International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Stabilization of Subgrade Soil using Lime & Steel Slag

Guided By- Prof. Bhor A. S. , Mr. Akshay Sinnarkar , Ms. Snehal Gadhave , Mr. Kishor Chache , Mr. Asutosh Gunjal

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Transport is an integral part of any nation's economy. Roads are considered to belifelines of country because it is most preferred and cost effective modes of transportation. Hence, it is essential develop well established and efficient network of roads in the country to provide accessibility in every corner of country in all weather.

The overall performance and durability of pavement majorly depends on its subgrade. Subgrade is an in situ soil which is compacted to its maximum dry density upon which pavement layers are laid. The loads on pavement must be transmitted to subgrade. The roads will rapidly detoriate if subgrade does not possess adequate bearing capacity. The soil in subgrade should not change in volume and resist deformation.

Black cotton soil is crucial material for pavement construction because of its swellingand shrinkage behaviour in varying moisture content. Black cotton soil form major soil group in India. To construct a durable pavement on such kind of road is a challenge to engineers. Due to changing water content in different weather roads on such subgrade results into failures of roads in the form of uneven settlement, heavy depression and cracking. Moreover, softened sub grade has tendency to penetrate upward in adjacent granular layer .Therefore to create subgrade layer the compressibility of such soil need tobe reduced i.e. soil need to be stabilize.

The engineering properties of black cotton soil can be increased by adding appropriate admixture in it .In our project we are using steel slag which is by product of metallurgicalindustry.

Expansive soil, also called as shrink-swell soil, is a very common cause of foundation problems. The construction of roads on naturally occurring expansive soils has been generally avoided due to their high potential to swell that will produce significant volumechanges and uplift forces on the pavement layers and have relatively low strength values. The prediction of volume changes, uplift forces and strength of these soils is alsocomplicated by the fact that, these soils are affected by the boundary conditions.

Black cotton soil is one of major soil deposits of India. They exhibit high rate of swellingand shrinkage when exposed to changes in moisture content and hence have been foundto be most troublesome from engineering consideration. The rate of montmorillonite is more in black cotton soil which causes expansiveness and crack occurs in soil without any warning which is dangerous for construction.

1.2 SOIL STABILIZATION

Soil Stabilization is the alteration of soils to enhance their engineering properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations.
Soil Stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub-soils are not suitable for construction. Stabilization can be used to treat a wide range of sub-grade materials, varying from expansive clays to granular materials. This process is accomplished using a wide variety of additives, including lime, fly-ash, and Portland cement. Other material by-products used in Stabilization include lime-kiln dust (LKD) and cement-kiln dust (CKD).

Fig 1.1

Fig 1.2

1.3 BENEFITS OF SOIL STABILIZATION

Benefits of Soil Stabilization process can include:

- Higher resistance (R) values
- Reduction in plasticity
- Lower permeability
- **Reduction** of pavement thickness
- Elimination of excavation, exporting unsuitable material and importing new materials
- Increase in MDD and OMC
- Provides "all-weather" access onto and within project sites

In addition, there are several environmental advantages. When unimproved roadways are stabilized and treated with the right additives, run-off of storm water will not cause erosion, which in turn sends thousands of tons of silt into our rivers and bays. This erosion clogs and silts vital waterways and fish habitat that would have been spawning grounds for future generations. Soil Stabilization methods help to preserve soils, water ways, unimproved roadways and much more.

Fig 1.3

1.4 METHODS OF SOIL STABILIZATION

Methods of stabilization can be broadly classified under two categories and these are as follows:

- Stabilization without additives.

- Stabilization with additives.

1.4.1 STABILIZATION WITHOUT ADDITIVES:

1.4.1.1 Mechanical Stabilization:

This approach involves improvement of soil by compacting to denser state or bychanging the gradation of soil. This can be achieved by either of following methods

- Compaction.
- Addition or removal of soil particles.

1.4.1.2 Stabilization by drainage:

The strength of soil depends upon the effective stress which in turn is adversely affected by ground water and hence excess pore water must be expelled out by using following methods:

- Application of external load.
- Electro-osmosis.
- Application of thermal gradient.

1.4.1.3 Ground reinforcement:

The following methods also help in increasing the shear strength of soil significantly.

- Stone columns and soil nailing.
- Geo synthetics.
- Grouting.

