Bearing Capacity of Strip Footing Rest on Reinforced Industrial Slags and Silty Clay Beneath

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Abstract
This study was done to investigate the bearing capacities of strip footing on reinforced and unreinforced copper slag and induction furnace slag overlay compacted silty clay (i.e. double layer system) and their effectiveness using model tank tests in laboratory. Various parameters are investigated such as H/B (thickness of top layer to width of footing), u/B (location of the first layer of reinforcement to the width of footing), h/B (vertical spacing between consecutive geogrid layers to width of footing), b/B (length of the geogrid layer to the width of footing). The effect of H/B ratios and geogrid reinforcement N values on BCR (bearing Capacity ratio) and SRR (settlement reduction ratio) were also investigated. The results show that there is significant increase in the bearing capacity with increasing H/B ratio as well as the no. of geogrid layers.

Keywords – *Copper Slag, Induction Furnace Slag, Silty Clay, Model Tank, Bearing Capacity Ratio & Settlement Reduction Ratio*

I. INTRODUCTION

Today with the increased globalization the network of highways are increasing at a very brisk rate. All the areas are connected through roads which are a great thing for us but side by side the conventional materials that are used in highways are depleting at an alarming rate and the material cost is hiking thus increasing the overall cost of the construction. In the sub base of the highways the granular material like sand and gravel is to be used. As the conventional materials are decreasing we try to use the industrial wastes that are granular, in sub base layer so as to effectively dump the waste from the industries and to find the suitable alternative for the granular materials and thus making our construction very economical. There are several techniques to improve the properties of the soil. Soil reinforcement and Double layer soil system are the techniques used to increase the engineering properties of the soil.

From the last few years several studies have been performed on laboratory model and field tests, related to beneficial effects of the reinforced materials, on the load bearing capacities of strip of soils in strip footings. From the several researches it is concluded that bearing capacities of the soil changes with various factors such as H/B(thickness of top layer to width of footing), u/B(location of the first layer of reinforcement to the width of footing), h/B(vertical spacing between consecutive geogrid layers to width of footing), b/B(length of the geogrid layer to the width of footing), H(thickness of soil layer) and N(number of geogrid layers).

Sharma, L., Kumar, S.J and Naval, S (2015) investigated the effect of bearing capacity of strip footing on geogrid reinforced sand overlay on stabilized expansive soil (i.e. double layer soil system) and check the different parameters contributing to their performance using laboratory model tank tests. The parameters investigated in this study include H/B (thickness of top sandy layer to width of footing) u/B (location of the 1st layer of reinforcement to width of footing), h/B (vertical spacing between consecutive geogrid layers to width of footing), b/B (length of the geogrid layer to width of footing). The effect of different H/B ratios and geogrid reinforcement N values on the bearing capacity ration (BCR) and settlement reduction ratio (SRR) were also investigated. The results show that bearing capacity increases significantly with increasing the H/B ratio as well as number of geogrid layers. The bearing capacity for the soil increases with an average of 12.35% using H/B equal to 0.5 and the bearing capacity increases with an average of 35.76%, 75.56% & 230.83% while using H/B equal to 1.0, 1.5 & 2.0.

Yadu, L and Tripathi, R.K (Geo-Congress 2014) investigated the effect of BCR's of strip footing for various granular fill thickness and number of geogrid layers in granular fill overlay on soft soil. The granulated blast furnace slag is the by- product of iron and steel industry. The effect on bearing capacity ratios of strip footing for various unreinforced GBS fill thickness has been observed and optimum thickness of GBS fill has been used to study the effect of no. of geogrid layers on bearing capacity. The test results indicate substantial improvement in terms of increase in bearing capacity ratio and reduction in the footing settlement due to provision of GBS fill overlay on soft soil. Optimum thickness of GBS fill increases the bearing capacity ratio of soft soil by 85%. Further, reinforcement of optimum GBS fill thickness by optimum number of layers increases the bearing capacity ratio by 419%.

II. MATERIALS USED

A. Copper Slag

Copper slag is a by-product material produced from the process of manufacturing copper. The slag is collected from Quality spares centre Faridabad.

Table 1. Physical Properties of Copper Slag

Physical Form	Angular Granules
Specific Gravity	3.5
Bulk Density	1.93 g/cc
Colour	Black
Cu	2.75
Cc	1.03

B. Induction Furnace Slag

In process of cast iron and ductile iron production, secondary raw material and industrial wastes are formed. The most abundant waste originating in the process is induction furnace slag. It contain about 10-15% metal. The slag is collected from Hansco Iron & steels pvt ltd Mandi Gobindgarh.

