

# Influence Of Admixture On Shear Parameters Of Copper Slag

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## Abstract

Generation of waste in erratic amounts is a part of almost every metal and non metal casting industry. These wastes can be converted to material goods if processed for ultimate recovery of valuables provided it is economical. Unsystematic disposal or dumping of these wastes may lead to environmental problems and therefore, presently the reuse of the waste materials in various fields is seen for quite some time. Copper slag is a waste product generated during the smelting process for the production of copper. It has been estimated that for every tonne of copper produced, about 1.8-2.2 tonnes of copper slag is generated as a waste. Due to increase in production capacity of copper, copper slag getting accumulated require additional dumping space and causing wastage of good cultivable land. The present paper discusses the laboratory test results of direct shear tests conducted on copper slag mixed with lime. The copper slag mixed with lime in various percentages were kept for curing and then tested after 7, 14, 28 days. Effective results are observed for the shear parameters like cohesion and angle of internal friction of copper slag on addition of lime from 0% to 10%. There is an increase in cohesion and decrease in angle of internal friction as the percentage of addition of lime increases and with the curing period.

Keywords – Copper Slag, Lime, Direct Shear test, Cohesion, Angle of internal friction.

## 1. Introduction

Pure copper is rarely found in nature, but is usually combined with other chemicals in the form of copper ores. The process of extracting copper from copper ore varies according to the type of ore and the desired purity of the final product. Once the waste

materials have been physically removed from the ore, the remaining copper concentrate must undergo several chemical reactions to remove the iron and sulphur. This process is called smelting. The recovery of sulphuric acid from the copper smelting process not only provides a profitable by-product, but it also significantly reduces the air pollution caused by the furnace exhaust. Copper slag (CS) is a waste product which comes out from the smelting process.

It has been estimated that the production of one tonne of blister copper generates 2.2 tonnes of slag. Metal industry slag, mine stone and mining waste are generally suitable for recycling or reuse and the use of these inorganic wastes as alternative materials in building, road and geotechnical applications have been reported [1, 2, 3, 4, 5, 6].

Copper slag, upon mixing with soil, can be used as an effective stabilizing agent for the improvement of problematic soils for use in highway embankments, sub-grades and sub-bases. Also, by mixing it with fly ash, it becomes suitable for embankment fill material. Slag, when mixed with fly ash and lime, develops pozzolanic reactions [7]. Fly ash has been widely accepted as embankment and structural fill material [8, 9].

Copper slag along with binding material or an admixture can be used as an alternative material to that of sand in road construction. If the copper slag is mixed with calcium-based compound like lime, the silica and alumina present in copper slag may react chemically on hydration and it may be used for the improvement of sub-grades and sub-bases. The present paper discusses the shear parameters of the copper slag when admixed with lime with varying percentages added and tested after 7, 14 and 28 days of curing period.

## 2. Experimental Study

### 2.1 Materials Used

#### 2.1.1 Copper Slag

Copper slag was collected from Sterilite Industries, Tuticorin, Tamil Nadu, India. The physical and chemical properties are presented in Tables 1 and 2 respectively.

**Table 1** Physical Properties of Copper Slag

Property	Value
Hardness, Moh's Scale	6.5 – 7.0
Specific Gravity	3.6
Plasticity Index	Non-Plastic
Swelling Index	Non-Swelling
Granule Shape	Angular, Sharp edges
Grain Size Analysis	
Gravel/Size (%)	1
Sand/Size (%)	98.9
Silt & Clay/Sizes (%)	0.05
MDD ( $\text{kN/m}^3$ )	23.5
OMC (%)	6
Direct Shear test	--
Cohesion ( $\text{kN/m}^2$ )	0
Angle of internal friction (degree)	40
Permeability( $\text{cm/sec}$ )	$15.43 \times 10^{-3}$
CBR (%)	3.5

**Table 2** Chemical Composition of Copper Slag

Property	(% wt)
Iron Oxide, $\text{Fe}_2\text{O}_3$	55 – 60
Silica, $\text{SiO}_2$	28- 30
Aluminium Oxide, $\text{Al}_2\text{O}_3$	1 – 3
Calcium Oxide, $\text{CaO}$	3– 5
Magnesium Oxide, $\text{MgO}$	1.0– 1.5

### 2.1.2 Lime

Locally accessible hydrated lime which consists of 95% of Calcium hydroxide is used in the present study.