1.4.2 SOIL STABILIZATION WITH ADDITIVES:

So many additives have been employed with different type soil with varying degree of success. An additive is satisfactory when it upgrades the quality of soil but all the requirements cannot be met at a time. For better results more than one additive can be introduced checking the suitability.

- Cement Stabilization.
- Lime Stabilization.
- Bitumen Stabilization.
- Salt Stabilization.
- Fly ash Stabilization
- Stabilization using steel slag

1.5 SCOPE OF PRESENT STUDY:

Many part around the globe such as India, U.S.A, Egypt etc are facing problems in construction work due to clayey soil. Damage to the light structures and road pavement has been reported. Replacement of soil with suitable one and disposal of the former is costly process and this is critical in developing country like ours where construction cost is quite high. Moreover pavement on clayey soil requires a greater thickness of base and sub-base course which results in increases the expenditure of project. To avoid this problem it becomes mandatory to increase the strength of the soil which in-turn will help in lessening the thickness of the pavement layers and thus project cost.

We are using here steel slag which is a by product of metallurgical industry. Lime is preferred because lime is cheaper and available anywhere. Lime stabilization is requires adequate clay content and a relatively high curing temperature and hence it is more suitable for tropical and subtropical countries like India. In India around 24 lakh metric ton slag produced per year (Central Bureau of Mines).Which is dumped in open landfill which causes the environmental hazards like pollution of ground water contamination with heavy metals, wastage of useful land hence this slag should be used in efficient manner.

1.6 OBJECTIVE OF THE STUDY:

The study is focused on

- Improvement of locally available expansive soil subgrade using some wastematerials like steel slag and lime

- Evaluation of strength parameters of soil using constant percentage of limeand varying percentage of steel slag.
- Determination of appropriate soil, lime and steel slag percentage to achievemaximum MDD and OMC content

CHAPTER 2

LITERATURE REVIEW

Many researchers have done their research work on subgrade strength determination and used various types of materials such as waste materials, crushed stone, geosynthetics etc. various scientists had different opinion to use those materials as subgrade material.Extensive literature review was carried out for selection of various tests to be performed during the study. The details of literature review are summarized below:

2.1 "Soil Modification by the Application of Steel Slag"

(By Isaac Akinwumi (2014))

Researcher provided experimental insights on the modification of a soil using electric arcfurnace (EAF) steel slag, which is limitedly used as a construction material because of itsvolumetric instability. Various percentages of pulverized steel slag were applied to a soil,having poor engineering properties, with the aim of improving the engineering propertiesof the soil. Sieve analysis, consistency limits, specific gravity, compaction, California bearing ratio (CBR), unconfined compression and permeability tests were performed on the soil and each of the soil-slag mixtures. The plasticity and the uncured strength of the soil were reduced and increased, respectively, by the addition of an optimal steel slag content of 8%. Pulverized steel slag is therefore recommended as a low-cost modifier or stabilizer of lateritic soils with poor engineering properties, because it made the soil sample in this study better suited for use as a soil subgrade material.

2.1.1 Material and Methods

Soil sample used in this research work was collected, by method of bulk disturbed sampling (for homogeneity), from the borrow pit of Covenant University area. It was collected at a depth not less than 0.5m from the ground, after the removal of 0.2m thick topsoil layer. Required quantity of soil was collected in a polythene bag to avoid moisture loss during transportation and before the determination of the natural moisture content of the soil in the laboratory. The samples were stored and air-dried in theGeotechnology laboratory of the Department of Civil Engineering, Covenant University, &Ota.

These samples were pulverized such that 75% of the samples passed through 75 mm sieve openings while all the samples passed through 0.425mm sieve openings. The oxide composition of the soil was determined using atomic absorption spectrophotometer whilethe chemical composition of the pulverized steel slag was obtained using standard X-ray fluorescence spectroscopy. Natural moisture content, specific gravity, sieve analysis and Atterberg's limits, compaction, California bearing ratio (CBR), unconfined compression and permeability tests were performed on the natural soil sample and on the soil slag mixtures of 5, 8 and 10% steel slag, by weight of the dry soil sample. The effects of adding steel slag to modify these engineering properties of the soil sample were determined. The procedures for the various tests were carried out in accordance with BSI.In order to determine the level or extent of laterization of the soil used, the percentage concentration of oxides of silica (SiO_2), iron (Fe_2O_3) and aluminium (Al_2O_3) in the soil were determined. A ternary or tri-plot of this composition is shown in Fig.2.2; the soil contains higher silica content when compared with the iron oxide content. This suggests that this soil was formed from laterite on an acidic rock and it contains some quartz. The ratio of silica-sesquioxides was determined to be 1.45. Thus, confirming that the soil is lateritic. According to the Schellmann scheme of classification of weathering products, this soil sample was taken from a weakly laterized profile. The chemical composition of the EAF slag used expressed in terms of oxides and calculated from elemental analysis determined by X-ray fluorescence.

