# Effect of addition of Copper Slag on the Load-Settlement Characteristics of Sandy Soil

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**Abstract**— Construction of civil engineering structures in weak soil sites creates problems due to excessive settlement and low bearing capacity of the soil at foundation level. Bearing capacity of soil can be improved by placing a layer of engineered granular fill (*i.e.* sand) of limited thickness at granular fill-soil interface. Use of industrial by products in construction has been in vogue in India for quite sometime. Copper slag is one of such industrial waste materials that are being used extensively in the civil engineering construction industry. This study is done to investigate the bearing capacity and settlement of circular footing of three different diameters resting on copper slag–soil mix. The tests were conducted by mixing different percentages of copper slag (5,10,15,20,25,30) to the soil. There was a decrease in settlement of footing and increase in load carrying capacity on increasing the percentage of copper slag and an optimum dosage of copper slag was found to be 25 % with the sand in terms of bearing capacity and settlement.

**Index Terms**— Circular footing ; Copper slag ; Diameter ; Industrial byproduct ; Plate load test ; Sand ; Settlement

## 1 INTRODUCTION

One of the most fundamental and important problems in the field of civil engineering is prediction of bearing capacity and settlement of building foundations and other structures. The load transmitted to the soil causes the settlement of the soil. As different type footings are used in variety of fields, nature of load transmitted also varies. By limiting the total settlement, differential settlements, the structures are ensured to be safe. The settlement of footing due to the load transmitted to soil must be within 50mm for structural safety purpose. This settlement depends upon various factors such as bearing capacity, type of soil, particle size, area and shape of the footings and so on. Granular fill-soft soil system is frequently used as base for unpaved roads, shallow foundations, storage tanks, heavy industrial equipment& car parks.

Many methods have been used to improve weak subsoil conditions encountered in construction work. As a solution, engineers tend to try on mixing materials that can be used with existing soil type without completely removing and refilling with another soil type. Mixing with cement as an alternative improvement technique has been widely used. Cement mixing is considered to be an expensive method and this research has attempted to study the use of another industrial byproduct; copper (Cu) slag as a replacement for cement. Utilization of industrial waste materials in the improvement of problematic soils is a cost efficient and environmental friendly method. It helps in reducing disposal problems caused by the various industrial wastes.

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## 2 MATERIALS

Sand ,Copper slag ,Test tank and circular plates are the materials used for the study.

### 2.1 SAND

Locally available Sand (Fig 1)was used for the study. The properties of the sand used for the study is given in table 1.

Fig 1. Sand used for the study

Table 1 Properties of sand

| SI.NO | Properties | Values |
|---|---|---|
| 1 | Specific gravity | 2.65 |
| 2 | Percentage of gravel (%)<br>Percentage of sand (%)<br>Percentage of fines (%) | 2.5<br>97.1<br>0.4 |
| 3 | Coefficient of uniformity ($c_u$) | 3.6 |
| 4 | Coefficient of curvature ($c_c$) | 1.05 |
| 5 | Gradation | Uniformly graded |
| 6 | Angle of internal friction | $42^0$ |
| 7 | Dry density(g/cc) | 1.72 |

### 2.2 COPPER SLAG

Copper slag used for the study (Fig 2) was collected from Johny industries, Karukutty. The properties of Copper Slag is shown in Table 2.

Fig.2 Copper Slag used for the study

Table 2 Properties of Copper Slag

| SI.NO | Properties | Values |
|---|---|---|
| 1 | Specific gravity | 3.63 |
| 2 | Percentage of gravel sized particles(%)<br>Percentage of sand sized particle(%)<br>Percentage of fines (%) | 0.15<br>98.2<br>1.65 |
| 3 | Coefficient of uniformity ($c_u$) | 3.6 |
| 4 | Coefficient of curvature ($c_c$) | 1.42 |
| 5 | Gradation | Uniformly graded |
| 6 | Angle of internal friction | $43^0$ |

### 2.3 TEST TANK

A test tank of dimensions 74.5 cm*74.5 cm*62 cm was used for the study. The tank was made of mild steel. Fig. 3 shows the test tank used for the study

Fig. 3 Test tank

### 2.3 CIRCULAR PLATES

Three circular plates of diameters 100 mm, 115 mm and 130 mm were used for the study as model footings. The plates were made of mild steel. Fig. 4 shows the circular plates used for the study.

