Study on Coefficient of Permeability of Copper slag when admixed with Lime

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Abstract: Production of waste in unpredictable amounts is almost in every part of metal and non-metal casting trade. These wastes can be converted to material goods if processed for vital improvement of valuables provided it is cost-effective. Random dumping of these wastes may lead to environmental problems and therefore, presently the reuse of the waste materials in various fields is seen for fairly various periods. 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 coefficient of permeability 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 were observed for the coefficient of permeability of copper slag on addition of lime from 0% to 10%. There is a decrease in coefficient of permeability value as the percentage of addition of lime increases and with the curing period. The coefficient of permeability is very high for copper slag alone. When copper slag is mixed with a binding material like lime, there is a reduction in permeability. Also upon mixing the same with an expansive soil, it may be suitable to reduce the swelling characteristics by developing pozzolanic reactions.

Keywords*: Copper Slag, Lime, Permeability, Curing Days*

1.0 Introduction

Pure copper is rarely found in nature, but is usually combined with other chemicals in the form of copper ores. 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 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].

Upon mixing with problematic soil, Copper slag can be used as an efficient stabilizing cause for the upgrading of 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 coefficient of permeability of the copper slag when admixed with lime with varying percentages added and tested after 7, 14 and 28 days of curing period.

2.0 Experimental Work
2.1 Materials used in the present work
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 (kN/m^3)	23.5
OMC (%)	6
Direct Shear test	
Cohesion (kN/m^2)	0
Angle of internal friction (degree)	40
Permeability(cm/sec)	15.43 x 10^{-3}
CBR (%)	3.5

Table 2: Chemical Composition of Copper Slag

Property	(% wt)
Iron Oxide, Fe_2O_3	55 – 60
Silica, SiO_2	28- 30
Aluminium Oxide, Al_2O_3	1 – 3
Calcium Oxide, CaO	3– 5
Magnesium Oxide, MgO	1.0– 1.5

2.1.2 Lime

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

2.2 Tests Conducted

Variable head permeability tests were conducted [10] for the copper slag mixed with lime of 2%, 4%, 6%, 8% and 10%. Copper slag with lime is mixed in various percentages in dry condition and then water is added as per optimum moisture content. The samples are kept for curing for 7 days, 14 days and 28 days. After the curing period the copper slag mixed admixture is tested for the coefficient of permeability.

In the present test coefficient of permeability of copper slag mixed with admixture is tested to study its behaviour. Future scope is to mix the copper slag along with admixture to the problematic soil and to study its behaviour in terms of coefficient of permeability of the soil specimen.

3.0 Results and Discussion

3.1 Permeability Test Results

Variable head permeability tests were conducted on the copper slag samples mixed with lime in various proportions of 2%, 4%, 6%, 8% and 10% after 7days, 14days and 28 days of curing period. Coefficient of permeability for the copper slag alone is reported as very high. The results of the tests conducted were presented below in Table 3.

Table 3: Coefficient of Permeability values (cm/sec) of Copper Slag when mixed with various % of Lime after curing for 7 days, 14 days and 28 days

% of Lime in copper slag	7 Days Curing	14 Days Curing	28 Days Curing
2	$5.85x10^{-3}$	$5.37x10^{-3}$	$5.08x10^{-3}$
4	$2.22x10^{-3}$	$2.01x10^{-3}$	$2.05x10^{-3}$
6	$1.3x10^{-3}$	$1.28x10^{-3}$	$1.08x10^{-3}$
8	$1.19x10^{-3}$	$1.08x10^{-3}$	$0.96x10^{-3}$
10	$1.05x10^{-3}$	$0.74x10^{-3}$	$0.32x10^{-3}$

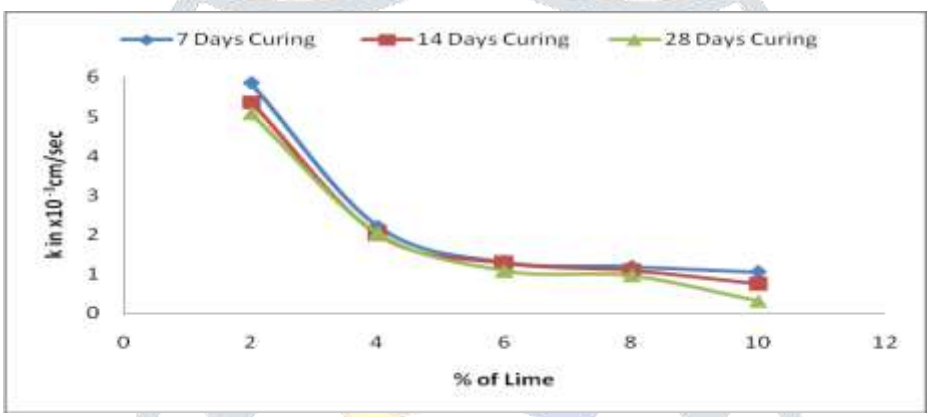

Fig. 1 Test results of Coefficient of Permeability for various % of Lime admixed with copper slag and tested after 7days, 14days and 28days of curing.