2.1.2 Results

The concentration of CaO, MgO, SiO_2, and MnO fell out of the envelope for the typical chemical composition of steel slag. CaO, MgO and SiO_2 had their concentration falling below the minimum concentration, most likely due to the leaching away of these oxides after exposure of the steel slag to weather A summary of the result of the geotechnical properties of the soil prior to addition of steel slag is presented. The soil, which is brown, contains about 50% of fines and a large percent of sand, which is in agreement with the silica content or quartz in the soil. The soil is classified as A-7-6 according to the American Association of State Highway and Transportation Officials (AASHTO) soil classification system and has a natural moisture content of 14.3%. With its plasticity

Index greater than 11, the fines are clayey, according to AASHTO system and the engineering properties of such a soil are mostly influenced by its mineralogy.

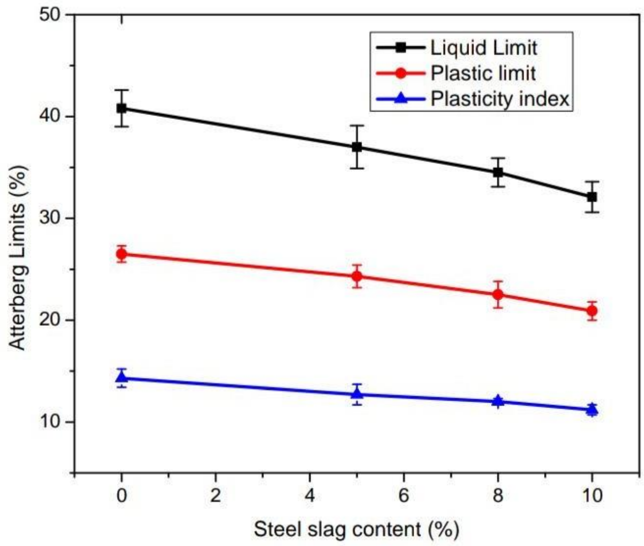
TABLE 2.1 Geotechnical properties of untreated soil

	Properties	Quantity
Gradation/Classification	Gravel (>4.75mm), %	1.3
	Sand (0.075- 4.75mm), %	48.5
	Silt and clay (<0.075mm), %	49.9
	AASHTO Soil classification system	A-7-6 (5)
	Unified soil classification system	CL- Sandy lean clay
Physical	Colour	Brown
	Natural moisture content	14.3
	Specific gravity	2.65
	Liquid limit %	40.9
	Plastic limit %	26.5
	Plasticity index %	14.4
	Maximum dry unit weight (kN/m^3)	18.2
	Optimum moisture content %	17.5
	permeability (cm/s)	1.68×10^{-4}
	Swell potential %	0.2
Strength	Unsoaked CBR %	51
	Soaked CBR %	49
	Unconfined compressive Strength (kN/m^2)	104

Liquid and plastic 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 and plasticity index progressively decreased. The decrease in plasticity indices of the soil-slag mixtures as the steel slag content increased was strongly correlated, r = - 0.997. The reduction in the clay-size particles of the soil-slag mixture and the consequentincrease in its silt-size particles are most likely responsible for the decrease in liquid and plastic limits, and plasticity index with progressive increase in slag content.

This reduction in clay-size particles may be due to the replacement of lower valence cations present in the soil by Ca2+ and Mg2+ present in the steel slag, reducing the sizeof the diffused water layer, thereby allowing the clay-sized particles in the soil and slagto approach each other more closely and get clumped-together to form silt-size particles. This behaviour is similar to that of lime modification of soils that leads to greater workability of the soil except that for lime-treated soils, their plastic limits were found to be higher than those of the natural soils.