Fig. 4 Circular plates of diameters 100 mm, 115 m and 130 mm

## 3.EXPERIMENTAL SET UP AND TEST PROCEDURE

A test tank of size 74.5 cm*74.5 cm *62 cm was used for the test. Circular footings of three diameters 100 mm,115 mm and 300 mm were used. The thickness of plate used was 25 mm. A proving ring capable of applying load upto 50 kN was used. Hydraulic jack was used for loading. A dial gauge of least count 0.01 mm was used for measuring settlement. The volume of test tank was calculated. The density of the soil was determined in the preliminary stage by laboratory testing. Using this density of soil and volume of tank, mass of soil to be filled in the test tank was calculated. Then this mass of soil was filled in the tank using sand raining technique.

Then Plate load tests were conducted on plates of three diameters 100mm, 115 mm and 300 mm resting on the soil in tank. Then the soil was mixed with different percentages of copper slag and plate load tests were conducted. The amount of copper slag corresponding to each percentage was taken, mixed with soil, filled in test tank and tested. The density of soil was maintained the same in all the tests. Here the variations in load settlement characteristics of the sandy soil when mixed with copper slag were studied. There was a significant improvement in bearing capacity and reduction in settlement of soil by increasing the percentage of copper slag and reducing the amount of soil.

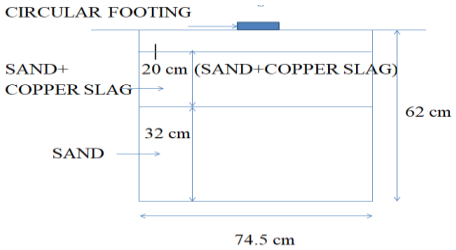


Fig. 5 Experimental set up sketch

## 4. Results and Discussions

Fig. 5 shows the load-settlement characteristics of the sandy soil using thee circular plates of diameters 100 mm, 115 mm and 130 mm.

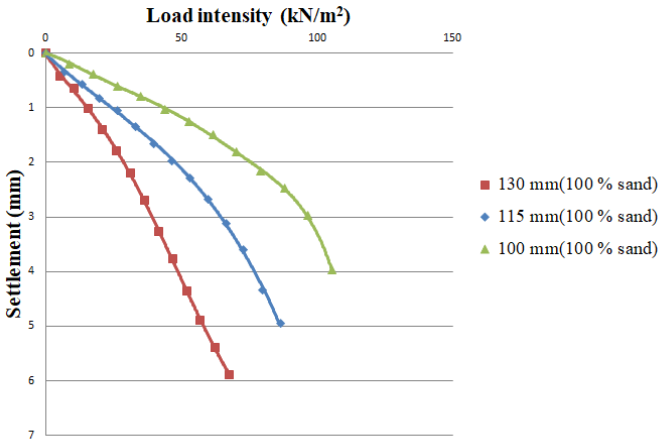


Fig. 6 Load-Settlement characteristics of sandy soil

From the figure, it can be seen that as the diameter of plate increases, settlement increases. Larger the plate size, larger the area beneath the plate resulting in larger settlements.

