An Experimental Study on Plasticity and Strength Characteristics of Laterite Soil Using Steel Slag

Rose Simon[1], P. M. Basil Saman[2], P. Jisna[3], V. Sreevidhya[4], E. M. Anju[5]
[1,2,3]Student, Department of Civil Engineering, IES College of Engineering, Thrissur, India
[4,5]Assistant Professor, Department of Civil Engineering, IES College of Engineering, Thrissur, India

***Abstract*: Soil is one of nature's abundant construction materials. Almost all type of construction is built with or upon the soil. If the strength of soil is poor, then stabilization is normally needed. In modern days' engineers have to face different kinds of problems like construct heavy structures, heavy mobility. But some places on earth soil have poor engineering properties like bad workability, low bearing capacity and strong compressibility. So, in order to improve strength of soil, add some stabilizers. The aim of this study is to improve the engineering properties of laterite soil using steel slag. Steel slag is a by-product of steel manufacturing industry which is dumped in large quantities every year. Thus, the disposal problem of industrial waste can be minimized. The samples were prepared by mixing the percentage of steel slag and soil as 5%, 8%, and 10% by the dry weight and also with different grades of steel slags. Standard proctor test, unconfined compressive strength, liquid limit and plastic limit tests are performed to analyse compressive strength, maximum dry density and optimum moisture content of soil mixture.**

***Keywords*: Laterite soil, Steel slag, Stabilization.**

1. Introduction

In civil engineering projects, foundation system is one of the important factors affecting the safety and stability of the structures. The foundation system consists of the structural foundation unit and the soil/rock strata below. Nowadays, due to scarcity of land, engineers are compelled to construct in soils with less bearing capacity and high compressibility. In these cases, improving the characteristics of unsuitable soil is a fundamental step for making construction. Pavement structures on poor soil sub grades show early distress causing the premature failure of the pavement. Soils usually has the potential to demonstrate undesirable engineering behaviour, such as low bearing capacity, high shrinkage and swell characteristics and high moisture susceptibility. Stabilisation of these soils is a usual practice for improving the strength. Soil stabilisation can be achieved by the use of techniques of adding a binder to the soil in order to improve the engineering properties of the soil.

Soil stabilisation involves the alteration of one or more of the soil properties. The quality of soil is measured in terms of the size of its particles and as such is described as well graded or poorly graded. The main purpose of undertaking the process is to prepare the land and build a strong foundation that can support the design loading. It is done to increase soil strength and durability as well as to suppress dust formation and prevent soil erosion.

2. Objectives

This study aims at the implementation of steel slag for soil stabilisation at suitable engineering fields. Through this even the weak soil conditions of a site can be improved without changing the soil. It is a time saving, economic and eco-friendly technique of soil stabilisation and the study intends for the wider implementation of steel slag in stabilization method.

3. Scope

This study aims at improving the properties of locally available cohesive soil using steel slag with addition of water. Steel slag was added at 5, 8 and 10% by weight of the soil. Following are the main scope of this study.

- This stabilisation method is more economical both in terms of cost and energy of soil rather than going for deep foundation or raft foundation.
- Stabilisation also provides more stability to the soil in slopes or other such places.
- Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful in dry and arid weather.
- The work outcomes can be used to execute soil stabilisation in a more economic, eco-friendly, and faster way.
- Generally recycled and waste particles are used and promoted in this project.
- Transportation costs, quarrying costs etc. can be reduced and resources are saved for future needs.

4. Materials and Methodology

A. Materials

1) Steel slag

Steel slag is a dark coloured porous material. It is the by-product of steel making, produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling.

Fig. 1. Steel slag

2) Soil

The soil used in the entire laboratory testing was locally available laterite soil. It was the excavated soil for laying foundation for a new multi storied building. The soil was reddish in colour and was well graded.