Fig 2.1 Variation of Atterberg limits with slag content



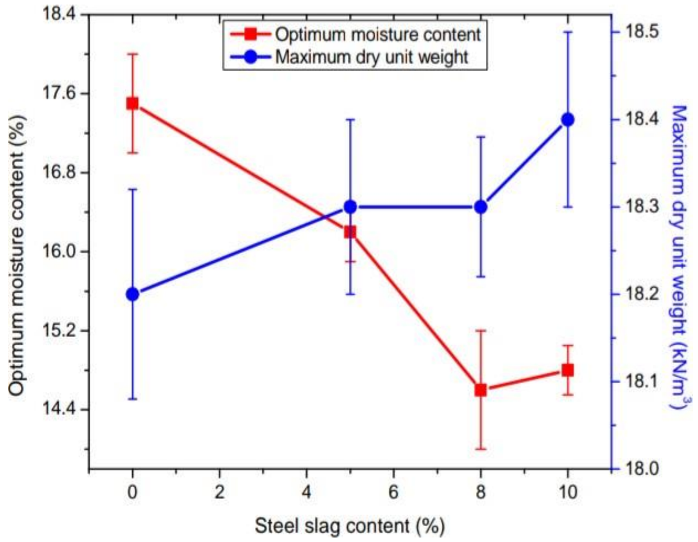


Fig 2.2 Variation of compaction characteristics with slag content

The maximum dry unit weight of the soil slightly increased with higher steel slagcontents. The increase in maximum dry unit weights of the soil-slag mixtures as the steel slag content increased was strongly correlated, *r* =0.93.The unsoaked CBR value for the soil progressively increased from 51% for the 0% slag content to 91% for 8% slag content before a decrease to 79% for 10% steel slag content was experienced.

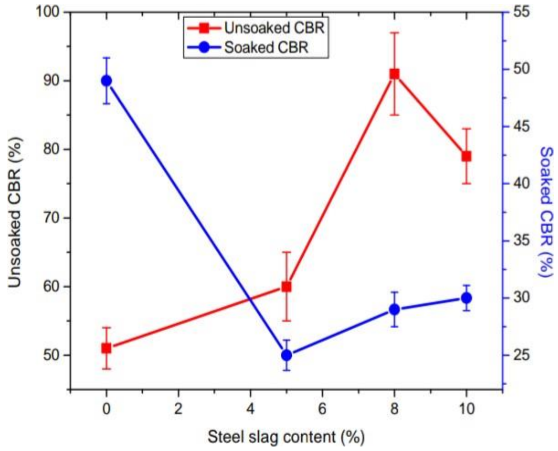


Fig 2.3 variation of CBR with slag content

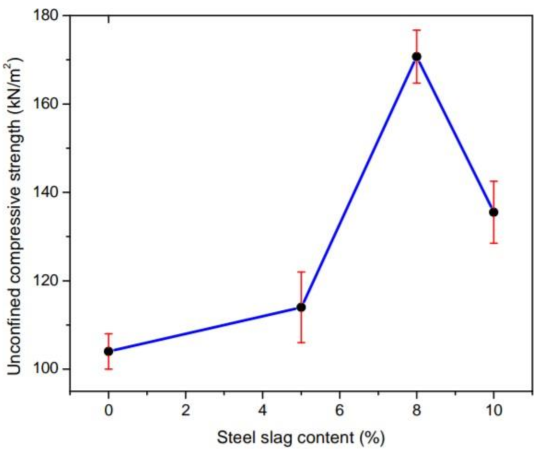


Fig 2.4 Variation of UCS with slag content

The increase in unsoaked CBR values of the soil-slag mixtures as the steel slag content increased was strongly correlated, *r* = 0.856.

2.1.3 Conclusion

This study provides experimental insights that show that pulverized steel slag was beneficially used to improve the plasticity, uncured strength and drainage characteristics of the lateritic soil without any adverse swell behaviour observed.

The improvement in the uncured strength of the soil was limited to the application of 8% steel slag to the soil. Addition of 8% of steel slag to the soil increased its unsoaked CBR by 40% and its unconfined compressive strength by 66.7kN/m2, while the liquid limit, plastic limit and plasticity index were reduced by 6.3%, 4.0% and 2.3%, respectively.

2.2 "Stabilization of clayey soil using steel slag"

(By Saurabh Kumar, Ved Parkash, Vishal Kumar (2016))

In modern days, engineers have to face different kinds of problems like construct heavy structure, heavy mobility. But some places on earth soil have poor engineering propertieslike bad workability, low bearing capacity and strong compressibility. So in order to improve the strength of soil, add some stabilizers. The aim of this study is to improve the engineering properties of clayey soil using steel slag. Specimens are prepared to knowthe properties of soil with percentage of 4%, 8%, 12%, 16% and 20% steel slag mixture passed through 180 micron and 300 micron sieve. Standard proctor test, unconfined compressive strength, liquid limit and plastic limit tests are performed to analysis compressive strength, Maximum dry density (MDD) and optimum moisture content (OMC) of soil mixture.