Table 2.Physical Properties of Iron Slag

Physical Form	Angular Granules
Specific Gravity	2.9
Bulk Density	1.74 g/cc
Colour	Black
Cu	11.14
Cc	0.88

C.Silty Clay

The soil is collected from jalandhar, Punjab, India
The soil is classified as medium plastic in nature with reddish brown colour.

Table 3. Physical Properties of Soil

Colour	Reddish **brown**
Physical Form	Fine Grained
Bulk Density	1.58 g/cc
Liquid Limit	27
Plastic limit	19
Plasticity index	8

D. Uniaxial Geogrid

Uniaxial geogrid is a high strength geo synthetic made of high molecular polymer after extruded and laminated and punched into regular mesh before longitudinal stretching. Uniaxial Geogrids are commonly used in applications where high long term loads are required to be mobilized. The geogrid used was SGi-040 and was bought from Courtesy M/S Strata Geosystems (India) Pvt. Ltd, Mumbai, India.

Table 4. Properties of Uniaxial Geogrid

Thickness	0.27mm
Aperture size	60x23mm
Cross Machine Direction	
Single rib tensile strength	33.9 kN/m
Single rib elongation at 30 kN/m	10.3%
Number of ribs per meter	38

Machine Direction	
Single rib tensile strength	43.4 kN/m
Single rib elongation at 30 kN/m	11%
Number of ribs per meter	37

III. EXPERIMENTAL METHODOLOGY

Experiments are performed on the use of copper slag and iron slag for finding out the optimum granular waste that can be used in roads and other construction sites instead of conventional materials. The following tests were performed on copper slag and iron slag placed over silty clay

Sieve Analysis, Model Tank Testing. Slags are used in different proportions with silty clay beneath. Silty clay soil sample is placed into the model tank and compacted thoroughly. Before running the test in the model tank. After compaction of the soil in the model tank up to desired depth. The slag layer will be placed above the soil. At the interface level of two soils will place a layer of geogrid. And then place the second layer of geogrid in between the slag layer. Then load will apply to the model footing by using a manual hydraulic pump system. The loading rate was kept constant in every test. The load and corresponding foundation settlement will be measured by using a load cell and a dial gauge, respectively.

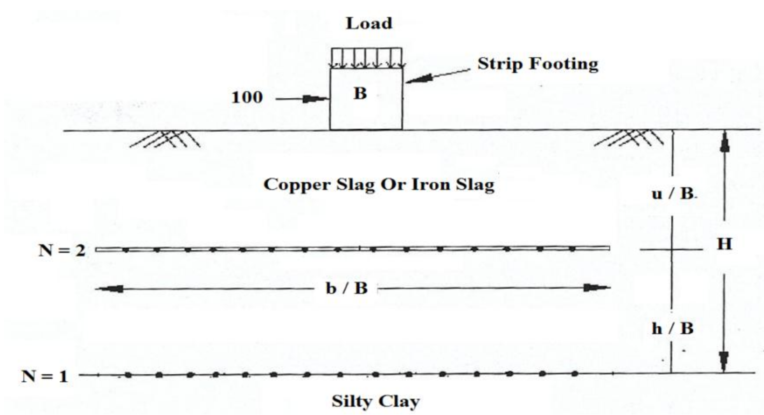

Fig 1- Schematic Positioning of Geogrids

IV. TEST SERIES DESCRIPTION

A sequence of model tank test were performed on double layer soil system. Total nine tests are performed with varying top layer thickness of materials in the double layer and varying number of geogrid layers. The parameters of the test and the schematic test models are presented.

