EVALUATION AND ANALYSIS OF SOIL STABILISATION WITH STEEL SLAG AND FLY ASH

DIWAKER KUDIAL[1], ANOOP SHARMA[2]

[1] PG student, Dept. of Civil Engineering, Sri Sai College ofEngineering and technology, Badhani, Pathankot, Punjab.

[2] Assistant Professor, Dept. of Civil Engineering, Sri Sai College ofEngineering and technology, Badhani, Pathankot, Punjab.

Abstract- Construction of structures over weak or soft soils possesses difficulties like differential settlements, poor strength and high compressibility. Clayey soils are poor in strength and they will result in poor pavement support and ultimately affects the pavement performance and its life period. Clayey soil also affects the design and construction of the pavement, resulting in higher cost of construction and early failure of pavement. Various techniques are available like soil stabilization, providing reinforcement etc. to improve load bearing capacity of soil. Soil stabilization is one of the modification technique used to improve the geotechnical properties of soil and has become the major practice in construction engineering which enables the effective utilization of industrial wastes as a stabilizer. This technique becomes more popular because of its easy availability and adaptability. Stabilization is a method of using the available waste materials for the production of low-cost roads construction. The present work describes a study carried out to check the improvements in the properties of Clayey soil with the addition of Fly ash and Steel slag. Fly ash and Steel slag are blended with unmodified soil in varying percentages to obtain the optimum percentage of admixture required for the soil stabilization. In this comparative study laboratory tests such as Atterberg's limit, Compaction test, CBR test and UCS test were carried out for both modified and unmodified clayey soil.

Key words: Standard proctor test, CBR test, UCS test.

1. INTRODUCTION

Just like other construction materials soil also has its own chemical and physical characteristics with regard its abilities on dealing with the loadings and other external forces. From all the other civil engineering fields soil engineering and soil mechanics is most complex field when it comes to factor of safety in design of sub-structures e.g. foundations, piles and other soil based constructions like sub-grade for pavements, embankments etc, requires a significantly a higher factor of safety in comparison of other construction materials . That's why the uncertainty in soil analysis and foundations designs is higher.

Therefore the geotechnical properties of the soil are analyzed before any major construction work, so as to ensure its stability against the load of the desired structures. The soil normally consists of rock particles, the air and the water are located in the empty spaces (called voids). It is essential to determine the geological properties of the soil that are influenced by the size of the particles, distribution of the grain size, form of the minerals present in the particles and the amount of that minerals. The engineering properties of the soil are generally are considered for carrying out the analysis of the site conditions and design of structures are the bulk unit weight, saturated unit weight, dry unit weight, permeability and porosity. Several laboratory tests are also conducted to check the suitability of the soil, including permeability, relative density, soil compaction characteristics and water content.

Sometimes the existing soil at a particular site may not be suitable for construction of structures due to its low bearing capacity, drainage problem and other problems like high compressibility etc. Clayey soil if found which is ineffective for the construction due to its low bearing capacity against the load due to its swell-shrink characteristics, there is the requirement to improve its characteristics by various ground improvement techniques or by changing the properties of such soils by using some industrial and agricultural wastes such as fly ash, rice husk etc having pozzolanic and fly ashitious properties, resulting in reduction of cost of improvement.

This study, particularly aims at testing the evaluation and analysis of soil stabilisation with steel slag and fly ash

LITERATURE REVIEW

Pawar et al. (2022) Using steel slag for soil stabilization is a modern application of steel slag. In this study the main approach is to investigate the effect of steel slag on the strength characteristics of clayey soil. Steel slag is blended with clayey soil in amounts of 10%, 15%, 20%, 25%, and 30% of dry weight. In our study, the optimum content of steel slag was determined by considering the maximum unconfined compressive strength. A series of further laboratory tests have been performed on this optimum mix to evaluate its suitability as a stabilizer material. The test was also conducted with conventional stabilizing material such as l0% fly ash and 5%cement with clayey soil and the obtained optimum mix was determined. Then the results are compared accordingly. In the above study, it has been observed that the addition of steel slag results in significant improvement in strength parameter as compared to fly ash but less strength in case of cement.

Joshi et al. (2018) The use of steel slag improves the bearing capacity and the strength of black cotton soil and indirectly it saves the construction cost. Different percentage of 5%, 10%, 15% and 20% steel slag have been used to stabilize the black cotton soil and to verify its suitability for using it as a construction material for road. The steel slag collected from Kalika Steel, Jalna and the black cotton soil collected form Himayatbaugh, Aurangabad. The overall program was conducted in 2 phases. In first phase all necessary test such as Atterberg limit, C.B.R and standard proctor compaction test on plain soil were being performed to analyse the maximum dry density (maximum dry density) and optimum moisture content (Optimum Moisture Content). And in 2 phase the black cotton soil was mixed with 5%, 10%, 15%, 20 % of steel slag.