Fig. 2. Soil

B. Methodology

First step was collection of materials. The materials used for the study is collected from native places. Then the index properties of laterite soil were found out to know the characteristics. Tests conducted are specific gravity, Atterberg limits, compaction characteristics and unconfined shear strength. Then 5%, 8%, 10% of steel slag is added and the properties of soil is found out.

5. Results and Discussion

For determining the type of soil and its properties these tests are conducted and results of the tests are tabulated.

Table 1
Engineering properties of soil

Properties	Values
Specific gravity	2.55
Maximum dry density (g/cc)	1.87
Optimum moisture content (%)	14.3
Liquid limit (%)	40.5
plastic limit (%)	29
shrinkage limit (%)	19.8
Plasticity index (%)	11.5
Soil classification	MI

In standard proctor test when steel slag is mixed with parent soil the value of maximum dry density of the soil slightly increased with higher steel slag contents. As the steel slag content increases it goes into the pores of soil and makes a very well packed structure. After increment in steel slag content, the particles of the soil were replaced by the steel slag and due to its less unit weight, the dry density of soil reduced with the addition of steel slag. On the other hand, the decrease in optimum moisture content with higher steel slag content may be attributed to agglomeration of clay particles - making the clay clusters behave more like larger aggregates.

The figure 3 shows the comparison of compaction curves obtained by adding 5%, 8% and 10% of steel slag (4.75mm sieve retained) into soil.

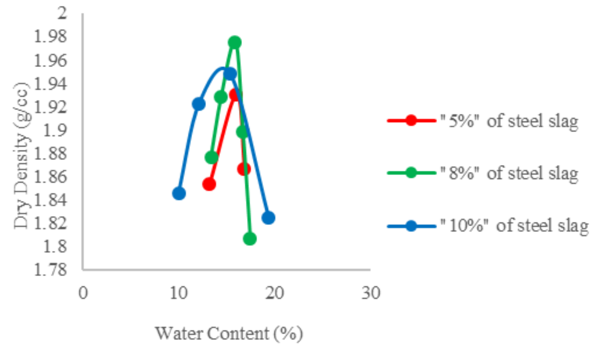

Fig. 3. Compaction curve for soil-steel slag (4.75mm sieve retained) mixes

From graph it is observed that, dry density first increases to 1.975g/cc on mixing steel slag with soil and then decreases to 1.948g/cc as the steel slag content is increased. The highest value of MDD is for 8% steel slag (4.75mm sieve retained).

The figure 4 shows the comparison of compaction curves obtained by adding 5%, 8% and 10% of steel slag (4.75mm sieve passed) into soil.

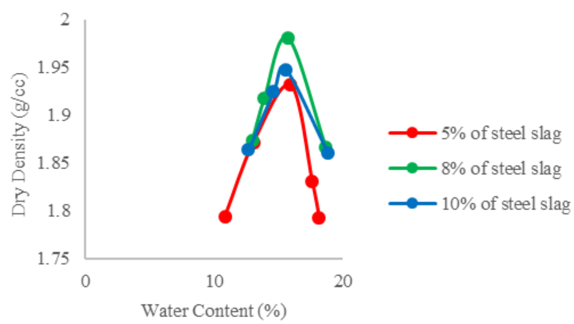

Fig. 4. Compaction curves for soil-steel slag (4.75mm sieve passed) mixes

From graph it is observed that, dry density first increases to 1.981g/cc on mixing steel slag with soil and then decreases to 1.948g/cc as the steel slag content is increased. The highest value of MDD is for 8% of steel slag (4.75mm sieve passed).

The figure 5 shows the comparison of compaction curves obtained by adding 5%, 8% and 10% of steel slag (0.425mm sieve passed) into soil.

From graph it is observed that, dry density first increases to 2.001g/cc on mixing steel slag with soil and then decreases to 1.956g/cc as the steel slag content is increased. The highest value of MDD is for 8% of steel slag (0.425mm sieve passed). Among the all three grades, maximum dry density (2.001g/cc) is obtained for 0.425mm sieve passed steel slag.