Table 5. Series of Model Tank Test

TEST SERIES	DESCRIPTION	VARIABLE PARAMETERS	CONSTANT PARAMETERS
A	Silty clay	-------	*OMC*
B	Unreinforced copper slag over silty clay	H/B = 1.0, 1.5, 2.0	R_d = 60%
C	Reinforced copper slag over silty clay	N = 1, 2	R_d = 60%, u/B = h/B = 0.75, H/B = 1.5
D	Unreinforced/Reinforced induction furnace slag over silty clay	H/B = as per result from series A and N= 1,2	R_d = 60%

A. *Test Series A* –

In this the tank is filled with silty clay upto 600mm depth and the pressure vs settlement values are calculated

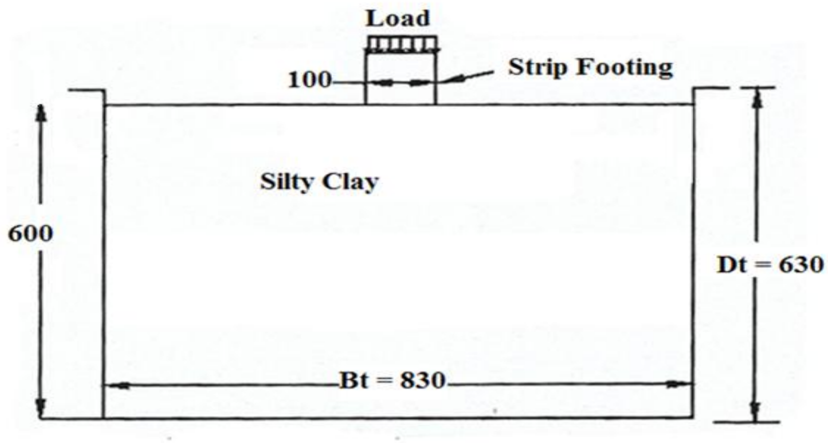

Fig 2- Model Tank with Soil

B. *Test Series B*

Series B consist of copper slag layer above the silty clay with no geogrid reinforcement. Three tests are conducted with three different H/B ratios i.e 1, 1.5, 2 where H/B is the top layer thickness of copper slag to the width of the footing fig. 3, 4 & 5 shows the cross-section of the footing with the different H/B ratios.

