sample is required, representative samples of the material shall be taken both before compaction and after compaction for determination of water content. If the sample is not to be soaked, representative sample of the material after the penetration shall be taken for the determination of the water content.

3.2.2 Test Procedure

The mould containing the specimen, with the base plate in position, shall be placed on the lower plate of the loading machine. Surcharge weights, sufficient to produce a pressure equal to the weight of the base material and the pavement, shall be placed on the specimen. If the specimen has been soaked previously, the surcharge shall be equal to that used during the soaking period. The annular weight above which the slotted weights are placed prevents the upheaval of the soil into the slots of the weights. The plunger shall be seated under a load of 39.2 N (4 kg) so that, full contact is established between surface of the specimen and plunger. The dial gauges of the proving ring and those for penetration are set to zero. The seating load for the plunger is ignored for the purpose of showing the load penetration relation. Load shall be applied such that the rate of penetration is approximately 1.25 mm/min. Load readings shall be recorded at penetrations of 0, 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5 mm. The maximum load and penetration shall be recorded if it occurs for a penetration of less than 12.5 mm. The plunger shall be raised and detached from the loading machine. About 0.5 N (50 g) of soil shall be collected from the top 30 mm layer of the specimen and the water content determined as per IS: 2720 (Part-II)-1973. The presence of any oversize particles shall be verified which may affect the results if they happen to be located directly below the penetration plunger.

4.0 RESULTS AND DISCUSSION

The Compaction and California Bearing Ratio tests were conducted based on Indian Standard (IS) procedure to the experimental programme. The effects of Copper slag, Steel slag on black cotton soil and also the combined effect of Copper slag and Steel slag on black cotton soil have been studied. The results and discussions are presented in the following sections.

4.1 Effect of copper slag on black cotton soil

Compaction Test

Compaction is the process of densification of soil mass by reducing air voids. The degree of compaction of soil mass is in terms of its Dry density. The degree of compaction mainly depends upon its moisture content, compaction energy and type of soil. For a given compaction energy, every soil attains the Maximum Dry Density (MDD) at a particular water content which is known as Optimum Moisture Content (OMC). The variation of dry unit weight of the soil and moisture content with respect to the black cotton soil with different percentage of copper slag is shown in Figure 4.1. It has been seen by laboratory experiments that as the water content is increased, the compacted unit weight goes on increasing till a maximum dry unit weight is achieved after which further addition of water decreases the unit weight. When relatively a small amount of water is present in soil, it is firmly held by the electrical forces at the surface of soil particles with a high concentration of electrolyte which prevents the diffuse double layer surrounding the particles from developing fully. The double layer depression leads to a low inter-particle repulsion and the particles do not move over one another easily when compactive energy is applied and hence high percentage air voids and low density is achieved.

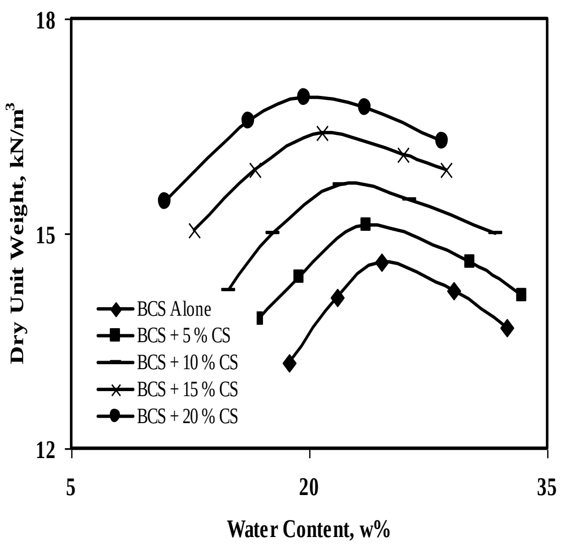

Figure 4.1: Dry Unit weight vs Water content with BCS treated with various percentages of copper slag.