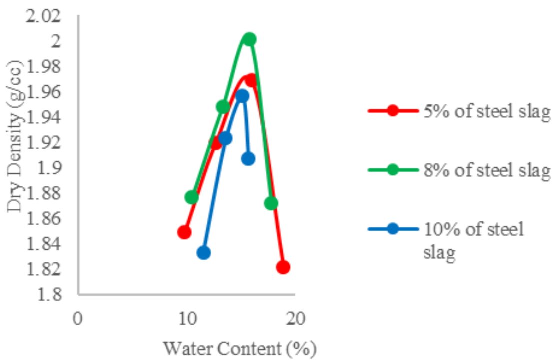

Fig. 5. Compaction curve for soil-steel slag (0.425mm sieve passed) mixes

The unconfined compressive strength of the natural and treated soils at their optimum moisture content and maximum dry density increases with increase in the percentage of steel slag. Increase in strength of the specimen was due to the high iron oxide content in chemical composition of the mixture with increasing steel slag content. As steel slag content increases the cohesion intercept decreases and the angle of internal friction increases. The increase in angle of internal friction and the decrease in cohesion intercept with the increase in steel slag is due to frictional nature of steel slag. Improvement in properties of unconfined compressive strength may be due to ion exchange at the surface of the particles.

The figure 6 shows the variation of compressive stress of the soil with different percentage of steel slag (4.75mm sieve retained) at optimum water content.

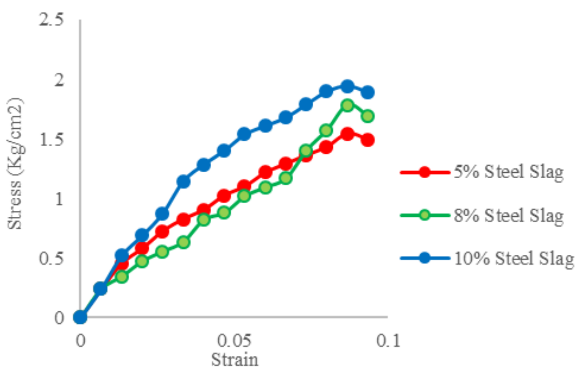

Fig. 6. Stress vs. Strain curves for soil-steel slag (4.75mm sieve retained) mixes

From the graph it is clear that the compressive stress increases with respect to the axial strain up to a certain point (1.942 kg/cm^2) and then it is decreased.

The figure 7 shows the variation of compressive stress of the soil with different percentage of steel slag (4.75mm sieve passed) at optimum water content.

From the graph it is clear that the compressive stress increases with respect to the axial strain up to a certain point (1.987 kg/cm^2) and then it is decreased.

The figure 8 shows the variation of compressive stress of the soil with different percentage of steel slag (0.425mm sieve passed) at optimum water content.

