Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 6, Issue 4; April-June, 2019, pp. 237-240

http://www.krishisanskriti.org/Publication.html

Cupola slag Granular Column-A Replacement to Natural Aggregate Granular Column in Weak Soils

GOURAV [1], PARDEEP SINGH[2] AND CHARNJEET SINGH[3]

[1]Post Graduate Student, Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, Affiliated to I.K. Gujral Punjab Technical University, Jalandhar, India.
[2]Assist. Prof., Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, Affiliated to I.K. Gujral Punjab Technical University, Jalandhar, India.
[3]Assist.Prof., Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, Affiliated to I.K. Gujral Punjab Technical University, Jalandhar, India.
E-mail: [1]gouravkumar1991@ymail.com, [2]pardeeprohla@yahoo.in,[3]charnjeet1989@gmail.com

Abstract—*In India about 12 million tons of slag is produced annually which produces lot of problems to the iron/steel manufacturers. Dumping problem of this huge waste puts extra burden on the manufacturers and overall cost running of industries. Usually this waste slag is dumped in the landfills. However recent trends for sustainable waste management make use of waste slag for various applications like production of cement, in concrete as granular aggregates, road granular materials. However use of slag aggregates in geotechnical engineering process is not investigated much.*

In case of soft soils Cu<15 kN/m^{2,} very limited ground improvement techniques are available for such soils. Piles however are one of versatile option available but in case of low cost construction for structures who can afford good settlement it doesn't fit well, granular columns can be answer to such problem.

In current study it has been evaluated, the effectiveness of cupola slag as granular column material against natural aggregates .it has founded that a significant increase in bearing capacity of weak soil using cupola slag granular column then natural aggregates granular column.

Keywords*: Cupola slag, soft soil, granular column.*

1. INTRODUCTION

Vast amount of slag is produced in India, and is dumped in landfills. About 12-13 million ton annually, slag is produced in India and creates lot of problem to the iron industry. However recent trends are encouraging use of slag in road paving material, concrete material, in cement industries .Iron/steel industry using modern techniques to avoid generation of slag, still however some percentage cannot be avoided. Cupola furnace is used to melt scrap metal and molten metal is drawn into desired shape. During this process, impurities present in the metal got accumulated and removed in the form of crystalline slag. This slag is collected in dumping area and creates problem for manufacturers. Such slag is in granular form and can be used in geotechnical formations.

In case of weak soils with low shear strength Cu<15kPa, few foundation design are available, pile foundation however is one of widely used foundation design but in case low cost construction granular column is one of option available. Structures with flexible foundation like oil tank storage, rail/ road embankments etc. can afford good settlement .Again in such cases granular column can be one of option. Use of waste slag aggregates as granular material can cut the cost of construction.

Hughes J.M.O. et. al. 1975 uses stone columns as reinforcing agent in case of soft / weak soils. They founded that bearing capacity of soil can be increased up to 2 times.Ambily et al.2007 founded that bearing capacity of granular column not only depends upon undrained shear strength of surrounding soft soil but also on angle of internal friction of granular material. They also concluded that if surrounding area of stone columns also loaded, it can further increase the bearing capacity of granular column.Vaitheswari K. and Sathyapriya S. 2018 founded that with introduction of steel slag granular column in soft soil the settlement reduction factor increase up to 9.1 times then untreated soil. They also concluded that with increase in L/D ratio bearing capacity of treated soil can increases up to 77.8%.Shubburet. al. 2009 founded in their study that bearing ratio of soil treated with enlarged base stone column embedded in soft soil, can be increase up to 1875% then untreated soil. They also concluded that with rise in area replacement ratio bearing ratio also increases. Mandeepet. al. reported the effectiveness of cupola furnace slag in concrete work. They founded up to 30% increase in compressive strength of concrete with partial replacement of natural aggregates in concrete. Kumar et. al. 2016 conducted several laboratory model tests on sand columns in black cotton soil. They have founded that with increase in L/D ratio bearing capacity of sand column increase however L/D ratio 8, there is no significant increase in bearing capacity of sand column. Prasad S.S.G. and Satyanarayana P.V.V. 2016 founded that settlement of marine clay decreases by improving with silica manganese slag granular column and decrease in settlement is up to 33% by using geosynthetic encasing around the granular column.

2. MATERIALS USED

The material in this study involves clayey soil, cupola slag aggregates and natural aggregates.