Shalabi et al. (2017) High expansion and reduction in shear strength and foundation bearing capacity will take place due to the increase in water content of these soils. The engineering properties of these kinds of soils can be improved by using additives and chemical stabilizers. In this work, by-product steel slag was used to improve the engineering properties of clay soils. Lab and field experimental programs were developed to investigate the effect of adding different percentages of steel slag on plasticity, swelling, compressibility, shear strength, compaction, and California bearing ratio (CBR) of the treated materials. The results of tests on the clay soil showed that as steel slag content increased, the soil dry density, plasticity, swelling potential, and cohesion intercept decreased and the angle of internal friction increased.

For the CBR, the results of the tests showed an increase in the CBR value with the increase in slag content.

Hattamleh et al. (2017) This study intended to explore the effectiveness of using fine steel slag aggregate (FSSA) in improving the geotechnical properties of high plastic subgrade soil. First soil and fine steel slag mechanical and engineering properties were evaluating. Then 0%, 5%, 10%, 15%, 20%, and 25% dry weight of soil of fine steel slag (FSSA) were added and mixed into the prepared soil samples. The effectiveness of the FSSA was judged by the improvement in consistency limits, compaction, free swell, unconfined compression strength, and California bearing ratio (CBR). From the test results, it is observed that 20% FSSA additives will reduce plasticity index and free swell by 26.3% and 58.3%, respectively. Furthermore, 20% FSSA additives will increase the unconfined compressive strength, maximum dry density, and CBR value by 100%, 6.9%, and 154%. By conclusion FSSA had a positive effect on the geotechnical properties of the soil and it can be used as admixture in proving geotechnical characteristics of

subgrade soil, not only solving the waste disposal problem.

Rokade et al. (2017) Addition of nylon fibre along with fly ash to measure the change in the strength parameters of black cotton soil. The CBR of the soil was determined by conducting three series of tests. Tests were carried out on the BC soil mixed with varying percentage of fly ash, from 10% to 40% out of which 20% came out to be cptimum. Then, nylon fibre with aspect ratios (length/ diameter) 20, 40, 60 and 80 and fiber contents were varied from 0.25% to 1.5% with 0.25% interval, out of which 0.75% of fibre content is considered as optimum on the basis of MDD and maximum CBR value.

Anil Kumar Sharma et al., (2016) By mixing of fly ash and Ground Granulate Blast Furnace slag binder was formed. In the beginning the initial strength test was done on different ratios of fly ash and GGBS mixture. It was observed that 70:30 mix of fly ash and GGBS given the higher strength than individual fly ash or GGBS, even in the lack of any chemical activators. The mixing of binder without lime indicated the decrease in both liquid limit and plasticity index. When the binder content increases, the OMC decreases while MDD increases. In order to achieve the strength characteristics of every combination of soil binder samples, the tests were done on different curing periods that is 7,14 and 28 days. From this it can be found that strength increases up to 20% of the binder content and thereafter it decreases.

2. MATERIAL AND METHODOLOGY

3.1 SOIL

3 The soil required for the project is taken from an empty field in Jammu. The soil is alluvial in nature and contains high amounts of clay. The total quantity of soil collected is about 120 Kg.

4 All the soil that is used is sieved using 4.75mm sieve before start of the tests. The soil is oven dried for 24 hours before use to eliminate presence of any moisture in the soil. Firstly, Virgin soil without any admixture is tested for its properties and strength value and after that it is tested along with the addition of various proportions of Steel Slag and Fly Ash The various properties of virgin soil that is used are:

5 Table 3.1 Properties of soil used

S. No.	Properties	Result
1.	Liquid limit (%)	44
2.	Plastic limit (%)	24
3.	Plasticity Index (%)	20
4.	Specific Gravity	2.69
5.	Maximum Dry Density (KN/m³)	17.75
6.	Optimum Moisture Content (%)	14.5
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	3.12
9.	CBR (%) (Unsoaked)	5.3
9.	UCS (kN/m²)	210

S. No.	Properties of soil	Value
1	Specific gravity	2.68
2	Liquid Limit (%)	44
3	Plastic Limit (%)	24.7
4	Plastic Index (%)	19.3
5	Maximum Dry Density (kN/m³)	19.1
6	Optimum Moisture Content (%)	13.2

7	CBR (soaked) CBR (unsoaked)	10.30 10.55
8	Unconfined compressive strength 28 days(kN/m^3)	190

5.1 Nano Silica

In this study, amorphous nano-silica with a solid content of more than99% will applied.