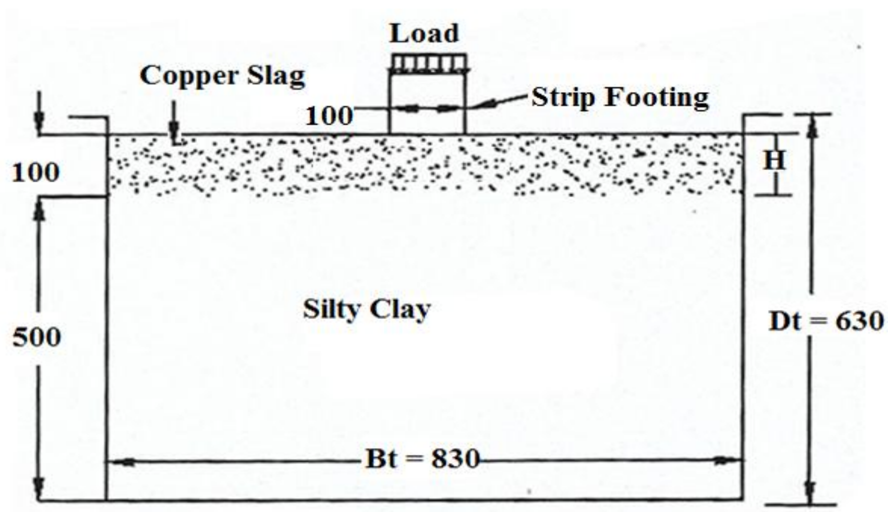

Fig 3- Test Series B with Copper Slag at H/B = 1.0

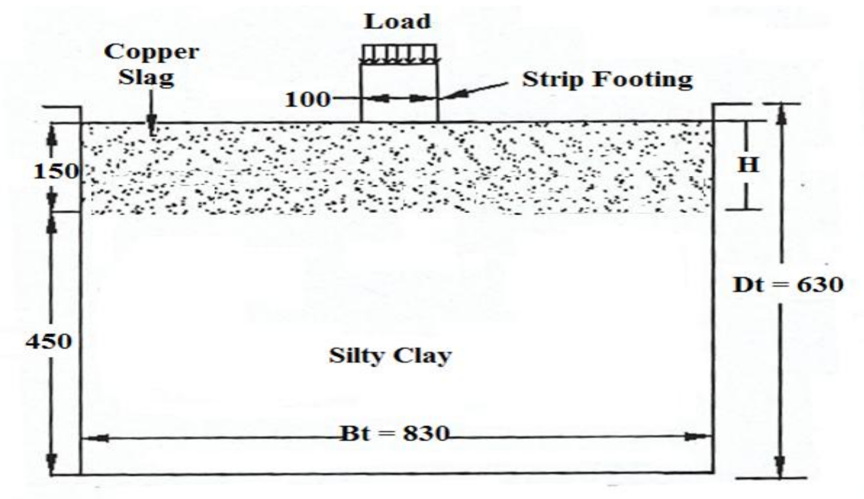

Fig 4-Test series B with copper slag at H/B = 1.5

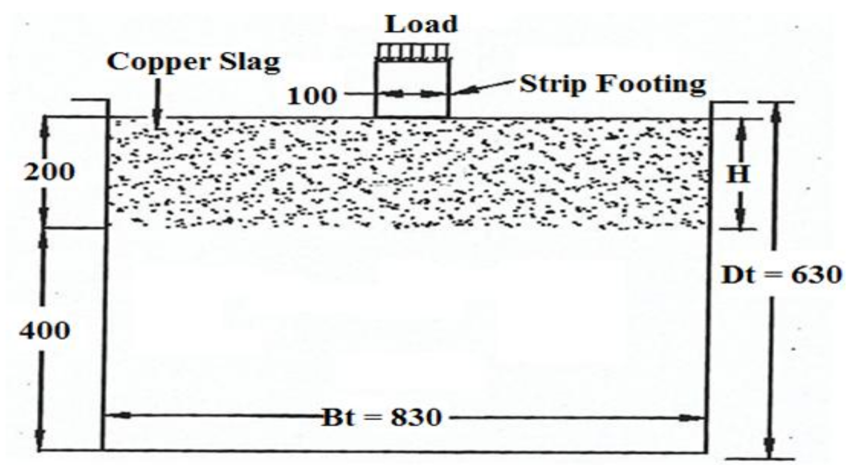

Fig 5- Test Series B with Copper Slag at H/B = 2.0

C. Test Series C –

It is the case of reinforced copper slag in which the optimum H/B ratio is selected and the geogrids are placed (N = 1, N = 2) as shown in the fig 6 & 7.

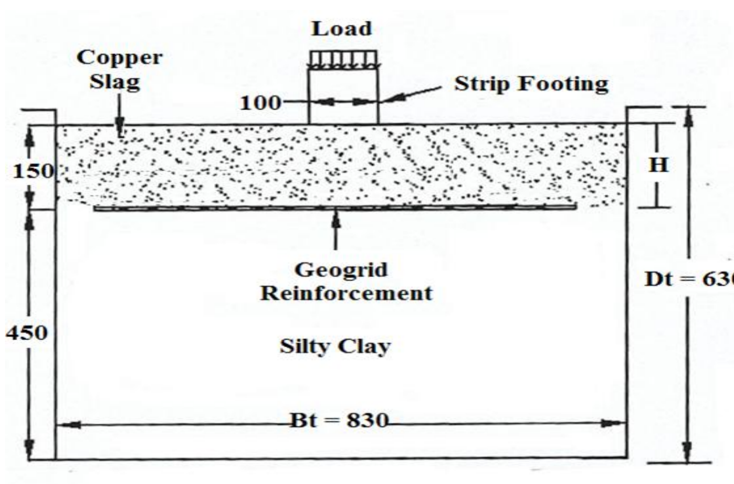

Fig 6-Test Series C with Reinforced Copper slag (N = 1)

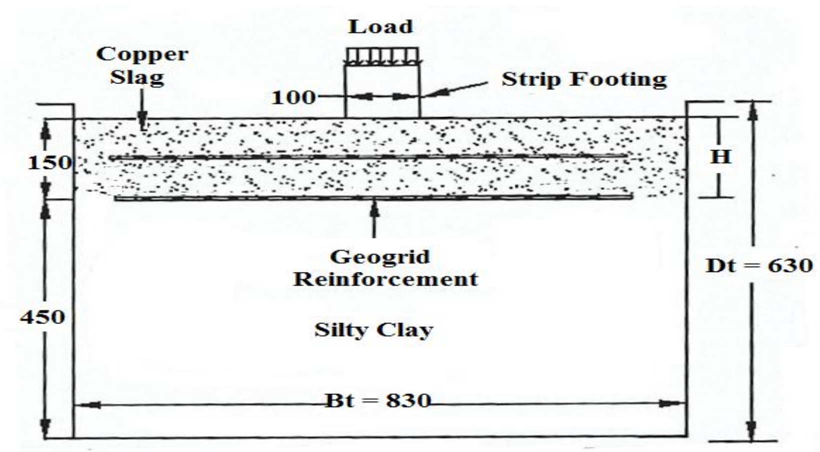

Fig 7- Test Series C with Reinforced Copper Slag (N = 2)

D. Test Series D –

In this test series the model tank test is carried out on both reinforced and unreinforced induction furnace slag keeping the optimum value of H/B = 1.5 and the reinforcement is done in two layers N=1 and N=2. The test series placement is same as in fig. 4, 6&7.