The increase in water content results in an expansion of double layer and a reduction in net attractive forces between particles or in an increased inter particle repulsion which permits the particles to slide more easily past one another into denser state of packing together , and hence higher density. After the optimum water content is reached, the air voids approach approximately a constant value as further increase in water content does not cause any appreciable decrease in them, even though a more orderly arrangement of particles may exist at higher water contents. The total voids due to water and air in combination go on increasing with increase of water content beyond the optimum and hence the dry density falls. The dry unit weight of the soil increases and the moisture content decreases with respect to the black cotton soil with different percentage of copper slag. i.e the maximum dry unit weight of the soil (MDD) increases from 14.6, 15.1, 15.8, 16.4 and 16.9; the optimum moisture content (OMC) decreases from 26.4, 23.2, 21.4, 20.8, and 19.7 for the black cotton soil with different percentage of copper slag (0, 5, 10, 15 and 20).

California Bearing Ratio(CBR)

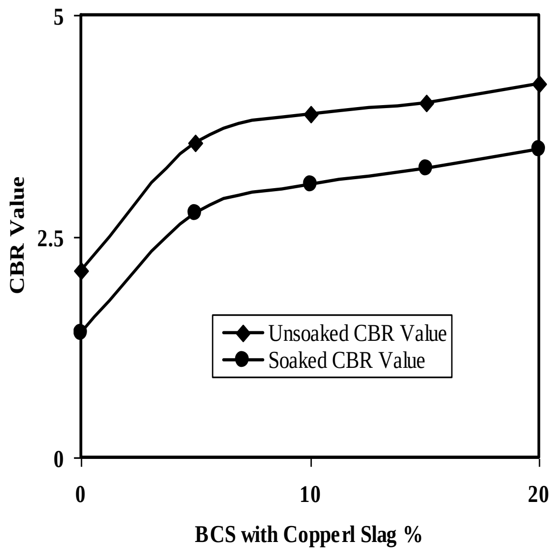

Figure 4.2: CBR Value vs BCS with various percentages of copper slag.

The variation of CBR for soaked and unsoaked specimen with respect to the Copper slag content is as shown in Figure 4.2**.** Addition of Copper slag (up to 20%) to black cotton soil increased the CBR for both soaked and unsoaked. The un soaked CBR values are 2.11, 3.55, 3.88, 4.0, 4.23 and for soaked CBR values are 1.4, 3.0, 3.08, 3.27, 3.49 for black cotton soils (BCS) alone, BCS with 5% copper slag, BCS with 10% Copper Slag, BCS with 15% Copper Slag and BCS with 20% copper slag.

4.2 Effect of steel slag on black cotton soil

Unit Weight of the Soil

The variation of MDD and OMC with respect to the Steel slag content is as shown in Figure 4.2. Addition of Steel slag to black cotton soil increased the maximum dry density with decrease in optimum moisture content. The dry unit weight of the soil increases and the moisture content decreases with respect to the black cotton soil with different percentage of copper slag. i.e the maximum dry unit weight of the soil (MDD) increases from 14.6, 14.8, 15.3, 15.9 and 16.2; the optimum moisture content (OMC) decreases from 26.4, 26.2, 23.5, 21.4, and 20.9 for the black cotton soil with different percentage of steel slag (0, 5, 10, 15 and 20).

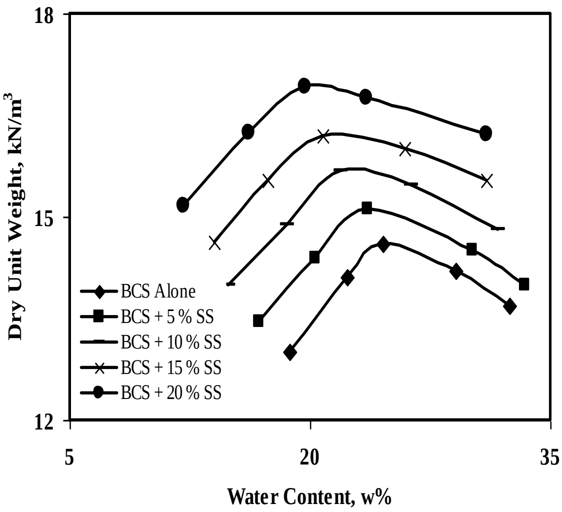

Figure 4.3: Dry Unit weight vs Water content with BCS treated with various percentages of steel slag.