(i) Nano Silica

(ii) Nano silica with soil

3.2 Steel Slag

Source of Steel Slag

Steel Slag used in this research work was collected from Ludhiana.

Table No 2. Chemical composition of Steel Slag

S.No	Compound	Composition (%)
1	Sio_2	10-19
2	Al_2O_3	1-3
3	FeO	10-40
4	CaO	40-52
5	MgO	5-10
6	MnO	5-8
7	P_2O_5	0.5-1

3.3 Fly Ash

Fly Ash that is used in this project is Known as Gujcon-CRF and is manufactured by Gujrat state fertilizers and chemicals limited which was collected from their warehouse in New Delhi.

The Classification of this Fly Ash is shown in table.

S. No	Compound	Class F Fly ash	Class C Fly ash
1.	Silica(Sio_2)	54.8	39.8
2.	Alumina (Al_2O_3)	25.9	16.9
3.	Calcium oxide (CaO)	8.6	24.2
4.	Iron oxide (Fe_2O_3)	6.9	5.8
5.	Magnesium oxide (MgO)	1.9	4.7
6.	Sulphur (S)	0.5	3.2

3.4 OBJECTIVES

The objectives of the research work are:

- To determine Atterberg's limit of the virgin soil and the different proportions of mix.
- To carry out Standard Proctor test and find out Maximum Dry Density (MDD) & Optimum Moisture Content (OMC) of virgin soil and the different proportions of mix.
- To find out California bearing ratio values at different proportions of Steel Slag and Fly Ash mix with clayey soil.
- To find out Unconfined Compresssion strength test values at Different proportions of Steel Slag and Fly Ash mix with clayey soil.

3.5 METHODOLOGY

The present project can serve as an effective method to utilize industrial wastes Steel Slag and Fly Ash in the construction of low cost rural roads and stabilize the subgrade of pavements where the soil is expansive in nature. These various tests needs to be carried out on samples selected for study:

1. Liquid Limit test and plastic limit test needed to be performed with the help of Cassegrande's Apparatus first on virgin soil and then the various proportions of the mix. The Plasticity Index of the Optimum Mix should be always less than that of virgin soil.

2. Standard Proctor Test is carried out to calculate Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of virgin soil which is then compared to MDD of mix proportions. The MDD of the optimum mix should always be higher than pure soil.

3. California bearing ratio test is conducted to calculate CBR Values at different proportions with material.

4. Unconfined compression strength test is conducted to calculate UCS Values at different proportions with material.

CHAPTER 4
RESULTS AND DISCUSSIONS

This chapter includes the complete details and information on all the different tests that were performed in this project. All the details about how the different materials of the project work are utilized and processed. The details about the soil, and all the mix proportions of soil with different materials. The results which include standard proctor test results, CBR test results, UCS test results and Atterbergs limits are shown in this chapter.

4.1 PROCESSING OF MATERIALS

The soil used in this project was collected from local soil deposits in Jammu. Then the soil is prepared by doing sieveing with 4.75mm sieve, the quantity retaining on 4.75 mm sieve is taken out of the sample soil and the soil passing 4.75mm sieve is over dried with a temperature of 105°C for 24 hours. All the lumps if present in the soil were cleared
with hammer.

4.2 TESTS CONDUCTED

Tests conducted in the laboratory for different objectives are as follows:

1. Liquid Limit Test (Casagrande's method)
2. Plastic Limite test (Thread method)
3. Standard Proctor test (OMC and MDD)
4. California Bearing Ratio test
5. Unconfined Compression strength test

4.3 MIX PROPORTIONS USED

Different proportions of different materials were used in the project work. Steel Slag was 20%,25% & 30% and Fly Ash used was 1.0%, 1.5%, & 2.0%.
Now, S=Soil, SS= Steel Slag, FA= Fly Ash

Table no. 4.1: Various Mix proportions of Soil, Steel Slag and Fly Ash

Sr. No.	Designation (S:SS:FA)
1	100:0:0
2	80:20:0
3	75:25:0
4	70:30:0
5	90:0:10
6	85:0:15
7	80:0:20
8	75:10:15
9	70:15:15
10	65:20:15

4.4 EXPERIMENTAL RESULTS

All the results of the experiments that were performed in the laboratory are shown in this section. The major experiments performed were Standard Proctor Test, California Bearing Ratio Test (CBR) and Unconfined Compression Test (UCS).