### 2.2 Tests Conducted

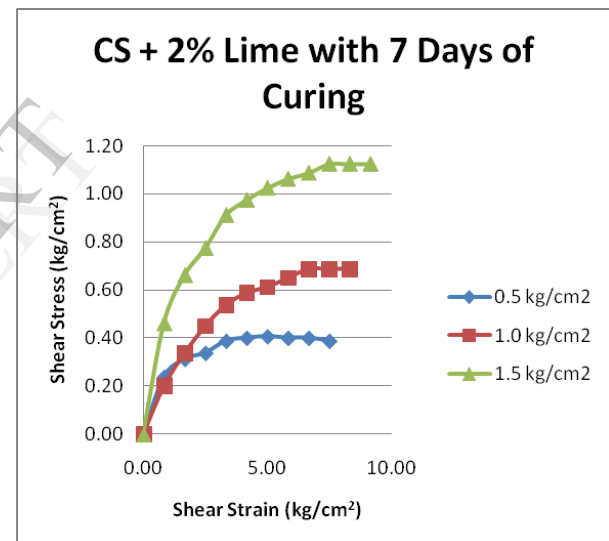
Compaction tests (11) were conducted for the copper slag mixed with Lime, as the % of lime increases from 2% to 10% the MDD

values are slightly increasing. Direct Shear tests were conducted (12) for the copper slag mixed with lime of 0%, 2% and 10%. Copper slag and lime are mixed in various percentages of lime in dry condition and then water is added. The samples are kept for curing for 7 days, 14 days and 28 days. After the curing period the copper slag mixed with lime is tested for the cohesion and angle of internal friction.

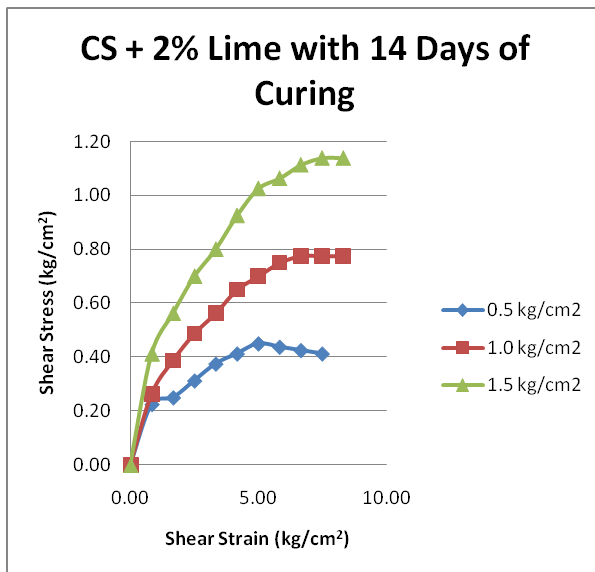
## 3. Results and Discussion

### 3.1 Direct Shear Results

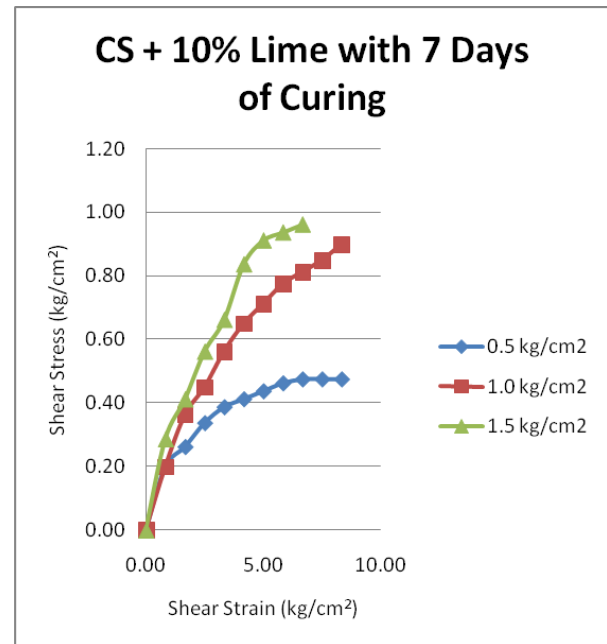
Direct shear tests were conducted on the copper slag samples mixed with lime in various proportions of 0%, 2% and 10% after 7days, 14days and 28 days of curing period. The results of the direct shear are presented below.