In fig 1, the variation is shown for the coefficient of permeability for various percentages of lime admixed copper slag is tested after 7days, 14days and 28days of curing. From the figure it is seen that with increase in percentage of admixture there is a decrease in coefficient of permeability. From the results it is observed that the reduction in percentage of coefficient of permeability of copper slag when mixed with various % of admixture and tested after 7days, 14days and 28days of curing were ranging between 62.1% and 97.9% when compared with the copper slag alone.

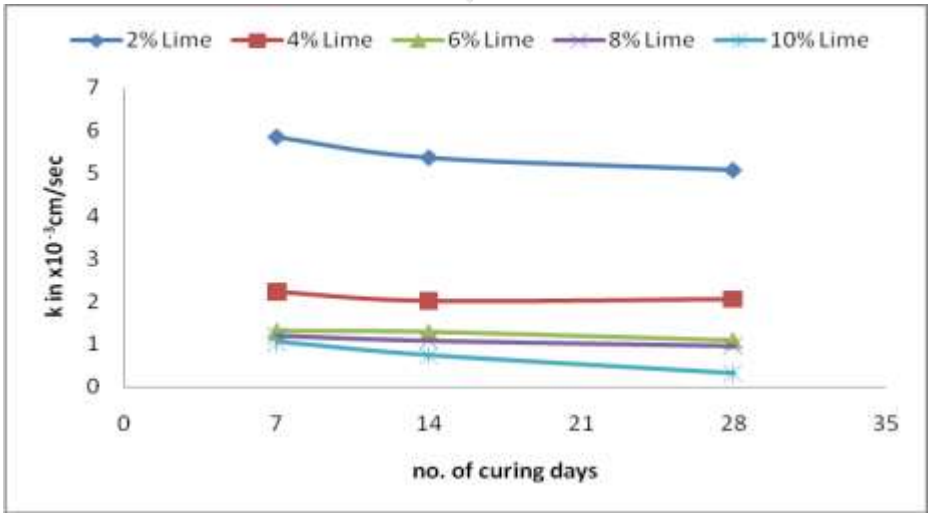

Fig. 2 Test results of Coefficient of Permeability Vs no. of curing days for various % of Lime admixed with copper slag.

In fig 2, the variation is shown for the coefficient of permeability for various curing days of lime admixed with copper slag is tested for various percentages. With increase in no. of curing days of the copper slag admixed with lime there is a decrease in coefficient of permeability. From the test results it is observed that the reduction in percentage of coefficient of permeability of copper slag when mixed with various % of lime range differently with the percentage and with curing period. For 2% and 10% lime the percentage reduction of permeability is between 4% and 5% from 7 days to 28 days of curing period. Whereas for 4%, 6%, 8% lime the percentage reduction of permeability is between 1% and 2% from 7 days to 28 days of curing period.

It is seen that coefficient of permeability for various % of lime admixed with copper slag and tested after 7days, 14days and 28days of curing, there is a decrease in coefficient of permeability with the increase in percentage of admixture and also with increase in curing period.

Also, it is observed that the reduction in percentage of coefficient of permeability of copper slag when compared to that of copper slag alone is between 62% and 93% for 2% to 10% lime respectively for 7days of curing period, 65% and 95% for 14days of curing period and 67% and 98% for 28days of curing period.

4.0 Conclusions

Based on the above variable head permeability test results of copper slag mixed with lime the below are the outlines presented.

1. Lime is used as a binding material to the copper slag to reduce the coefficient of permeability.
2. Lime mixed Copper slag in various percentages gives effective and improved results of coefficient of permeability when compared with the copper slag alone.
3. As the % of lime increases from 2% to 10% the there is a decrease in coefficient of permeability. From the results, it was noticed that a decrease in coefficient of permeability is even with the number of curing days from 7 to 28.
4. Percentage decrease of coefficient of permeability is from 62% to 98% for the copper slag mixed with lime of varying percentage from 2% to 10% after curing for 7 to 28 days.
5. When Lime is mixed with copper slag along with expansive soils may be advantageous in terms of stabilization.

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