4.5 STANDARD PROCTOR TEST

4.5.1 Untreated Soil and Steel Slag Mix

Table 4.2: Results of OMC and MDD for Untreated soil and SS mix

SOIL:SS	MDD (kN/m³)	OMC (%)
100:0	17.75	14.5
80:20	18.04	14.10
75:25	18.78	13.5
70:30	18.96	13.2

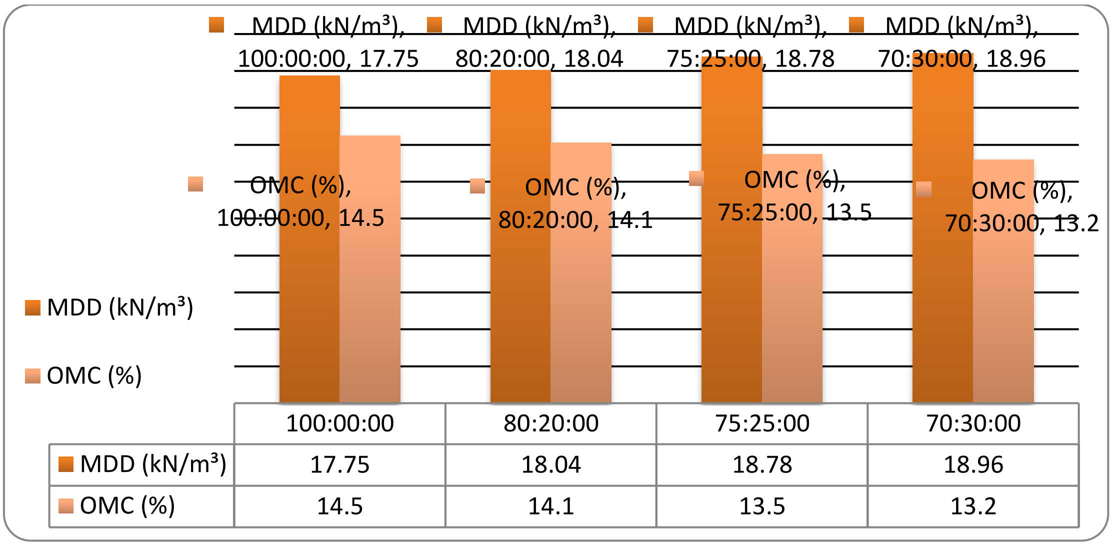


Fig:-1 Variations b/w MDD and OMC of Steel Slag & soil with different proportions