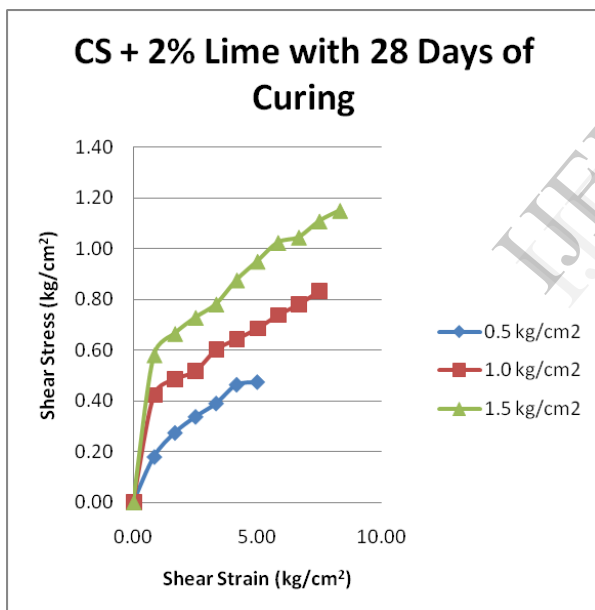
**Fig. 1** Test results of Shear strain Vs Shear stress for Copper slag mixed with 2% Lime after 7days of curing for the normal stress  $0.5\text{kg/cm}^2$ ,  $1.0\text{kg/cm}^2$  and  $1.5\text{kg/cm}^2$ .



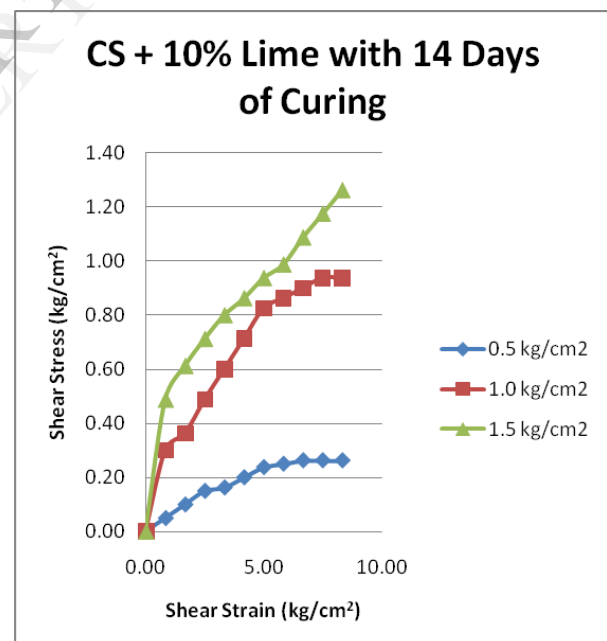
**Fig. 2** Test results of Shear strain Vs Shear stress for Copper slag mixed with 2% Lime after 14days of curing for the normal stress  $0.5\text{kg/cm}^2$ ,  $1.0\text{kg/cm}^2$  and  $1.5\text{kg/cm}^2$ .



**Fig. 4** Test results of Shear strain Vs Shear stress for Copper slag mixed with 10% Lime after 7days of curing for the normal stress  $0.5\text{kg/cm}^2$ ,  $1.0\text{kg/cm}^2$  and  $1.5\text{kg/cm}^2$ .