California Bearing Ratio(CBR)

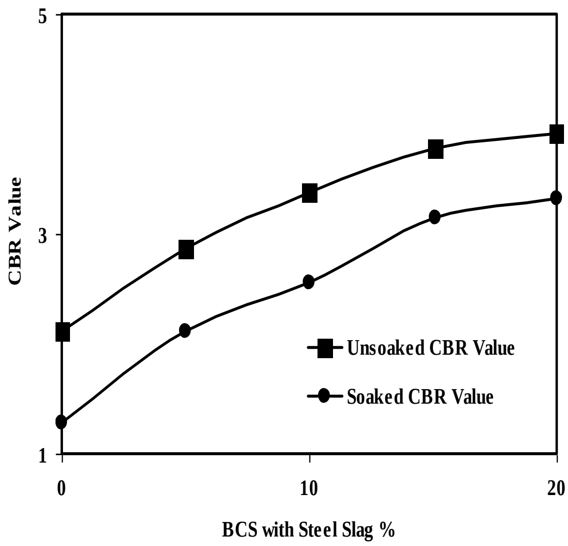

Figure 4.4: CBR Value vs BCS with various percentages of steel slag.

The variation of CBR for soaked and unsoaked specimen with respect to the Steel slag content is as shown in figure 4.8 and table 4.8**.** Addition of Steel slag (5% to 20%) to black cotton soil increased the CBR for both soaked and unsoaked shown in Figure 4.4. Further addition of Steel slag reduces the CBR for both soaked and unsoaked. CBR of unsoaked soil specimen is greater than that of soaked soil specimen. The unsoaked CBR values are 2.11, 2.68, 3.0, 3.78, 3.91 and for soaked CBR values are 1.4, 1.7, 2.13, 3.15, 3.32 for black cotton soils (BCS) alone, BCS with 5% copper slag, BCS with 10% Copper Slag, BCS with 15% Copper Slag and BCS with 20% Copper Slag

4.3 Effect of varying percentage of steel slag and constant copper slag treated with black cotton soil

Unit Weight of the Soil

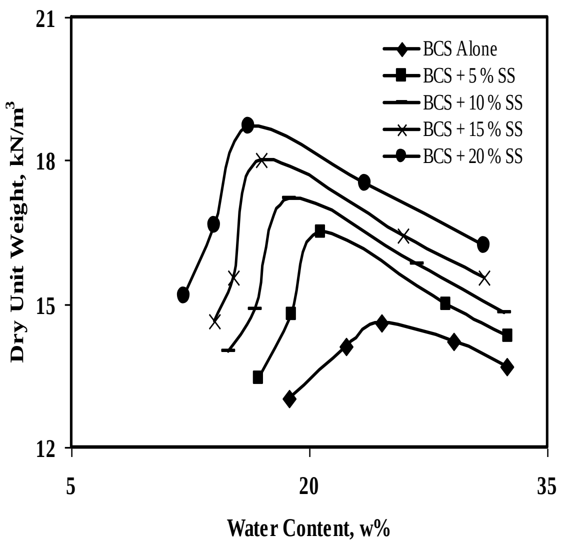

Fig 4.5: Dry Unit weight vs Water content with BCS treated with various % of steel and 20 % copper slag.

Addition of various percentages of Steel slag keeping 20% constant copper slag treated black cotton soil the maximum dry density increased and the optimum moisture content decreased shown in Figure 4.5. The dry unit weight of the soil increases and the moisture content decreases with respect to the black cotton soil with different percentage of copper slag. i.e the maximum dry unit weight of the soil (MDD) increases from 14.6, 16.5, 17.2, 18.0 and 18.7; the optimum moisture content (OMC) decreases from 26.4, 20.7, 18.7, 17.0 and 16.2 for the black cotton soil with different percentage of steel slag (0, 5, 10, 15 and 20).

California Bearing Ratio (CBR)

The variation of CBR for soaked and unsoaked with respect to the Steel slag from 5% to 20% Copper slag as 20% constant treated black cotton soil content is as shown in figure 4.6 and table 4.9. Addition of Steel slag (5% to 20%) and 20% Copper slag treated black cotton soil increased the CBR for both soaked and unsoaked. The unsoaked CBR values are 2.11,3.75, 4.13, 4.63, 4.82 and for soaked CBR values are 1.4, 3.0, 3.27, 3.4, 3.62 for black cotton soils (BCS) alone, BCS with 5% copper slag, BCS with 10% Copper Slag, BCS with 15% Copper Slag and BCS with 20% Copper Slag.