V. RESULTS AND DISCUSSION

Series of tests were performed on silty clay, copper slag and iron slag with and without geogrid reinforcement layer. The results are presented and discussed below.

A. Grain Size Distribution

Grain size distribution tests carried on copper slag and iron slag. The results are presented in fig. 11 & 12. From the curve the gradation parameters of the material, coefficient of uniformity (Cu) and coefficient of curvature(Cc) are determined. As per the Unified Soil Classification the copper slag is classified as well graded sand (SW) and iron slag is classified as poorly graded sand (SP). The physical parameters and grain size analysis results are presented in the table.A poorly graded soil will have better drainage than a well graded soil because there are more void spaces in a poorly graded soil.

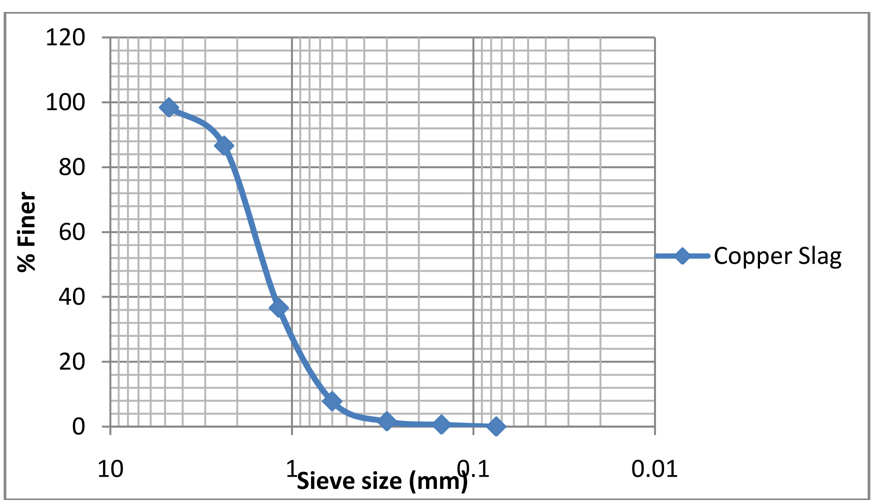

Fig 11 - Grain Size Distribution Curve for Copper Slag

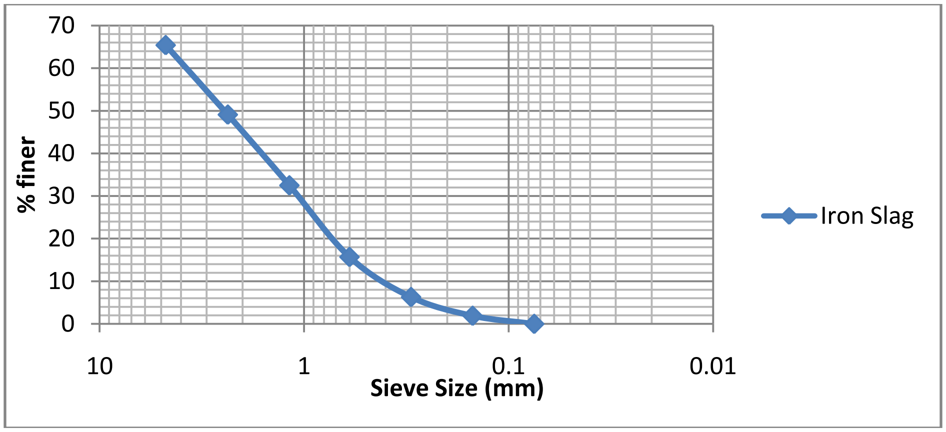

Fig 12 - Grain Size Distribution Curve for Iron Slag

The results from the test are shown in tabular form below.