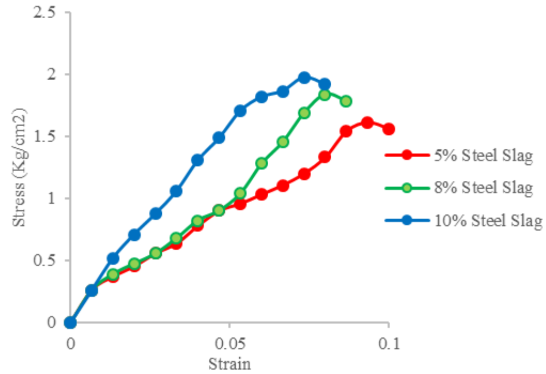

Fig. 7. Stress vs. Strain curves for soil-steel slag (4.75mm sieve passed) mixes

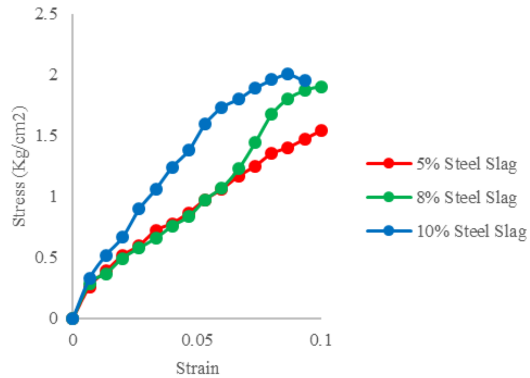

Fig. 8. Stress vs Strain curves for soil-steel slag (0.425mm sieve passed) mixes

From the graph it is clear that the compressive stress increases with respect to the axial strain up to a certain point (2.039 kg/cm^2) and then it is decreased. From the graphs, the unconfined compressive strength increases with respect to the grade of steel slag. Grade of 0.425mm sieve passed shows maximum strength.

The limits and the plasticity index of the lateritic soil sample were determined in order to characterize its condition by water content. With progressive increment in percentage of steel slag content in the lateritic soil, the liquid limit, plastic limit, shrinkage limit and plasticity index progressively decreased. The probable reason for reducing the liquid limit, plastic limit and plasticity index of modified soil may be the use of non-plastic material as steel slag.

Figure 9 shows the variation of liquid limit with different percentage of steel slag with different grade.

From the graph it is found that as the percentage of steel slag increases the liquid limit is reduced. As the percentage of steel slag is increased up to 10% the liquid limit is reduced to 38.5% for 4.75mm sieve retained, 36% for 4.75mm sieve passed and 34% for 0.425mm sieve passed steel slag.

Figure 10 shows the variation of plastic limit with different percentage of steel slag with different grades.

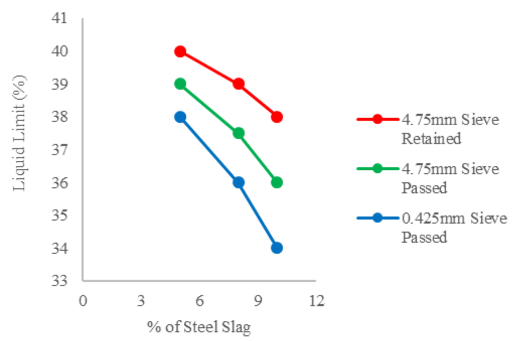

Fig. 9. Variation of liquid limits with different percentage of steel slag

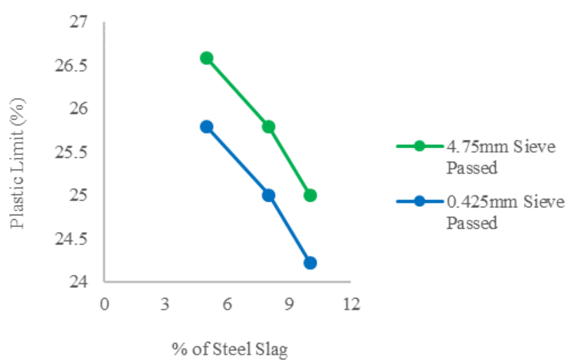

Fig. 10. Variation of plastic limits with different percentage of steel slag

The soil has been modified by the addition of steel slag in the range of 0% to 10%. The plastic limit of the soil without modification is found to be 29% and after modification the plastic limit was reduced to 25% for 4.75mm sieve passed and 24% for 0.425mm sieve passed steel slag.

Figure 11 shows the variation of plasticity index with different percentage of steel slag with different grades.