### 4.1 Load-Settlement Characteristics of Soil Mixed with Copper Slag

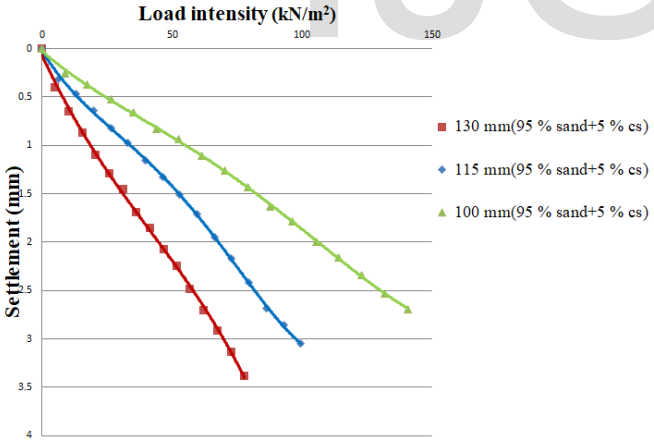


Fig. 7 Load-Settlement characteristics of 95 % sand+ 5 % Copper Slag

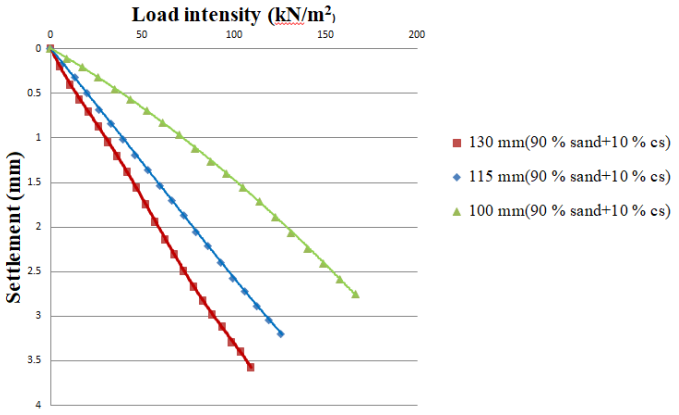


Fig. 8 Load-Settlement characteristics of 90 % sand+10 % Copper Slag

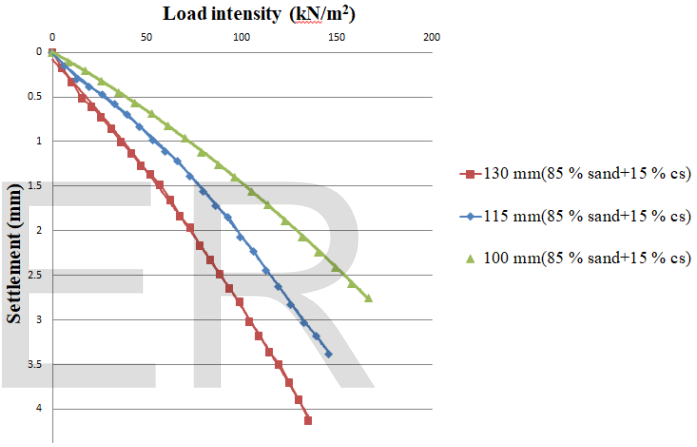


Fig. 9 Load-Settlement characteristics of 85 % sand+15 % Copper Slag

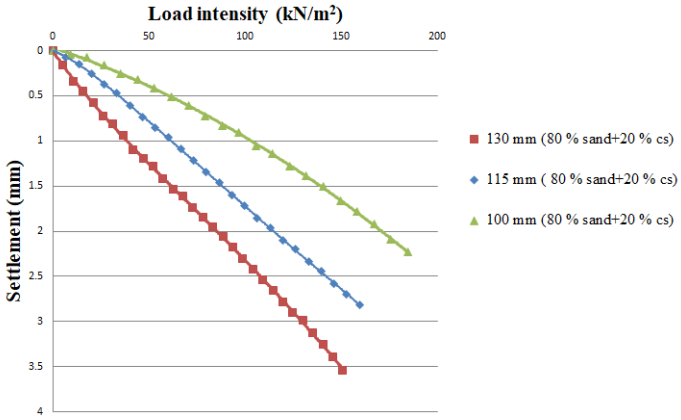


Fig. 10 Load-Settlement characteristics of 80 % sand+20 % Copper Slag

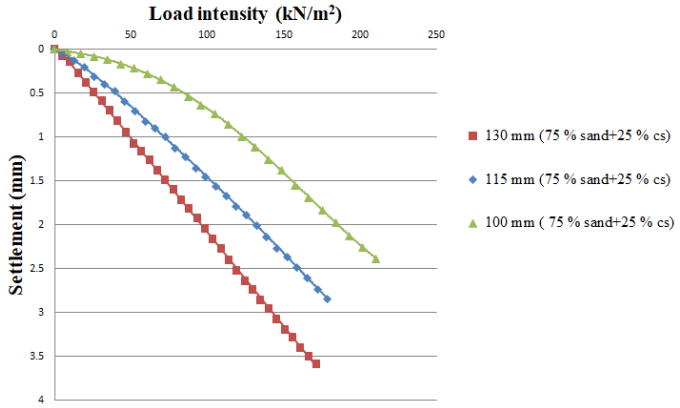


Fig. 11 Load-Settlement characteristics of 75 % sand+25 % Copper Slag

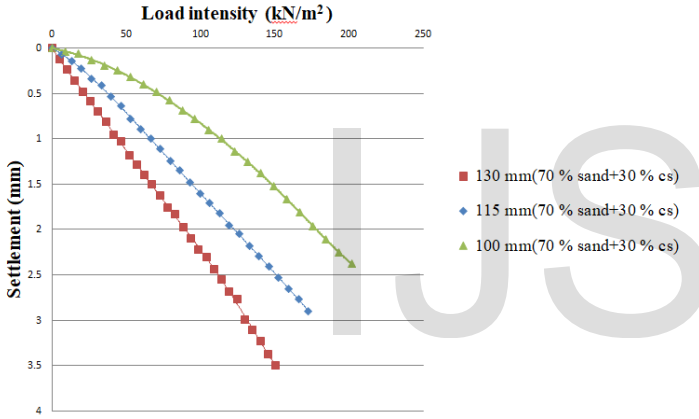


Fig. 12 Load-Settlement characteristics of 70 % sand+30 % Copper Slag

In the case of plate diameter, the same trend is observed for all combinations of soil and copper slag. As the dimension of plate increases, settlement increases. Hence least settlement is observed for the minimum plate dimension ie..130mm.

From the above load-settlement curves, it is understood that as the percentage of Copper slag increases and the percentage of sand decreases in soil-copper slag mix, there is considerable reduction in settlement. The high angularity and friction angle of copper slag aggregates contributes to high stability and load-bearing capacity.