Table 5 Grain size Analysis Result for Copper Slag

Copper Slag	
D60	1.8mm
D10	0.65mm
D30	1.1mm
Cu	2.76
Cc	1.03
Gradation	SW

Table 6 Grain Size Analysis Result for Induction Furnace Slag

Induction furnace Slag	
D60	3.9mm
D10	0.35mm
D30	1.1mm
Cu	11.1
Cc	0.88
Gradation	SP

B. Load - Settlement Characterstics

The results of test series are presented in terms of Pressure V/S Setlement Bearing Capacity Ratio (BCR) and Settlement Reduction Ratio (SRR). The following well established equation is used for the evaluation of BCR

$$BCR = \frac{qR}{qo}$$

qR = Ultimate bearing capacity of reinforced soil
qo = Ultimate bearing capacity of unreinforced soil
SR = Settlement of reinforced soil

Settlement Reduction Ratio (SRR) defined as percentage reduction in settlement due to unreinforced/reinforced slag overlay on silty clay soil relative to silty clay soil bed at a constant load.

$$SRR = \frac{(So - SR)}{So}$$

So = Settlement of soil layer

The bearing pressure curves for the above test series are shown in fig 13-17 .

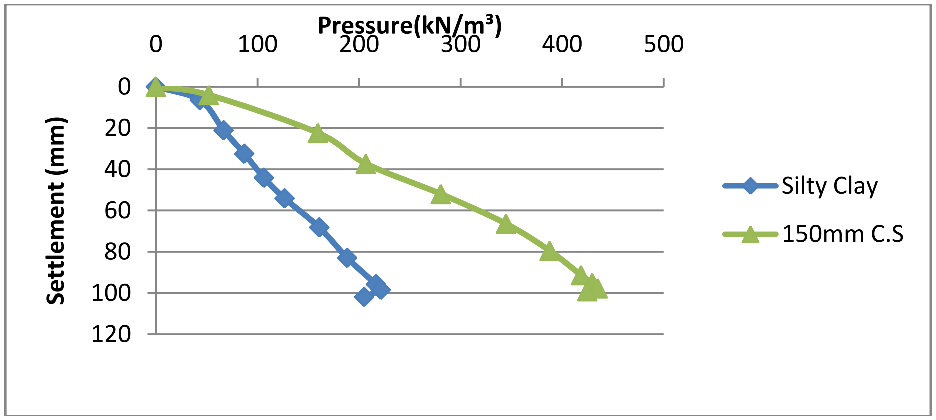

Fig 13- Silty Clay at 600mm depth graph

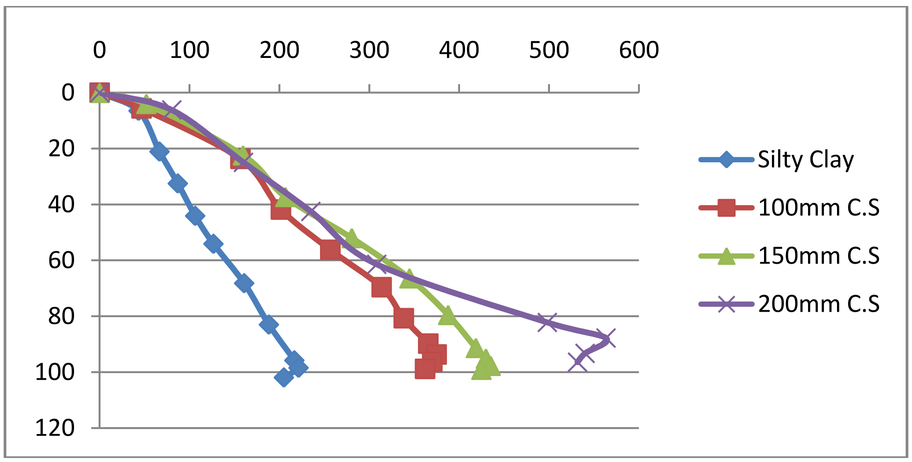

Fig 14- Copper Slag (unreinforced) at H/B = 1, 1.5 & 2

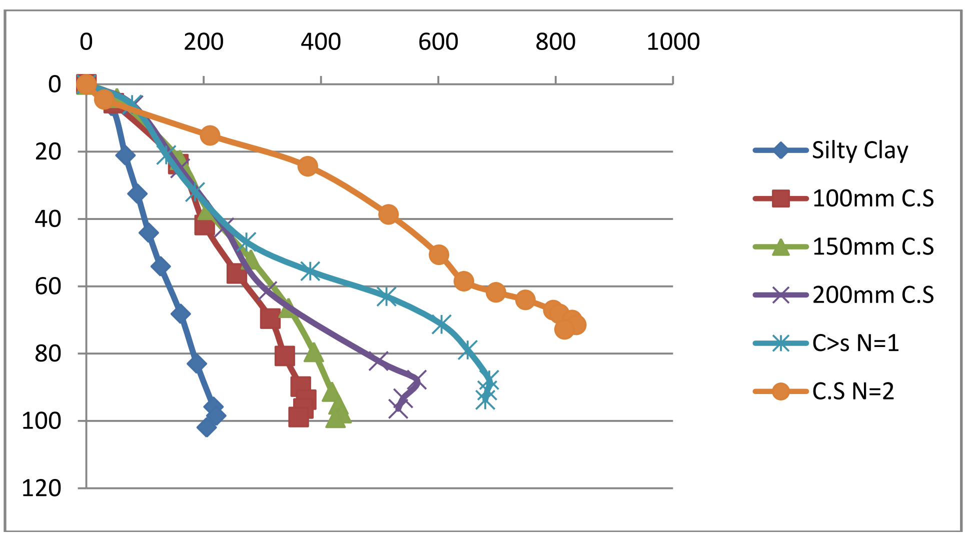

Fig 15- Copper Slag(reinforced) at H/B = 1.5

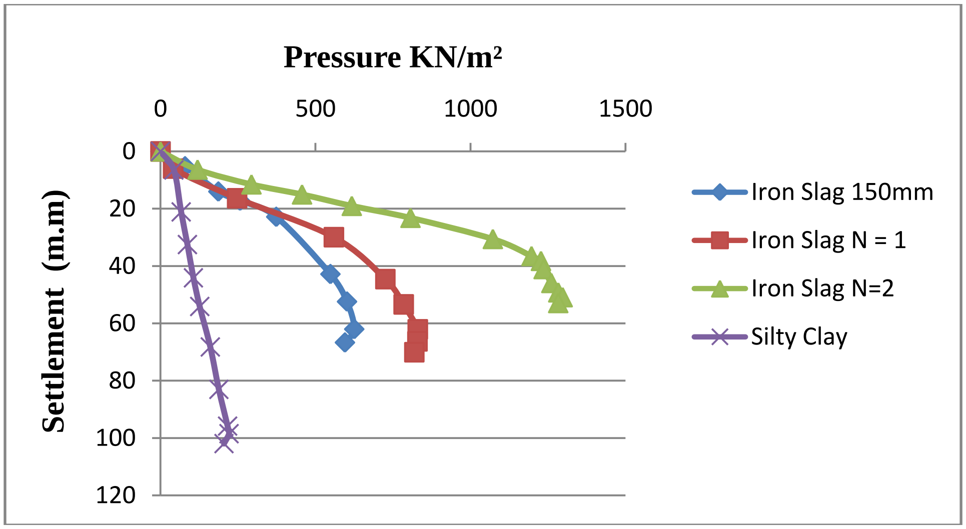

Fig 16- Iron Slag(reinforced) at H/B = 1.5

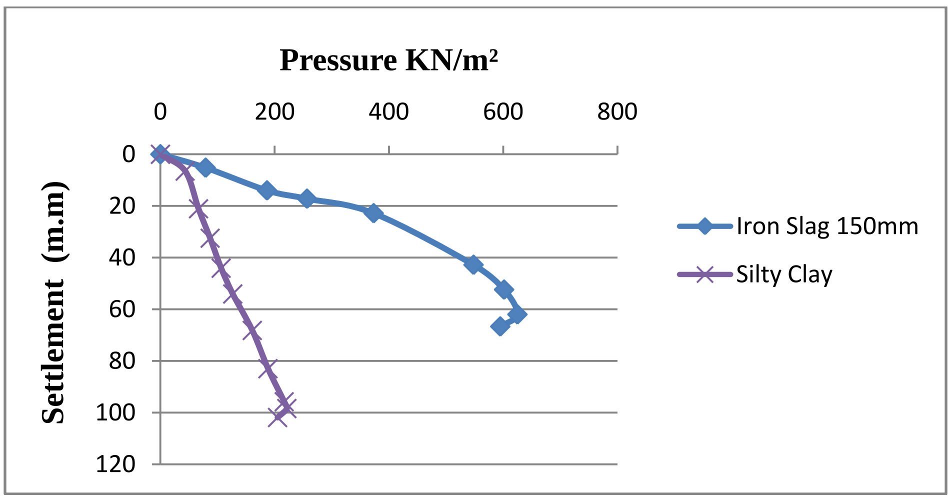

Fig 17- Iron Slag (unreinforced) at H/B = 1.5

VI. CONCLUSIONS

Based on the above results the following conclusions are drawn

- The Ultimate Bearing Pressure of Silty Clay obtained is 221.33 kN/m² and the settlement at failure is 98.45mm.