4.5.2 CLAYEY SOIL AND FLY ASH MIXES

Table no. 4.3: Results of OMC and MDD for mix proportions of Soil and Fly Ash

SOIL:FA	MDD (kN/m³)	OMC (%)
100:0:0	17.75	14.5
90:10	16.90	15.40
85:15	15.85	16.30
80:20	16.12	15.77

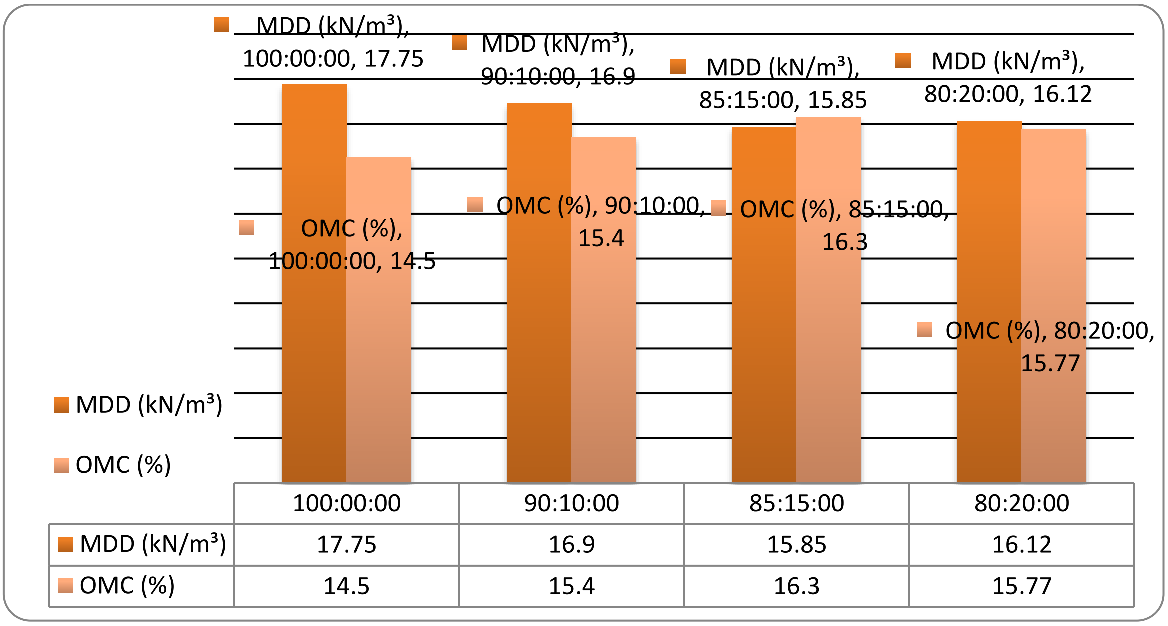


Fig:-2 Variations b/w MDD and OMC of Fly Ash & soil with different proportions

4.5.3 CLAYEY SOIL-STEEL SLAG AND FLY ASH MIXES

Table no. 4.4: Results of OMC and MDD for mix proportions of Soil, Steel Slag and Fly Ash

SOIL:SS:FA	MDD (kN/m³)	OMC (%)
100:0:0	17.75	14.5
75:10:15	16.80	15.02
70:15:15	17.80	14.40
65:20:15	18.26	13.7

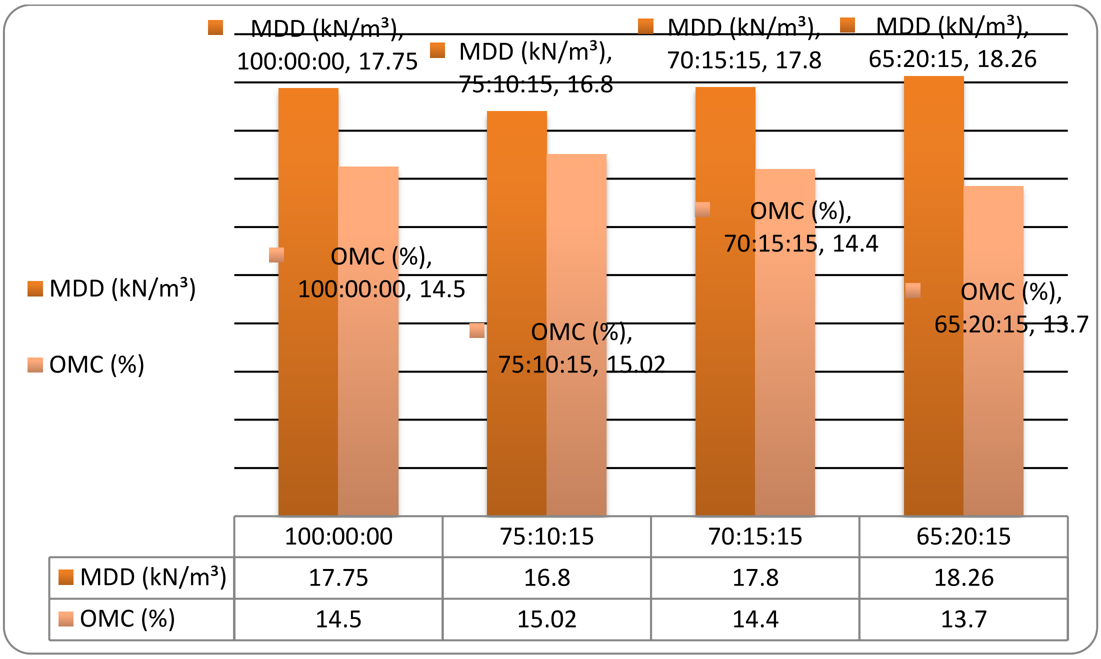


Fig:-3 variations b/w MDD and OMC of Steel Slag, Fly Ash & soil with different proportions

4.6 Unconfined Compression Strength Test

Table 4.5: Results of UCS Test of untreated soil

Clayey Soil	Curing Period (Days)	UCS (kN/m^2)
100 : 00	7	210

Table 4.6: Results of UCS of Steel Slag

Clayey Soil : SS	Curing Period (Days)	UCS (kN/m^2)
100 : 00	7	210
80:20:0	7	383
75:25:0	7	442
70:30:0	7	521