### 4.2 VARIATIONS IN LOAD-SETTLEMENT CHARACTERISTICS WITH INCREASE IN PERCENTAGE OF COPPER SLAG FOR EACH PLATE DIAMETER

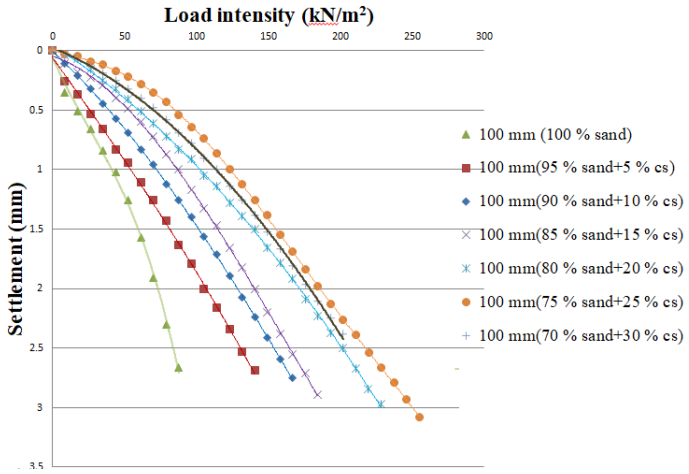


Fig. 13 Load-Settlement characteristics for plate diameter 100 mm

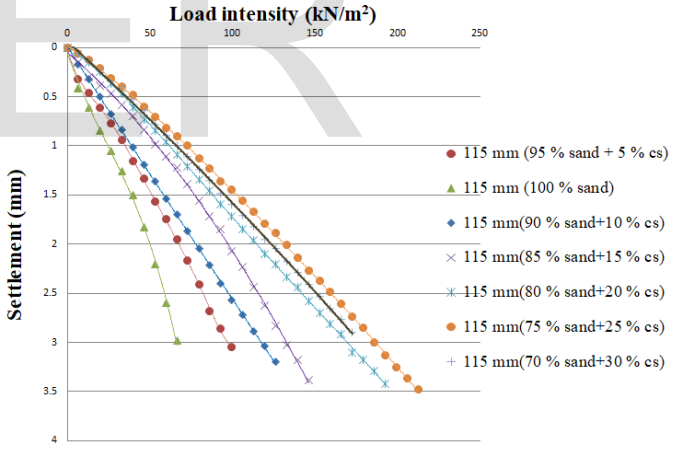


Fig. 14 Load-Settlement characteristics for plate diameter 115 mm

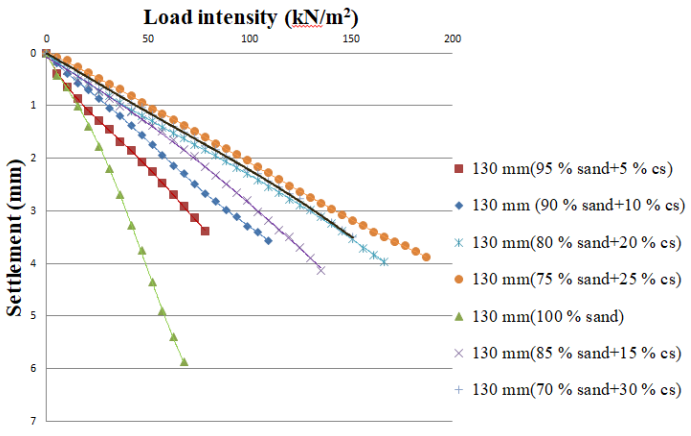


Fig. 15 Load-Settlement characteristics for plate diameter

130 mm

From the above graphs, it can be seen that as the percentage of copper slag increases, there is considerable reduction in settlement for each plate diameter. But this reduction in settlement is seen upto 75 % sand+25 % copper slag beyond which further increase in percentage of copper slag increases the settlement to a small extent. That means in a combination of 70 % sand+30 % copper slag, there is a slight increase in settlement compared to the previous combinations of sand and copper slag. Hence 75 % sand+25 % copper slag is taken as the optimum combination of sand-copper slag mix that can be used in pavement subgrades and highway embankments for attaining maximum strength.

Table 3 Variations in ultimate load with increase in percentage of copper slag

| Ultimate load (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 % sand | 95 % sand+ 5 % cs | 90 % sand+ 10 % cs | 85 % sand+ 15 % cs | 80 % sand+ 20 % cs | 75 % sand+ 25 % cs | 70 % sand+ 30 % cs |
| 100 mm | 70.28 | 79.06 | 87.853 | 96.38 | 106.28 | 122.99 | 114.20 |
| 115 mm | 66.42 | 72.88 | 86.35 | 93.57 | 105.42 | 112.93 | 106.28 |
| 130 mm | 57.03 | 67.57 | 83.17 | 93.00 | 103.96 | 109.16 | 102.10 |

From the above table , it is clear that as plate dimension increases, ultimate load decreases. As the plate dimension increases, footing area beneath the plate also increases. Hence the ultimate load in which the plate can withstand decreases.