- In double layer soil system, copper slag placed as top layer over silty clay of various dimensions 100mm, 150mm, 200mm (H/B = 1, 1.5, 2.0), the ultimate bearing pressure obtained is 374.83, 435, 563.33 kN/m² at settlements 93.68, 97.70, 87.7mm respectively.
- Copper slag with silty clay beneath, the bearing pressure with geogrid reinforcement at interface and middle of copper slag is 691.66 and 835 kN/m² and settlement 87.8 and 71.45mm respectively.
- In double layer soil system, iron slag placed as top layer over silty clay of dimension 150mm (H/B = 1.5), the ultimate bearing pressure obtained is 625 kN/m² at 48 mm settlement .
- Iron slag with silty clay beneath, the bearing pressure with geogrid reinforcement at interface and middle of copper slag is 830 and 1297.166 kN/m² and 62.05 and 50.86 mm respectively.

REFRENCES

[1] Prasad, P.S and Ramana, G.V (2016); "Feasibility study of copper slag as a structural fill in reinforced soil structures" International Journal of Geotextiles and Geomembranes Vol. 44, Issue 6, pg. 623-640

[2] Sharma, L., Kumar, S.J and Naval, S (2015); "Effect of bearing capacity of strip footing on reinforced double layer soil system with fly ash stabilized clayey soil" Int. Journal of Engineering Research and Applications, Vol. 5 , Issue 8, (Part 4), pp. 10 – 16

[3] Tripathi, R.K and Yadu, L (2014); "Effect of depth and number of layers of reinforcement on bearing capacity ratio of the strip footing resting on granulated blast furnance slag reinforced with geogrid" Geo-congress 2014