2.2.1 Objectives of the study

The thesis is focused on

1) Improvement in engineering property of locally available soil.

2) Reducing the plasticity of soil to achieve more stable soil.

3) Determination of strength of soil by using standard proctor test and unconfinedcompressive strength test and how soil’s plastic limit and liquid limit results are obtained.

4) Gain of strength characteristics of soil using different percentage of steel slag.

2.2.2 Materials

A) Soil

About 80 kg clayey soils were collected from Kaithal (Haryana) and remove impuritiesin college soil lab. After that soil was grind and passed in sieve through 4.75 micron to remove the fraction of gravel and prevent impurities. Soil was oven dried for 24 hours before performing of tests.

B) Slag

Around 20kg of Steel slag was taken from steel industry at Jagadhari (Yamunanagar). The steel slag was oven dried and sieved from 180 microns and 300 microns.

2.2.3 Methodology

The Compaction Test, Unconfined Compressive Strength, Atterberg's Limit Test have taken for this study. Slag is added in the soil with variable percentage (4%, 8%, 12%, 16%, and 20%).

2.2.4 Results and Discussion

A. Compaction Test

In standard proctor test when steel slag is mixed with parent soil the value of (MDD) isin increasing order and (OMC) value is in decreasing order. Where parent soil have (MDD) value is 1.55 gm/cc and (OMC) value is 24.16% after performing the standard proctor test. Percentage of slag is mix with soil specimen the highest result of (MDD) is

1.73 gm/cc and 1.71 gm/cc for material passed through 180µ and 300µ sieve. Where highest result of (OMC) are 22.82% and 26.13% for material passed through 180µ and 300µ sieve.