Fig:-4 UCS Values of Clayey soil And Steel Slag

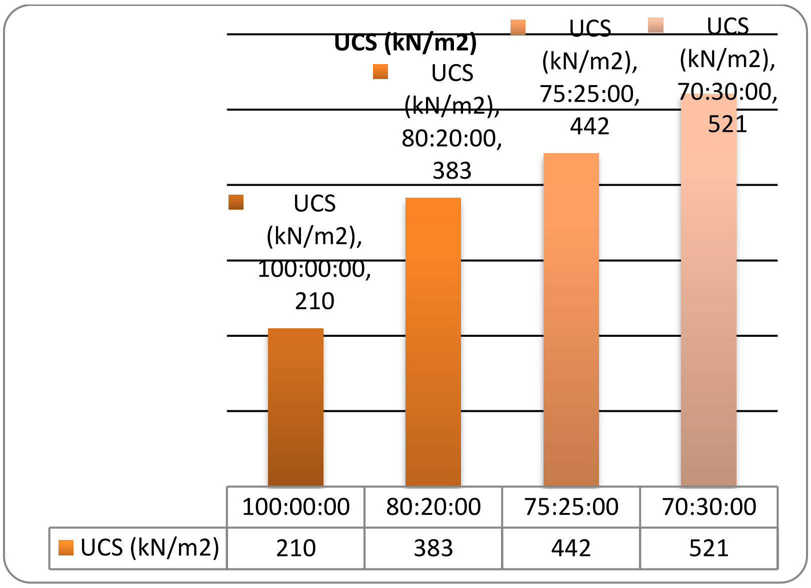


Table 4.7: Results of UCS of Fly Ash

Clayey Soil : FA	Curing Period (Days)	UCS (kN/m^2)
100 : 00	7	210
90:10	7	369
85:15	7	530
80:20	7	480

Fig:-5 UCS Value of Clayey soil And Fly Ash

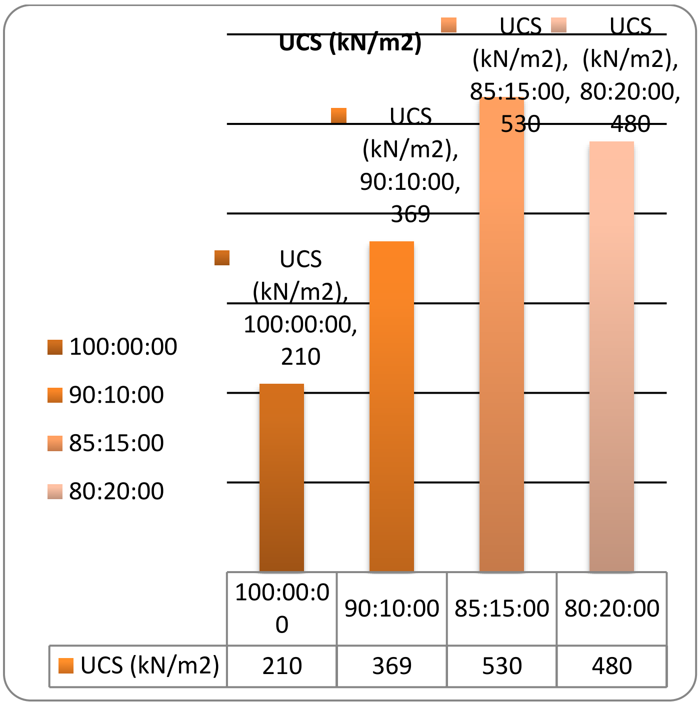
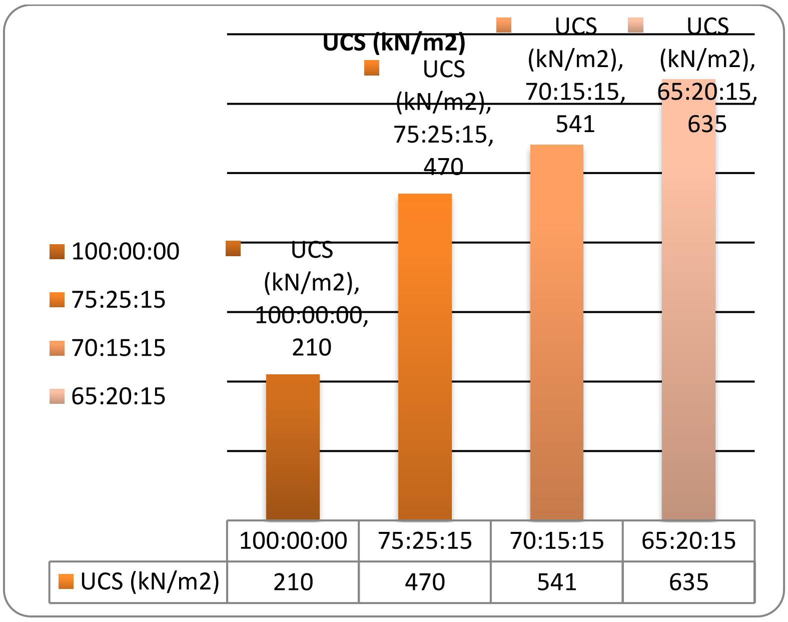


Table 4.8: Results of UCS of Steel Slag and Fly Ash Mix with Soil

Clayey Soil :SS: FA	Curing Period (Days)	UCS (kN/m²)
100:00:00	7	210
75:25:15	7	470
70:15:15	7	541
65:20:15	7	635

Fig:-6 UCS Value of Clayey soil of Steel Slag and Fly Ash



4.7 California Bearing Ratio Test

Table 4.9: Results of CBR value for untreated soil sample.

