

Soil Stabilization Using Steel Slag and Sodium Lignosulfonate

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ABSTRACT

This research paper deals about the experimental study on the stabilization of soil using steel slag and sodium lignosulfonate. A series of tests to find compaction properties and unconfined compressive strength have been conducted. The effect of (0, 4, 8, 12, 16) percentages of steel slag combined with (0, 1, 2, 3, 4) percentages of sodium lignosulfonate has been studied. All the sodium lignosulfonate and steel slag samples are cured for 14 day before testing. Sodium lignosulfonate is adhesive material which physically binds soil particles together and steel slag mechanically improves gradation of soil and makes bonds with clay particles. Moreover steel slag is waste material. These both materials unlike cement are non-toxic and environment friendly. The results show that unconfined compressive value, maximum dry density of soil increases whereas OMC of soil decreases highly.

1. Introduction

Steel slag and sodium lignosulfonate are waste materials. Steel slag consists of positively charged oxides like magnesium, calcium which can make bond with negatively charged clay surface. Sodium lignosulfonate is a sticky material which can bind the particles of soil physically. Hence we can expected that soil will be stabilized using steel slag and sodium lignosulfonate.. Many geotechnical lab tests like CBR, proctor test, shear test has been done in past on both steel slag and sodium lignosulfonate, but none test has been performed yet on combined effect of both sodium lignosulfonate and steel slag on clay soil. So to find the effect of steel slag and sodium lignosulfonate on soil stabilization of soil this research is conducted.

1.1 Steel Slag

Steel slag is a waste material formed during manufacturing process of steel. Steel is formed when small percentage of carbon in form of limestone and coke is added to scrap iron or iron ore at high temperature. Steel slag is a granular material. Its colour is glossy black. Steel slag is of two types- ferric and non-ferric. Steel slag consists of calcium silicates, ferrites and fused oxides of calcium, iron, magnesium, manganese, aluminium. Steel slag does not contains any organic matter as it is formed at high temperature of 1200° Celsius. Steel slag annual production is 90-135 million metric tonnes in the world and in India it is around 12 million metric tonnes every year (according to Indian minerals yearbook may 2016). Steel slag physical properties are-well graded, angular shape, high shear strength, less than 3% water absorption, high degree of internal friction angle, dry unit weight of 1600-1920 kg/m³ (according to National Slag Association (NSA) Environmental Science& Technology).

1.2 Sodium Lignosulfonate

Sodium lignosulfonate is natural polymer obtained from lignin. It becomes a sticky material, when it reacts with water. Its colour is brown. It is obtained when calcium obtained by bisulphite pulping from pulp waste is bonded with lignin waste.

Lignin waste is obtained when sodium hydroxyl molecule is mixed with 10% of milk of lime and heated at 95° Celsius for 30 minutes. This solution is then allowed to settle down and filtered. Cement stabilization is the most common type of stabilization used currently but during manufacture of cement a lot of pollution is produced. Advantage of sodium lignosulfonate over cement is that it is non-toxic and environment friendly.

Table 1. Sodium Lignosulfonate Properties

Molecular formula	C20 H24 Na2O10S2
Molecular weight	534.51 g/mol
Appearance	Powder
Color	Brown
PH	6
Solubility	Soluble
Sulphur (%)	4
Sodium (%)	10

1.3 Literature Review

Magdizumwari et al. (2017) investigated the effect of Steel slag on black cotton soil. They added Steel slag in 5,10,15,20 and 30 percent in the soil. Addition of Steel slag decreases Liquid limit, plastic limit, optimum moisture content, free swell of soil and increases Unconfined compressive strength and Maximum dry density of soil. The optimum percentage of Steel slag was found to be 10%.

Aadepooja et al. (2018) wanted to decrease problem of dumping of slag and protect environment. So they use Steel slag for stabilizing expensive soil to increase bearing capacity of the soil and decrease construction cost. They add 5%, 10%, 15% and 20% of Steel slag in expansive soil. They collect Steel slag from Kalika steel, Jalna. They tested atterberg limits, compaction properties and C.B.R. value of soil by adding Steel slag in the soil. The results shows decrease in Optimum moisture content value by 5.47% and increase in Maximum dry

density and C.B.R. value by 15.9% and 46.8% respectively. The optimum % of Steel slag was found to be 15%.