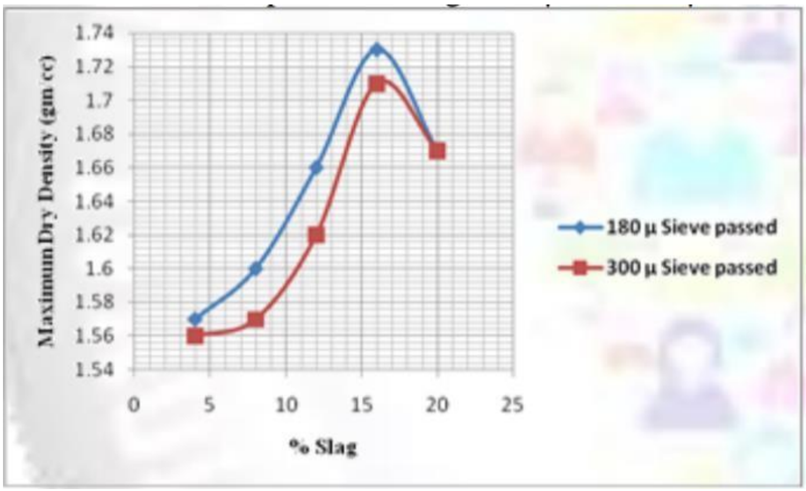


Fig 2.5 Variation of MDD with different % of steel slag

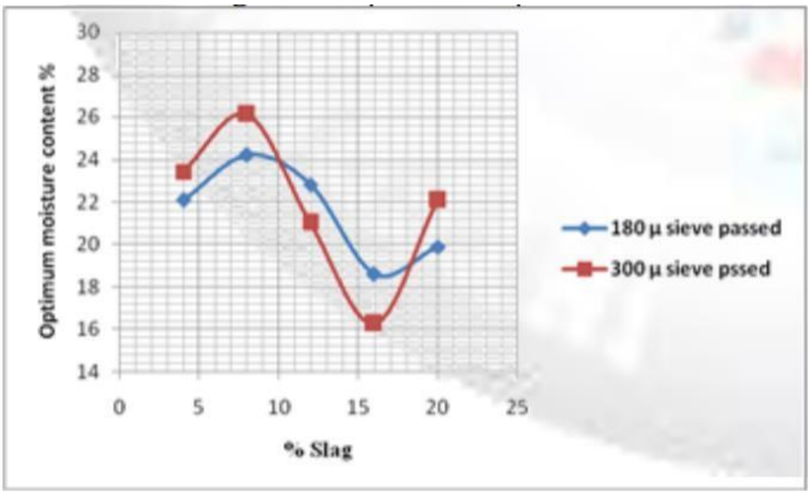


Fig 2.6 Variation of OMC with different % of steel slag

B. Unconfined Compression Test

The unconfined compressive quality is 3.03 Kg/cm2 at optimum moisture content of 24.16% and MDD 1.55 gm/cc from compaction test. The unconfined compressive strength of the soil mix with steel slag shows increasing strength for some samples with the increment of steel slag. The result of UCS shows increasing order in strength.

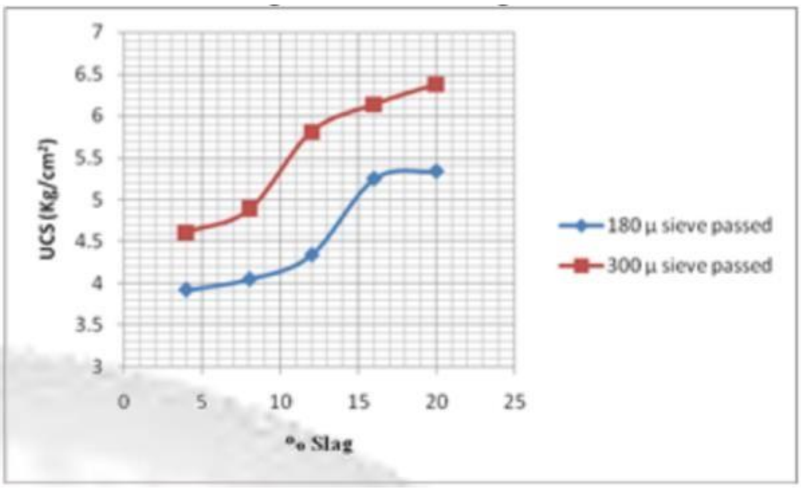


Fig 2.7 Variation of UCS with different % of steel slag

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

C. Atterberg's Limit Test

The liquid limit and plastic limit of samples show decreasing trend as we add % of steel slag for parent soil liquid limit is 46.05%, plastic limit is 22.49%, and plasticity index is 24.56% due to fineness of slag.

2.2.5 Conclusion

In this project, strength characteristics of clayey soil with steel slag havebeen studied. The following conclusions can be made based on the test results. With the addition ofslag percentage in the soil the maximum dry density in increasing order and the optimum moisture content start decreasing at both slag passed through 180 µ and 300 µ sieves.

CHAPTER 3

EXPERIMENTAL INVESTIGATION

3.1 SOIL SAMPLE

Soil sample used in this investigation was collected from SANGALI PHATA. The top layer upto 300 mm has been cleared and the soil below that is collected for this investigation. The main problem with soil is swelling shrinkage behaviour due to varyingpercentage of moisture content and low bearing capacity.

3.2 STEEL SLAG

Steel slag is collected from Rambo Industries Coimbatore. Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, slag consists of calcium, magnesium manganese and aluminium silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slagrequired for various end-use consumers. Although, the chemical composition of slag mayremain unchanged, physical properties vary widely with the changing process of cooling. The physical characteristics of steel slag are given in Table 3.1:

TABLE 3.1 Physical Characteristics of Steel Slag

Characteristics	**Values**
Specific Gravity	3.19
Colour	Greyish
Natural Moisture Content	0.26%
Cu	2.09
Cc	1.64

3.2.1 PRODUCTION

The slag produced at blast furnace during pig iron manufacturing is called blast furnace slag. The slag produced at steel melting shop is known as steel slag. Slag output obtained during pig iron and steel production is variable and depends mainly on composition of raw materials and type of furnace. Typically, for e feed containing 60 to 65% iron, blast furnace (BF) slag production ranges from about 300 to 540 kg per tonne of pig or crude iron produced, whereas 15 to 200 kg per tonne of slag is generated per tonne of liquid steel. Lower grade ores yield much higher slag fractions, sometimes as high as onetonne of slag per tonne of pig iron produced. Steel slag output is approximately 20% by mass of the crude steel output. The information regarding plant wise capacity of iron and steel slag in the country is given in Table- 3.2.