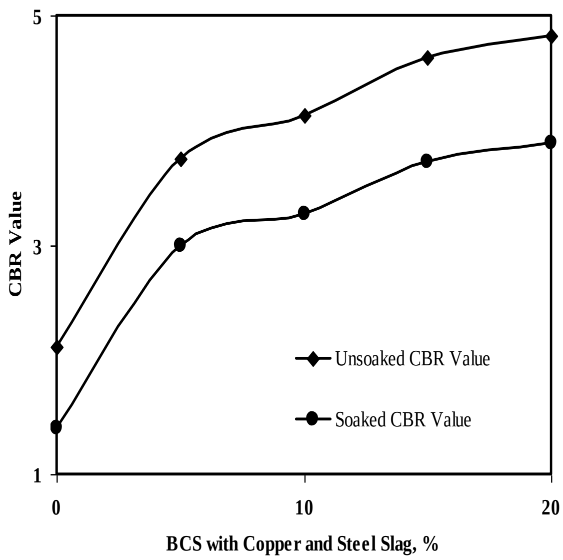

Figure 4.6 CBR Value vs BCS with BCS treated with various percentages of steel and (20 %) copper slag.

5.0 CONCLUSION

1. With increase in the percentage of copper slag, dry density of soil increased to a maximum value 1.69 g/cc at 20%, percentage increase is 15.7%. The percentage of increases in dry density are 3.4%, 8.2%, 12.3%, 15.7% for with increases of copper slag from zero, 5%, 10%, 15% and 20%.
2. With increasing the percentage of steel slag dry density of soil attains maximum value 1.62 g/cc from 1.46gm/cc at 20% of steel slag, increased percentage is 10.9%. The percentage of increases in dry density are 1.3%, 4.8%, 8.9%, 10.9% for with increases of steel slag from zero, 5%, 10%, 15% and 20%.
3. With increasing the varying percentage of steel slag + constant 20% copper slag dry density of soil attains maximum value 1.87 g/cc at 20%, increased percentage is 28%.

The percentage of increases in dry density are 13.0%, 17.8%, 23.2%, 28.0% for with increases of copper slag from zero, 5%, 10%, 15% and 20%.

4. When soil treated with copper slag, CBR value is maximum at 20% of copper slag is 4.23 for unsoaked, increase in percentage is 100.4%. For soaked soil CBR the maximum CBR value is 3.49. Percentage increase is 149.2% compared to untreated soaked soil. The percentage of increases in unsoaked CBR values are 68.2%, 83.9%, 89.6%, 100.4% for with increases of copper slag from zero, 5%, 10%, 15% and 20%. The percentage of increases in soaked CBR values are 114.3%, 120.0%, 133.6%, 149.2% for with increases of copper slag from zero, 5%, 10%, 15% and 20%.
5. When soil is treated with steel slag, maximum CBR value obtained at 20% of steel slag is 3.91, percentage increase is 85.3f or unsoaked soil. For soaked soil sample the percentage increase is 137.5%. The percentage of increases in unsoaked CBR values are 27.0%, 42.2%, 79.1%, 85.3% for with increases of steel slag from zero, 5%, 10%, 15% and 20%. The percentage of increases in soaked CBR values are 21.4%, 52.1%, 125.0%, 137.5% for with increases of steel slag from zero, 5%, 10%, 15% and 20%.
6. CBR value for the soil is 4.82 at 20% of steel slag + 20% of copper slag for unsoaked treated soil and percentage increase is 128%. For soaked soil sample maximum CBR is 3.62, percentage increase is 158.5%. The percentage of increases in unsoaked CBR values are 77.8%, 95.7%, 119.4%, 128.0% for with increases of steel slag + 20% of copper slag steel slag from zero, 5%, 10%, 15% and 20%. The percentage of increases in soaked CBR values are 114.3%, 133.6%, 142.8%, 158.5% for with increases of steel slag + 20% of copper slag steel slag from zero, 5%, 10%, 15% and 20%.

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