Sahanaantaratani et al. (2017) investigated the effect of pond ash and Sodium lignosulfonate on geotechnical properties of black cotton soil. The aim of study was to find effect of pond ash and sodium lignosulfonate on Maximum dry density, optimum moisture content and unconfined compressive strength of expansive soil. For this purpose, they add both materials in soil individually and then combined. Pond ash was added to parent soil in 6%, 12%, 18% and 24% by weight. Sodium lignosulfonate was added to parent soil in 1%, 2%, 3% and 4% by weight. Firstly optimum % of pond ash was found and kept constant while chemical % was varied. To find maximum dry density and optimum moisture content light compaction test was used. For all tests, recommendation from IS codes were taken. They conclude that sodium lignosulfonate alone give better results as compare to pond ash or combination of both. Optimum % for addition of sodium lignosulfonate was found to be 2%. Sodium lignosulfonate reduce liquid limit, plasticity index, and optimum moisture content. Sodium lignosulfonate increases plastic limit and unconfined compressive strength of soil.

Nair aswathi et al. (2017) investigated the effect of sodium lignosulfonate and cement on geotechnical properties of marine clay. Marine soil is expansive soil with large amount of organic content. It shrinks and contracts with change in water content. Many researchers from many years are working on problem of destruction caused by swelling and shrinking of marine clays. In this study they use sodium lignosulfonate to improve strength of soil and compare its effect with cement stabilized soil. They focus on modulus of elasticity of soil and strain in soil. So they conducted unconfined compressive strength tests on virgin soil, sodium lignosulfonate treated soils and cement treated soils. The results show that sodium lignosulfonate improves soil more than cement. Soil stabilizers like cement are toxic in nature, thus make soil infertile for agriculture and cause soil pollution, whereas sodium lignosulfonate is an environment friendly, non-toxic chemical which doesn't pollute the environment. Results show 53.33% increase in unconfined compressive strength of soil with addition of 5% sodium lignosulfonate by weight.

2. Materials

2.1 Clay Soil

The soil for this research purpose is taken from the village Pamal, Ludhiana. The soil was collected from 2 to 3 m depth from ground surface.

Table 2 Properties of the Soil

S.No.	Property	Value
1	Liquid limit %	43
2	Plastic limit %	20
3	Plasticity index %	23
4	Soil classification(isc)	Cl
5	Specific gravity	2.56
6	Bulk density	20.4kN/m ³
7	Dry density	17.58kN/m ³

8	OMC %	16
9	UCS	98.2 KN/m ²
13	Sand %	1
14	Clay + Silt %	99

2.2. Steel Slag

Steel slag is a granular waste material in form of aggregates. The Steel slag is taken from Sokhi steels Pvt. Limited a furnace in Ludhiana. The Steel slag aggregates passing 4.75 mm sieve were taken for the research purpose. Steel slag was added in 4%, 8%, 12% and 16% by weight in the soil. The specific gravity of steel slag is found to be 2.81. The Steel slag mixed samples are cured for 14 days before testing.

2.3. Sodium Lignosulfonate

Sodium Lignosulfonate is a by-product obtained during the manufacturing process of paper. It is bought online from indiamart from Ajay chemical shop in Delhi. It is added in 1%, 2%, 3% and 4% in soil. The specific gravity of soil was found to be 1.63. The Sodium Lignosulfonate mixed samples are cured for 14 days before testing.

3. Results

3.1. Standard Proctor Test

The maximum dry density of soil increase by 9.08% with addition of 16% steel slag. The effect of different % of steel slag on maximum dry density is shown in fig..Below.

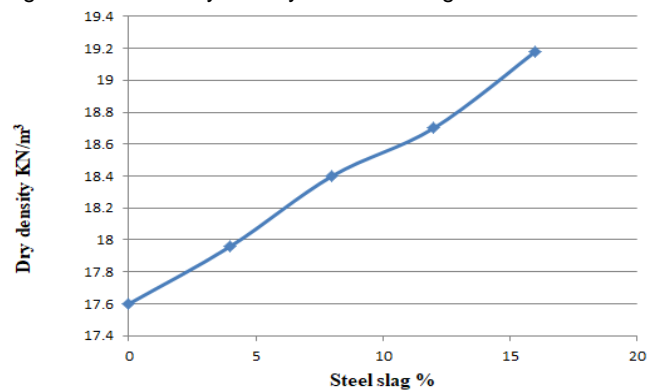


Figure 1. Effect of steel slag on maximum dry density

The optimum moisture content of soil decreases by 25.0% with the addition of steel slag. The effect of different % of steel slag on optimum moisture content is shown in fig. below.