[4] Tripathi, R.K and Yadu, L (2014); "Effect on bearing capacity ratio of strip footing for various granular fill thickness and number of geogrid layers in granular fill overlay on soft soil" Geo-congress 2014

[5] Madheswaran, C.K., Ambily, P.S., Rajamane, N.P and Dattatreya, J.K(2014) "Studies on use of Copper Slag as Replacement Material for River Sand in Building Constructions" Springer 2014, Vol. 95, Issue 3, pp. 169 – 177

[6] Gill, K.S., Choudhary, A.K., Jha, J.N and Shukla, S.K (ASCE 2013); "Large model footing load test on multi-layer reinforced coal ash slope" Geo-congress 2013

[7] John, A and John, E (2013) "Study on the partial replacement of fine aggregates using induction furnace slag" American Journal Of Engineering Research , Vol 4 , Issue 2320-0936

[8] Choudhary, A.K., Jha, J.N and Gill, K.S (2010); "Laboratory investigation of bearing capacity of strip footing on reinforced flyash slope"Int. Journal of Geotextiles and Geomembranes,

[9] Consoli, N.C., Rosa, F.D and Fonini, A (2009); "Plate load tests on cemented soil layers overlaying weaker soils" Journal of Geotechnical and Geoenviromental Engineering, Vol. 135, Issue. 12, pp. 1846 – 1856

[10] EI Sawwaf, M (2007); "Behaviour of strip footing on geogrid reinforced sand over a soft clay slope" Int. Journal Of Geotextiles and Geomembranes, Vol.25, Issue. 1, pp. 50-60

[11] Alawaji, H.A(2001);"Settlement and bearing capacity of geogrid-reinforced sand over collapsible soil" Int. Journal Of Geotextiles and Geomembranes, Vol. 19, Issue. 2, pp. 75–88.

[12] Adams, M.T and Collin, J.G(Jan 1997);"Large model spread footing load tests on geosynthetic reinforced soil foundations"Int. Journal of Geotechnical and Geoenvironmental Engineering, Vol. 123, Issue. 1, pp. 66-72