Clayey soil is collect from Vill. Pamal, Distt. Ludhiana, Punjab. The various properties of the soil can be listed below in table:-

Table 1: Properties of soil

Specific gravity	2.53
Liquid limit	42 %
Plastic limit	25%
Plasticity index	17
IS soil classification	CI
Optimum moisture content	14 %
Max Dry Density	18.43 kN/m^3
Bulk density at 25% moisture content	19 kN/m^3
Coeff. of permeability	1.537 x 10^{-4} mm/sec

It has been founded that clayey soil consists of 53% of clay and 47 % of silt. The hydrometer grain size analysis has been shown below

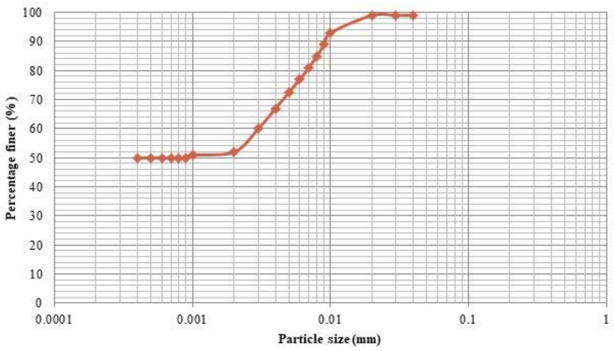

Figure 1 Grain size analysis of soil

Cupola furnace slag is collected from Shree Ram foundry works, Vill. Gill, Distt. Ludhiana, Punjab. The collected slag is in crystalline form and little glassy nature. The aggregates used in current study were of size ranging 2-10 mm. The properties of cupola slag are listed in following table:-

Table 2 Properties of slag aggregates

Specific gravity	2.76
Max bulk density	16 kN/m^3
Mini bulk density	15 kN/m^3
Cu	1.58
Cc	0.9958
IS classification	Well graded
Angle of internal friction	49°

Mandeep et al. 2014 in their work reported that cupola furnace slag consists mainly of silica and calcium oxide as main constituents. Other constituents include aluminum oxide, ferrous oxide, manganese oxide and magnesium oxide.

Table 3 Chemical composition of cupola slag

Silica oxide	47.99 %
Calcium oxide	24.33 %
Aluminum oxide	16.58 %
Magnesium oxide	7.79 %
Ferrous oxide	1.56 %
Manganese oxide	1.19 %

Natural aggregates used were collected from transportation lab, Guru Nanak Dev Engineering College. The size of aggregates ranging between 2-10 mm. The properties of aggregates are listed below:-

Specific gravity	2.51
Max bulk density	16 kN/m^3
Mini bulk density	15 kN/m^3
Cu	2
Cc	1.23
Angle of internal friction	46°

3. EXPERIMENTAL STUDY

Model tests on clay bed, clay bed reinforced with natural aggregate granular column, clay bed with cupola slag aggregate granular column. The constructed columns were end bearing with L/D ratio 4.5. The granular columns constructed were 50 mm in diameter. Model footing used was of mild steel with 100mm in diameter and thickness of 12 mm. [8] The model footing was double the diameter of granular column to represent the unit cell area and with area replacement ratio of 25%.The procedure for construction of clay bed, clay bed reinforced with natural aggregate granular column, clay bed with cupola slag aggregate granular column.

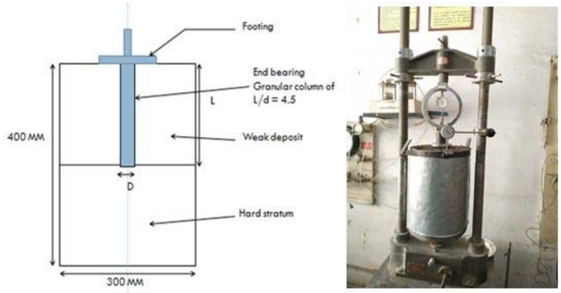

Figure 2 Line diagram of arrangement and test setup arrangement

3.1. PREPARATION OF CLAY BED

Soil was air dried and pulverized with wooden mallet and passed through 4.75mm sieve to remove any vegetation if present. The water content was determined by conducting several unconfined compressive strength tests on soil and water content corresponding to shear strength of 15kPa was selected and found to be 25 %.The soil is mixed with required quantity of water and filled in model tank in layers. Each layer was compacted corresponding to IS 2720 part 7 (1980).before filling the tank a thin layer of lubricating oil is applied on the tank boundaries to minimize friction between soil and tank wall. After clay bed was prepared it was leveled and trimmed. Tank was covered with wet gunny bag which was further covered with plastic sheet to avoid any moisture loss. The prepared soil bed was left for 24 hours for moisture equalization. [2], [8] Uses similar technique for preparation of clay bed