TABLE-3.2: Plant wise Capacity of Iron and Steel Slag in the Country

Steel Plant	Capacity for granulation ('000 tpy)
Bhilai Steel Plant, Durg, Chhattisgarh	2675
Bokaro Steel Plant, Bokaro, Jharkhand	7884
Rourkela Steel Plant, Rourkela, Odisha	600
Durgapur Steel Plant, Durgapur, West Bengal	566
IISCO Steel Plant, Burnpur, West Bengal	400 kg/THM
Visvesvaraya Iron & Steel Plant, Bhadravati, Karnataka	400 kg/THM
Rashtriya Ispat Nigam Ltd, Visakhapatnam, Andhra Pradesh	1440
IDCOL Kalinga Iron Works Ltd,Barbil, Odisha	53
JSW Steel Ltd, Bellary, Karnataka Tata	N.A.2100
Steel Ltd, Jamshedpur, JharkhandVisa	175
Steel Ltd, Kalinganagar, Odisha Neelachal	-
Ispat Nigam Ltd	
Kalinganagar, OdishaSona Alloys Pvt. Ltd, Satara, Maharashtra	100.8

3.2.2 CHEMICAL COMPOSITION

The iron content is the major basic difference between blast furnace slag and steel slag. In BF slag, FeO is around 0.70%, whereas, in case of steel slag, total iron content varies from 16 to 25%. The chemical analysis of granulated BF slag and steel slag generated in steel plants is given in Table – 3.3.

3.3 LIME

Lime is collected from hardware shop. For this investigation hydrated lime is used which is ordinary pure lime, in white powder form, available in market. It has got the tendency of absorbing carbonic acid from the atmosphere in presence of water. Stabilization of soils with hydrated lime is applicable to far heavier clayey soils and is less suitable for granular materials and second it is used more widely as a construction expedient that is toprepare a soil for further treatment or to render a sufficient improvement to support construction traffic. The mineral composition of lime is given in Table-3.4.

TABLE-3.4: Mineral Composition of Lime

Mineral composition	Lime %
Silica	1.5
Alumina	1.5
Iron Oxide	2.0
Calcium Oxide	81.5
Magnesium Oxide	0.5
Carbon di Oxide	5
Sodium Oxide	0.5
Calcium carbonate	7
Sulphur	0.5

Fig 3.4 Lime

3.3.1 LIME STABILIZATION

Soil stabilization significantly changes the characteristics of a soil to produce long-term permanent strength and stability, particularly with respect to the action of water and frost Lime, either alone or in combination with other materials, can be used to treat a range of soil types. The mineralogical properties of the soils will determine their degree of reactivity with lime and the ultimate strength that the stabilized layers will develop. In general, fine- grained clay soils and a Plasticity Index greater than 10 are considered tobe good candidates for stabilization. Soils containing significant amounts of organic material (greater than about 1 percent) or sulphates (greater than 0.3 percent) may requireadditional lime and/or special construction procedures.

SUB-GRADES OR SUB-BASES: Lime can permanently stabilize fine-grained soil employed as a subgrade or sub base to create a layer with structural value in the pavement system. The treated soils may be in-place (subgrade) or borrow materials. Subgrade stabilization usually involves in-place "road mixing," and generally requires adding 3 to 6 percent lime by weight of the dry soil.

Fig 3.5 Lim

CHAPTER 4

CONCLUSION

It was found that with 5% of lime and 20% of steel slag, the mix yielded higher strength than that of conventional addition of 8% of lime. Also the problem of dumping of steel slag on ground has been solved.

1. Result showed that liquid limit of combination decreased by 38.67% than thatof black cotton soil which affects shear strength of soil.
2. The plastic limit for combination had been decreased by 30%
3. From standard proctor test it had been observed that Max.dry density increases from 1.25 gm/cm^3 to 1.80 gm/cm^3 i.e. increased by 44%.
4. CBR value for unsoaked condition is increased by 45% thereby decreasing thickness of sub base by 53.33%.
5. CBR value for soaked condition is increased by 55% which ensures safety in heavy rainfall region.
6. Based on direct shear test, the cohesion intercept decreases from 0.253 $kg/cm^2$to 0.20 kg/cm^2 and angle of internal friction (ø) which is decreased from 22.58˚ to 28.76˚.
7. The results of Unconfined Compression Test showed that shear strength increased by %
8. Cost analysis brings us to conclude that total cost of road is reduced by 16.25%