Clayey soil	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	3.12	5.3

Table 4.10: Results of CBR of Steel Slag

Mix Proportions (CS:SS)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	3.12	5.3
80:20:0	4.10	6.20
75:25:0	4.93	7.8
70:30:0	5.30	8.4

Fig:-7 CBR Percentages of Clayey soil And Steel Slag

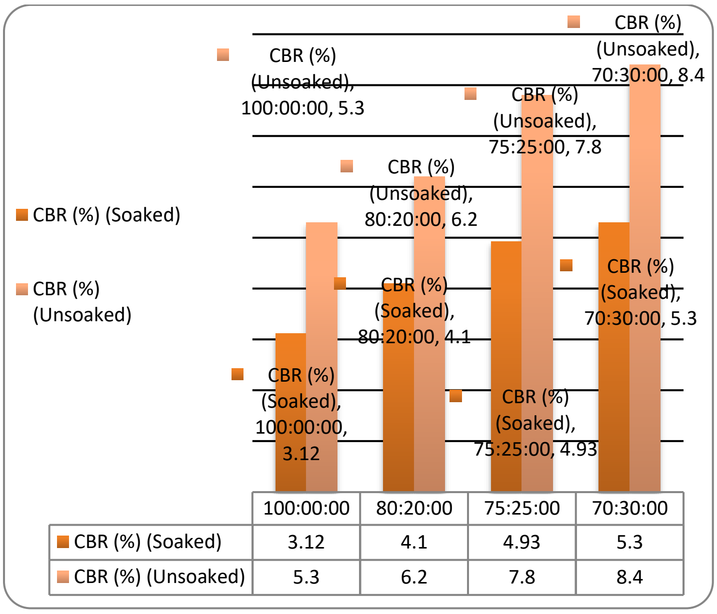
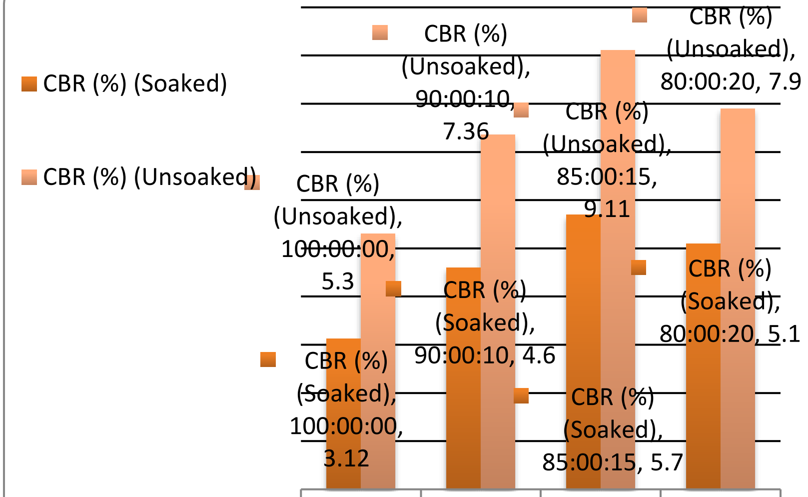


Table 4.11: Results of Soil and Fly Ash

Mix Proportions (CS:FA)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	3.12	5.3
90:00:10	4.6	7.36
85:00:15	5.7	9.11
80:00:20	5.1	7.9