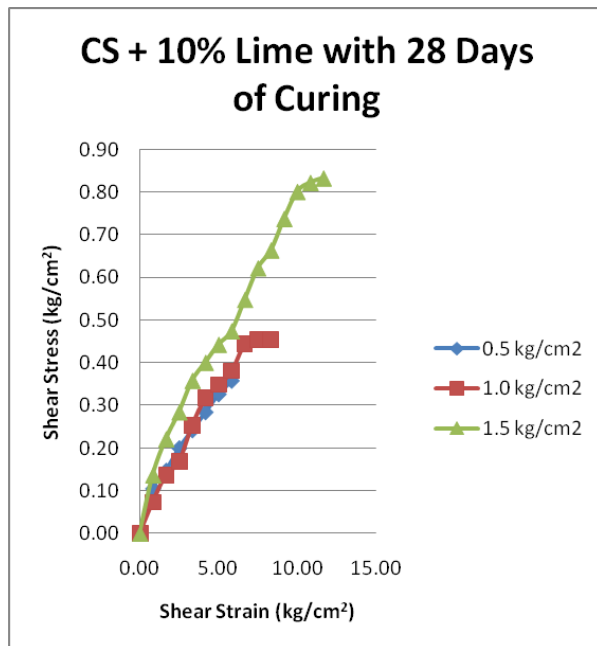


**Fig. 3** Test results of Shear strain Vs Shear stress for Copper slag mixed with 2% Lime after 28days of curing for the normal stress  $0.5\text{kg/cm}^2$ ,  $1.0\text{kg/cm}^2$  and  $1.5\text{kg/cm}^2$ .

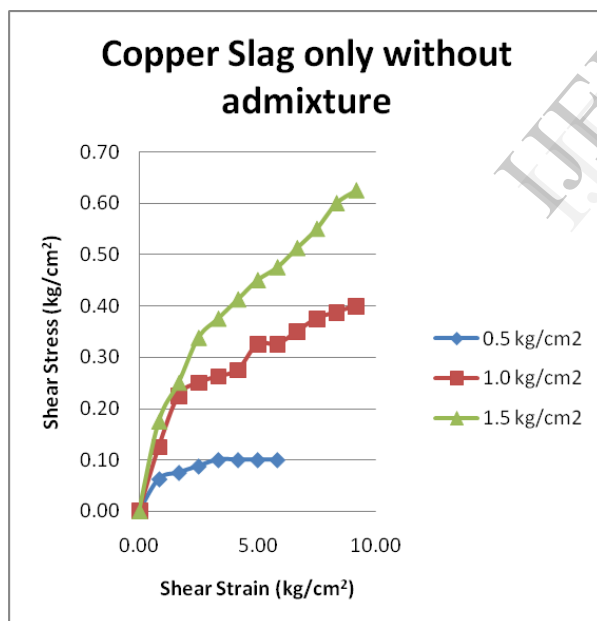


**Fig. 5** Test results of Shear strain Vs Shear stress for Copper slag mixed with 10% Lime after 14days of curing for the normal stress  $0.5\text{kg/cm}^2$ ,  $1.0\text{kg/cm}^2$  and  $1.5\text{kg/cm}^2$ .

In fig 1, fig 2 and fig 3, the variation of shear strain with shear stress is shown for the normal stress of  $0.5\text{kg/cm}^2$ ,  $1.0\text{kg/cm}^2$  and  $1.5\text{kg/cm}^2$  when copper slag is mixed with 2% lime and is tested after 7days, 14days and 28days of curing. From these figures it can be seen that with increase in curing period there is an increase shear stress values.