Table 4 Improvement in ultimate load with increase in percentage of copper slag

| Improvement in ultimate load (%) | | | | | | |
|---|---|---|---|---|---|---|
| Diameter of plate | 95 % sand+ 5 % cs | 90 % sand+ 10 % cs | 85 % sand+ 15 % cs | 80 % sand+ 20 % cs | 75 % sand+ 25 % cs | 70 % sand+ 30 % cs |
| 100 mm | 12.49 | 25 | 37.13 | 51.22 | 75 | 62.49 |
| 115 mm | 8.86 | 19.93 | 40.87 | 58.71 | 70.02 | 60.01 |
| 130 mm | 18.48 | 45.83 | 63.07 | 82.29 | 91.40 | 79.02 |

Table 4 shows the improvement in ultimate load with increase in percentage of copper slag for each plate diameter. From the table, it is understood that maximum improvement in ultimate load is obtained for 130 mm diameter plate with increase in percentage of copper slag.

## 5. Conclusions

Copper slag which is an industrial byproduct is produced in large amounts and it should be dumped in an effective way. Otherwise these materials would cause environmental problems. Behaviour of copper slag is similar to that of medium sands and that it can be used as a construction material in place of sands, such as backfill of retaining walls and landfill for the construction of shallow foundations.Copper slag has high angularity and friction angle (up to $52^0$) of aggregates contribute to the stability and load bearing capacity.

- From the study carried out here, it can be inferred that

❖ As the diameter of circular plate increases, there is considerable reduction in settlement

❖ As the percentage of copper slag in sand-copper slag mix increases, settlement decreases and ultimate load increases

❖ The optimum amount of sand-copper slag mix is found to be 70 % sand+25 % copper slag beyond which increase in percentage of copper slag also increases settlement

## REFERENCES


- Dr. Rajesh Kumar Tripathi and Laxmikant Yadu (2014), S.M.Ali Tasallo, Buddhima Indraratna and Gabriele Chiaro(2015), "Field investigation on compaction and strength performance of two coal wash-BOS slag mixtures", Geotechnical Special Publication (pp. 2359-2368). American Society of Civil Engineers
- "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 Technical Papers, GSP 234 © ASCE 2014
- Sumanav Wadhwa, J. Sudheer Kumar (2017), "Bearing Capacity of Strip Footing Rest on Reinforced Industrial Slags and Silty Clay Beneath",SSRG International Journal of Civil Engineering ( SSRG – IJCE ) 4 (8 )
- C. Lavanya, A. Srirama Rao, N. Darga Kumar (2015), "Study on load-settlement behaviour of copper slag-cushioned expansive soil bed",Proceedings of **50th** indian geotechnical conference,College of Engineering , Pune, Maharashtra, India
- Mallik K P, Aruna T(2015), "Load Settlement Behaviour of Model Footing Tests on Black Cotton Soil Reinforced with Untreated and Treated Jute Fibers with Optimum Dosage of Copper Slag ",International journal of geotechnical engineering ,4(7)
- Laxmikant Yadua, Dr. R.K. Tripathi (2013), "Effect of the length of geogrid layers in the bearing capacity ratio of geogrid reinforced granular fill-soft subgrade soil system",Geotechnique, 104 ( 225 – 234)
- Temel Yetimoglu, Jonathan T. H. Wu etal (1994), "Bearing capacity of rectangular footings on geogrid-reinforced sand", J. Geotech. Engrg. 120(2083-2099
- S.M.Ali Tasallo, Buddhima Indraratna and Gabriele Chiaro(2015), "Field investigation on compaction and strength performance of two coal wash-BOS slag mixtures", Geotechnical Special Publication (pp. 2359-2368). American Society of Civil Engineers
- C. Lavanya, A. Sreerama Rao,N. Darga Kumar(2011), "A review on utilization of copper slag in geotechnical applications", Proceedings of Indian Geotechnical Conference December 15-17, Kochi (Paper No.H-212)
- Viji C . M(2014) "Shear Strength and Load Settlement Behaviour of Copper Slag in Sand Pile",IJCE 3(9)
- D. A. M. Araujo, C. M. L. Costa, Y. D. J. Costa(2017), "Dimension Effect on Plate Load Test Results", International conference on geotechnical resarch and engineering,17.191

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