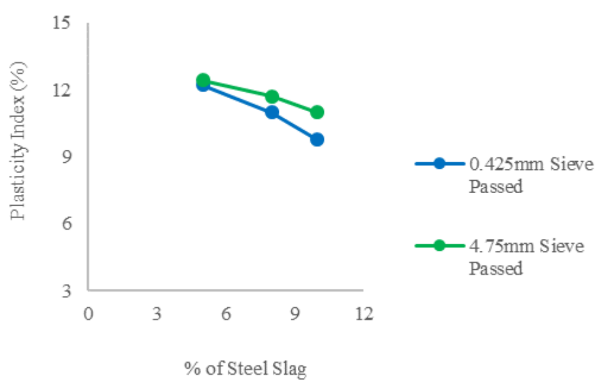

Fig. 11. Variation of plasticity index with different percentage of steel slag

As the percentage of steel slag increased up to 10% the value of liquid limit and plastic limit is reduced. Similarly, the value of plasticity index is decreased. From the graph it is clear that the reduced value of plasticity index is % for 4.75mm sieve passed and % for 0.425mm sieve passed steel slag. From the graph it is clear that as the steel slag become finer the shrinkage limit is reduced to 17% for 0.475mm sieve retained, 16.6% for 0.475mm sieve passed and 16.2% for 0.425mm sieve passed.

6. Conclusion

- The MDD result shows the increasing trend for soil slag mixture of different grade and decreasing trend for OMC.
- The unconfined compressive strength of soil slag mixture increases as the percentage of steel slag increases.
- By addition of 10% steel slag in soil, the value of liquid limit, plastic limit, shrinkage limit and plasticity index are reduced.
- From the results we conclude that 0.425mm grade steel slag is more effective.

References

[1] Chippada Srinivas, “Experimental Investigation on Expansive Soil Stabilization by Using Steel Slag”, in *International Journal of Mechanics and Solids*, vol. 12, pp. 71-76, 2017.
[2] Huang Yi et.al., “An overview of utilization of steel slag”, in *Procedia Environmental Sciences*, vol. 16, pp. 791-801, 2012.
[3] Kalpana Patel and Adarsh Patel, “Effects of Steel Slag on the Strength Properties of Clay, Lateritic and Black Cotton Clay Soil”, in *SAMRIDDHI-A Journal of Physical Sciences, Engineering and Technology*, vol. 8, no. 2, 2016.
[4] Koranne, Bansode, “Innovative Ground Improvement Technique for Utilization of Steel Slag for Roads”, in *Indian Geotechnical Conference, IGS Mumbai*, 2010.
[5] Saurabh Kumar et.al, “Stabilisation of Clayey Soil using Steel Slag”, in *International Journal for Research in Technological Studies*, vol. 3, no. 11, 2016.
[6] Akinwumi, et.al, “Effects of Steel Slag Addition on the Plasticity, Strength and Permeability of Lateritic Soil”, *ASCE*, 2013.
[7] S. M. Ali Jawaid and Shipra Chaubey, “Soil stabilization using steel slag”, *International Journal for research analysis*, vol. 5, no. 1, 2016.
[8] Hussien Aldeeky and Omar Al Hattamleh, “Experimental Study on the Utilization of Fine Steel Slag on Stabilizing High Plastic Subgrade Soil”, *Research article*, 2017.
[9] S. S. Bachhav et.al., “Use of steel slag in construction of flexible pavement”, *International Journal of Engineering and Innovative Technology*, vol. 5, no. 11, 2016.
[10] M. Kameswara Rao and S. Prabhu Kumar, “Utilization of Pulverized Steel Slag for Stabilization of Lateritic Sandy Soils”, in *International Journal for Research in Applied Science & Engineering Technology*, vol. 5, no. 8, 2017.
[11] D. Koteswara Rao et.al., “A Laboratory Study on the Effect of Steel Slag for improving the Properties of Marine Clay for Foundation Beds”, in International *Journal of science and Engineering Research*, vol. 5, no. 7, 2014.
[12] Joseph O. Akinmusuru, “Potential beneficial uses of steel slag wastes for civil engineering purposes”, in *Resources, Conservation and Recycling*, vol. 5, no. 1, pp. 73-80, February 1991.
[13] Huang Yi et.al., “An overview of utilization of steel slag”, in *Procedia Environmental Sciences*, vol. 16, pp. 791-801, 2012.