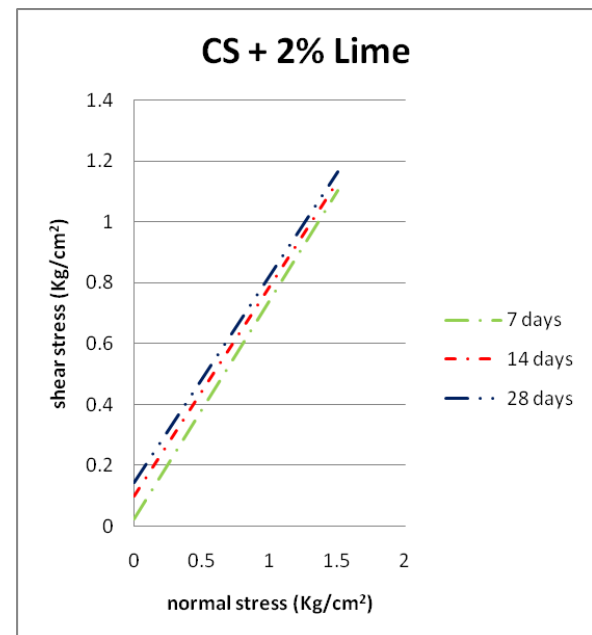
**Fig. 6** Test results of Shear strain Vs Shear stress for Copper slag mixed with 10% Lime after 28days of curing for the normal stress 0.5kg/cm<sup>2</sup>, 1.0kg/cm<sup>2</sup> and 1.5kg/cm<sup>2</sup>.



**Fig. 7** Test results of Shear strain Vs Shear stress for Copper slag mixed with 0% Lime for the normal stress 0.5kg/cm<sup>2</sup>, 1.0kg/cm<sup>2</sup> and 1.5kg/cm<sup>2</sup>.

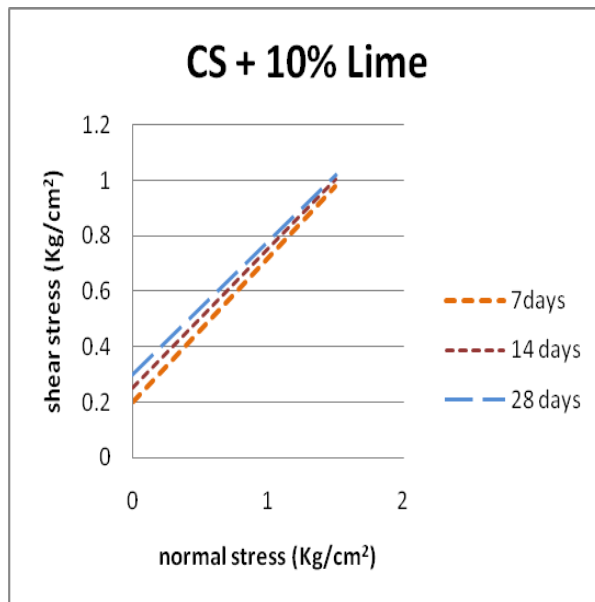
In fig 4, fig 5 and fig 6, the variation of shear strain with shear stress is shown for the normal stress of 0.5kg/cm<sup>2</sup>, 1.0kg/cm<sup>2</sup> and 1.5kg/cm<sup>2</sup> when copper slag is mixed with 10% lime and is tested after 7days, 14days and 28days of

curing. From these figures it can be seen that with increase in curing period there is an increase shear stress values.



**Fig. 8** Test results of Normal stress Vs Shear stress for Copper slag mixed with 2% Lime after 7days, 14days and 28days of curing.

In fig 8, the variation of normal stress with shear stress is shown for 7days, 14days and 28days of curing when copper slag is mixed with 2% lime. From this figure it is seen that with increase in curing period there is an increase in cohesion. The shear parameters are effectively changing with the increasing in curing period. Cohesion is increasing with increase in curing period and also with addition of 2% lime. Angle of internal friction is decreasing with increase in curing period and with addition of 2% lime.



**Fig. 9** Test results of Normal stress Vs Shear stress for Copper slag mixed with 10% Lime after 7days, 14days and 28days of curing.

In fig 9, the variation of normal stress with shear stress is shown for 7days, 14days and 28days of curing when copper slag is mixed with 10% lime. From this figure it is seen that with increase in curing period there is an increase in cohesion. The shear parameters are effectively changing with the increasing in curing period. Cohesion is increasing with increase in curing period and also with addition of 10% lime. Angle of internal friction is decreasing with increase in curing period and with addition of 10% lime.