3.2 CONSTRUCTION OF GRANULAR COLUMN

For construction of granular column, a PVC pipe of outer diameter 50mm is used. Pipe is coated with thin layer of lubricating oil to avoid suction effect during insertion. The pipe is placed at center of tank and slowly pushed down. After required insertion of pipe in bed, a special auger is used to remove soil inside pipe. When soil is completely removed, the aggregates are filled in empty bore in layers. Each layer of aggregates is compacted using steel rod with 10 blows from height of fall of 100mm.after compaction of a layer , pipe is gently pull up and an overlap of 5mm between pipe and filled is maintained. [1],[2],[8] used similar techniques for compaction of aggregates. After construction of granular column in soil, the tank was covered with wet gunny bag and plastic sheet and left for 24 hours for moisture equalization.

Both granular columns either of natural aggregates or cupola slag granular column and constructed in above mentioned method.

3.3 TESTING

After 24 hours, model testing was done. Testing was done with triaxial loading frame. Proving ring of capacity 49.05kN was used. Load was applied through model steel footing. Loading was done at constant rate of 2mm/minute up to 25 mm of settlement. A thin layer of sand is placed over bed. This ensures a perfect leveled surface and loading of entire area.

3.4.POST TEST ANALYSIS.

After testing was done, granular material was carefully handpicked and thin paste of plaster of Paris was poured and left for 24 hours to obtain deformed shape of granular column.

4. RESULTS AND DISCUSSION

Testing was done on clay bed, clay bed reinforced with natural aggregate granular column and clay bed with cupola slag granular column. All constructed granular columns were end bearing with L/D ratio 4.5.

The load carrying capacity of clayey soil bed reinforced with natural aggregate improvedup to 180% then untreated clayey soil bed.

The load carrying capacity of clayey soil bed reinforced with cupola slag granular column improved up to 250% then untreated clayey soil bed.

It has also been founded that clayey soil bed reinforced with cupola slag granular column carries 25% more load then clayey soil reinforced with natural aggregate granular column.

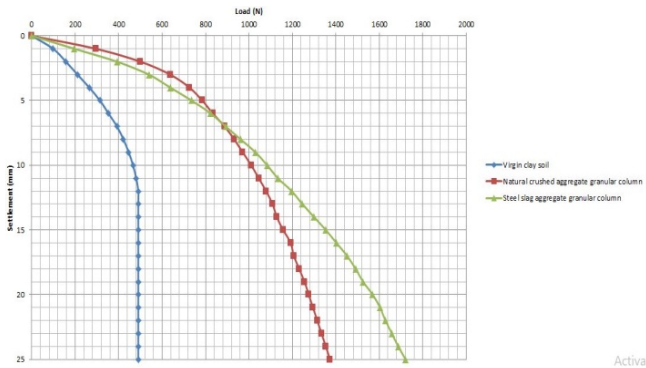

Figure 3 load versus settlement response

By observing graphs, initially cupola slag granular column carries less load then natural aggregate granular column but when settlement surpasses 7mm, rise in load carrying capacity for cupola slag granular column compared to natural aggregate granular column. [1]Best explanation this is more angle of internal friction of cupola slag aggregates then natural aggregates. As this gives more interlocking frictional resistance to cupola slag aggregates the natural aggregates and more stability of granular column.

Bearing capacity ratio, BCR (bearing capacity of reinforced soil versus unreinforced soil) founds to increases from 2.80 to 3.50.

5. Bulging analysis

After completion of test, the granular material is carefully picked up and thin paste of plaster of paris is added and left for 24 hours to take deformed shape. After 24 hours soil around plaster of paris specimen is carefully removed and deformed shape of granular column is obtained.

Figure 4 Deformed shape of cupola slag granular column

Figure 5 Deformed shape of natural aggregate granular column

Table 4 Increment in diameter after testing for cupola slag granular column

At top	53 mm
At middle	55 mm
At bottom	52 mm

Table 5 Increment in diameter after testing for natural aggregate granular column

At top	53 mm
At middle	58 mm
At bottom	54 mm

It has been observed in both cases that bulging lies between 2D-3D, Where D is diameter of granular column.

6. Conclusions

The conclusions derived from present study can be listed below:-

a. Load carrying capacity of clayey bed reinforced with natural aggregate column is increased up to 180% compared to unreinforced clayey bed.
b. Load carrying capacity of clayey bed reinforced with cupola slag granular column is increased up to 250% compared to unreinforced clayey bed.
c. Cupola slag granular column carries 25 % more load then natural aggregate granular column.
d. Load carrying capacity of granular column may be affected by angle of internal friction of granular material.
e. Bulging of granular column lies between 2D – 3D where D is diameter of granular column.

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