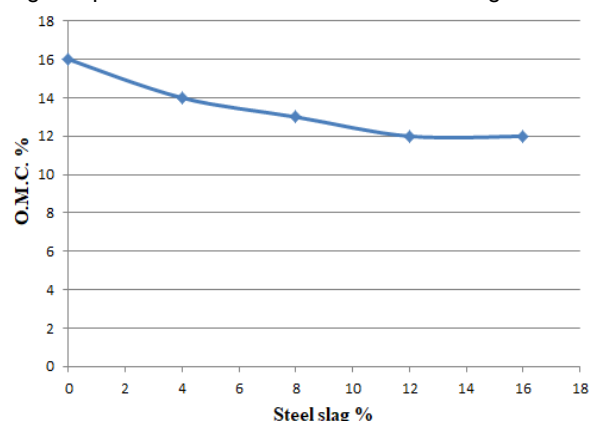


Figure 2. Effect of steel slag on optimum moisture content

The maximum dry density of the soil increases by 7.40% with addition of sodium lignosulfonate up to 2%. The effect of different % of sodium lignosulfonate on maximum dry density is shown in fig. below.

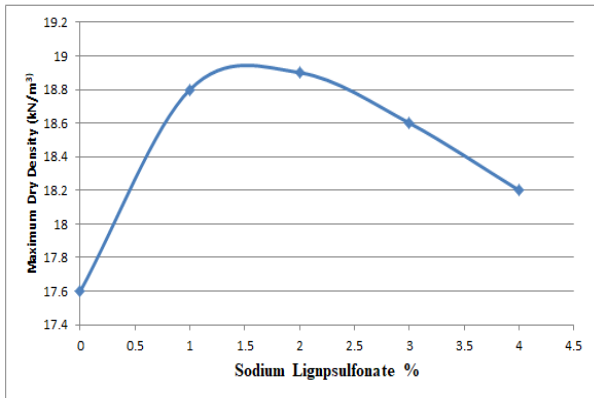


Figure 3 Effect of sodium lignosulfonate on Maximum dry density

The optimum moisture content of soil decreases by 43.70% with addition of 4% sodium lignosulfonate. The effect of different % of sodium lignosulfonate on optimum moisture content is shown in fig. below.

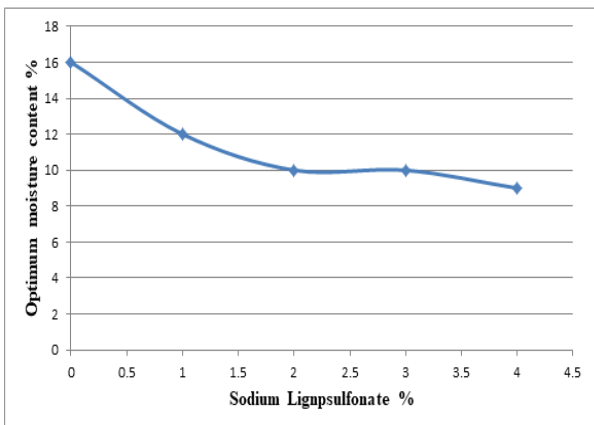


Figure 4. Effect of sodium lignosulfonate on optimum moisture content

The maximum dry density of soil increases with addition of steel slag and sodium lignosulfonate in soil. The effect of different % of steel slag on maximum dry density is shown in fig. below.

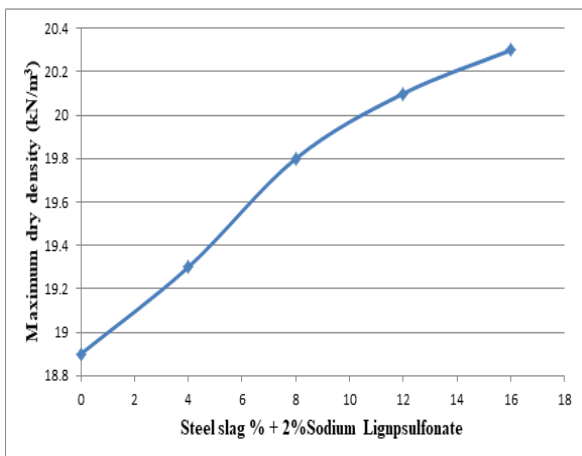


Figure 5. Effect of steel slag and sodium lignosulfonate on maximum dry density

The optimum moisture content of soil decreases with addition of steel slag and sodium lignosulfonate in soil. The effect of different % of steel slag on optimum moisture content is shown in fig. below.