#### 4. Conclusions

Based on the above test results the below outlines are given.

- Copper Slag is a waste product coming out from the smelting process for the production of copper.
- Lime mixed Copper slag in various percentages gives effective and improved results of cohesion when compared to copper slag without any admixture.
- As the % of Lime increases from 2% to 10% the MDD values are slightly increasing.
- Copper slag when mixed with 2% Lime and 10% Lime, results increase

in cohesion and decrease in angle of internal friction.

- From the results, it was noticed that an increase in cohesion is seen which is nearly 12 times when 10% lime is mixed with copper slag when it is compared with copper slag mixed with the 2% lime.
- Lime admixed copper slag when tested after 7 days, 14 days and 28 days of curing results improvement in cohesion and decrease in angle of internal friction as the curing period increases.
- When Lime mixed with CS along with soils may result in beneficial effects in terms of stabilization of clayey deposits.
- As a future study, the combination of CS and Cement or lime along the soil can be mixed and relevant geotechnical testing can be carried out to bring out the efficacy of CS along with the cement or lime in the soil stabilization process.

#### 5. References

- [1] Hartlen, J., Carling, M & Nagasaka, Y. (1997) Recycling or reuse of waste materials in geotechnical applications, *Proceedings of the second International Congress on Environmental Geotechnics*, Osaka, Japan, pp 1493-1513.
- [2] Kamon, M. (1997) Geotechnical utilization of industrial wastes, *Proceedings of the second International Congress on Environmental Geotechnics*, Osaka, Japan, pp 1293-1309.
- [3] Kamon, M. & Katsumi, T. (1994) Civil Engineering use of industrial waste in Japan, *Proceedings of the International Symposium on Developments in Geotechnical Engineering*, Bangkok, Thailand, pp 265-278.
- [4] Sarsby, R. (2000) *Environmental Geotechnics*, Thomas Telford Ltd., London, UK.
- [5] Vazquez, E., Roca, A., Lopez-soler, A., Fernandez-Turiel, J.L., Querol, X & Felipo, M.T. (1991) Physico-Chemical and mineralogy characterization of mining wastes used in construction, Waste materials in construction, *Proceedings of the International Conference on Environmental Implications of*

*Construction with Waste Materials*, Maastricht, The Netherlands, pp 215-223.

[6] Comans, R.N.J., van der Sloot, H.A., Hoede, D. & Bonouvie, P.A. (1991) Chemical Processes at a redox/pH interface arising from the use of steel slag in the aquatic environment, *Waste materials in construction, Proceedings of the International Conference on Environmental Implications of Construction with Waste Materials*, Maastricht, The Netherlands, pp 243-254.

[7] Chu, S.C. and Kao, H.S. (1993) A study of Engineering Properties of a clay modified by Fly ash and Slag, *Proceedings, Fly ash for Soil Improvement, American Society of Civil Engineers*, Geotechnical Special Publication, No. 36, pp 89 – 99.

[8] McLaren, R.J. and A.M. Digionia, (1987) The typical engineering properties of fly ash, *Proceedings of Conference on Geotechnical Practice for Waste Disposal*, Geotechnical Special Publication NO 13, ASCE, R.D. Woods (ed.), pp 683-697.

[9] Martin, P.J., R.A. Collins, J.S. Browning and J.F. Biehl, (1990) Properties and use of fly ashes for embankments, *Journal of Energy Engineering, ASCE*, 116(2), pp 71-86.

[10] Katti R.K. (1979), “Search for solutions for problems in black cotton soils”, *Indian Geotechnical Journal*, 9, pp 1-80.

[11] IS: 2720 (part-16) (1979), “Laboratory Determination of Proctor Compaction test”, *Bureau of Indian Standards*.

[12] IS: 2720 (part-13) (1986), “Laboratory Determination of Direct Shear Test”, *Bureau of Indian Standards*.