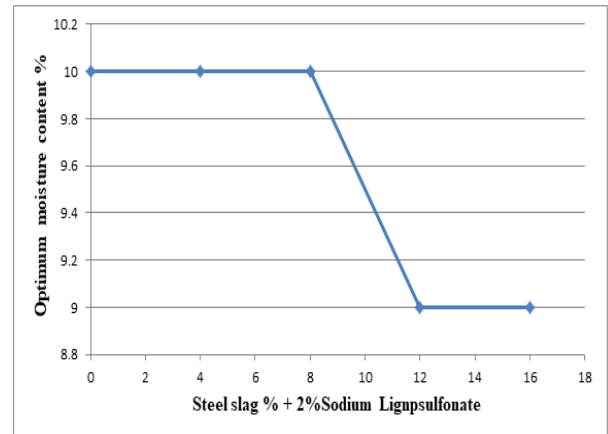


Figure 6. Effect of steel slag and sodium lignosulfonate on optimum moisture content

3.2 Unconfined Compressive Strength Test

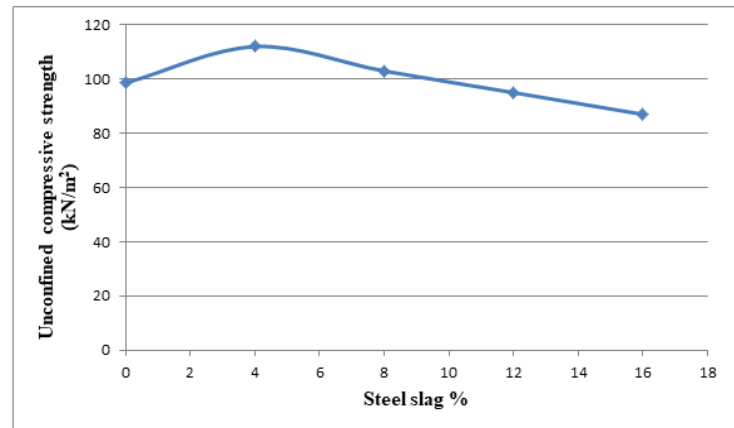


Figure 7. Effect of steel slag on unconfined compressive strength

The unconfined compressive strength of soil increases by 11.27% with addition of 4% steel slag in soil and then goes on decreasing with further addition.

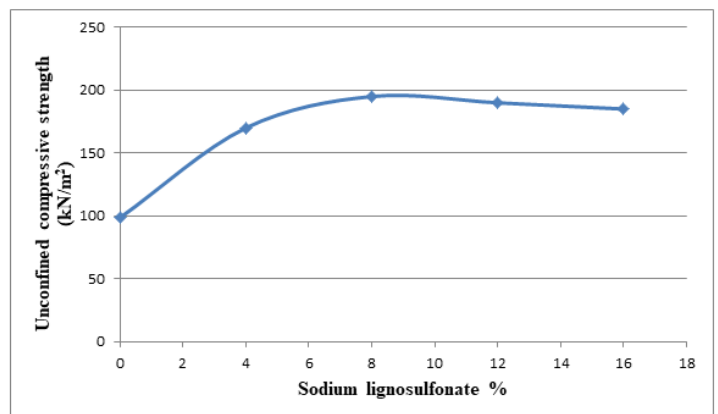


Figure 8. Effect of sodium lignosulfonate on unconfined compressive strength

The unconfined compressive strength of soil increases by 99.04% with addition of 2% sodium lignosulfonate in soil and then goes on decreasing with further addition.

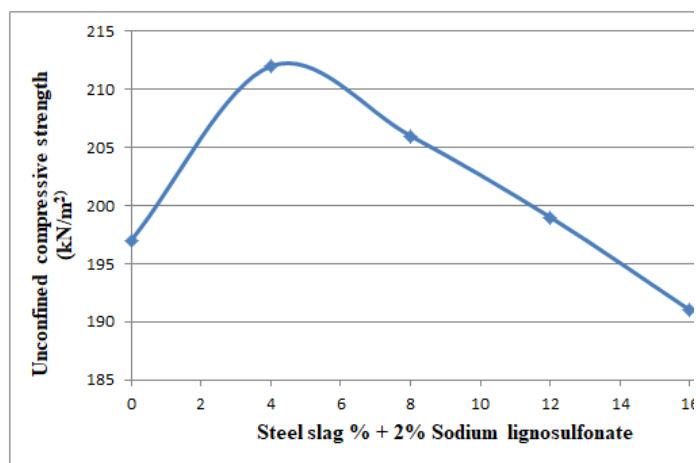


Figure 9. Effect of steel slag and sodium lignosulfonate on unconfined compressive strength

The unconfined compressive strength of soil increases by with addition of 4% steel slag and 2% sodium lignosulfonate in

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soil and then goes on decreasing with further addition of steel slag.

4. Conclusions

1. The maximum dry density of soil increases continuously with addition of steel slag.
2. The maximum dry density of soil increases with addition of sodium lignosulfonate up to 2% and then decreases.
3. The optimum moisture content of soil decreases with addition of steel slag and sodium lignosulfonate.
4. The unconfined compressive strength of soil increases with addition of steel slag and sodium lignosulfonate up to 4% and 2% respectively.
5. The optimum % of steel slag and sodium lignosulfonate to stabilize clay soil are 4% and 2% respectively.