Fig:-8 CBR Percentages of Clayey soil And Fly Ash

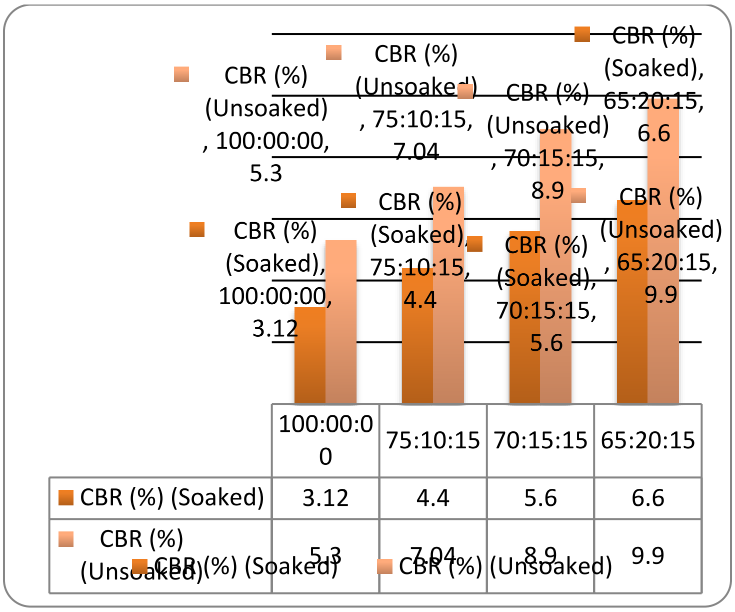


	100:00:00	90:00:10	85:00:15	80:00:20
CBR (%) (Soaked)	3.12	4.6	5.7	5.1
CBR (%) (Unsoaked)	5.3	7.36	9.11	7.9

Table 4.12: Results of CBR of Steel Slag and Fly Ash Mix with Soil

Mix Proportions (CS:SS:FA)	**CBR (%) (Soaked)**	**CBR (%) (Unsoaked)**
100:00:00	3.12	5.3
75:10:15	4.4	7.04
70:15:15	5.6	8.9
65:20:15	6.6	9.9

Fig:-9 CBR Percentages of Clayey soil, Steel Slag and Fly Ash



4.8 DISCUSSIONS

4.8.1 MODIFIED PROCTOR TEST:

- An decrease of OMC from 14.5 to 13.2% and increase of M.D.D. from 17.75 to 18.96% when the percentages of Steel Slag are used as 20%, 25% and 30% respectively.
- There is an also increase of OMC from 14.5 to 15.77% and decrease of MDD from 17.75 to 16.12% when the percentages of Fly Ash are used as 10%, 15% and 20% respectively.
- There is an also increase of MDD from 17.75 to 18.26% and decrease of OMC from 14.5 to 13.7% when the percentages of Steel Slag vary from 10%, 15% and 20% and Fly Ash is fixed at 15%.

- There is a decrease in MDD of modified soil with increase in percentage of Fly ash, due to the lower specific gravity of Fly ash as compared to the unmodified soil and OMC of modified soil is increase as the percentages of Fly ash increases, due to the increase in cohesive property of soil.
- With Fly Ash kept constant at 15% MDD increases with an addition of Steel Slag content in soil and Fly Ash mix. The reason behind of such behavior is high percentages of reduction in voids affect the density of soil+ Steel slag mixes.

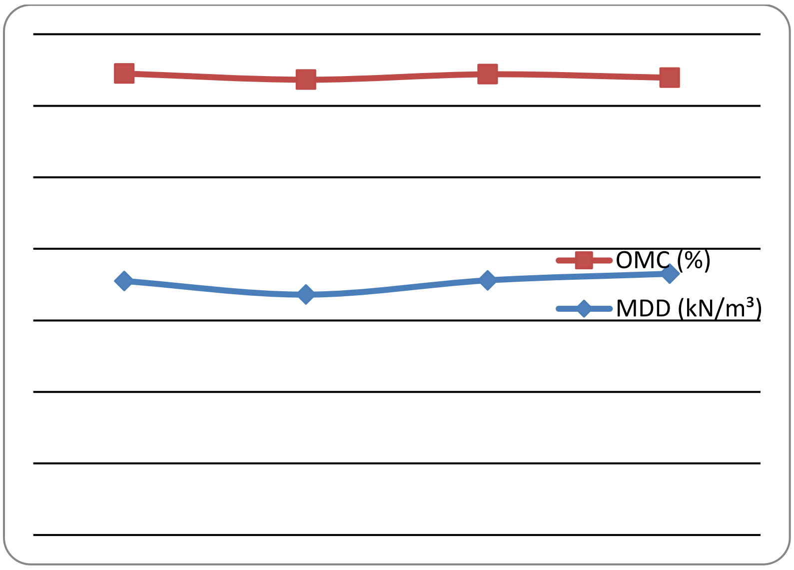


Fig:-10 Variations b/w MDD and OMC values of Steel Slag mix with Fly Ash

4.8.2 CBR TEST:

- The CBR value of untreated soil is 3.12 and it increases to 1.69 times with addition of 30% Steel Slag when observed in soaked conditions. This enhancement is because of binding action of Steel Slag.
- The CBR value of untreated soil is 3.12 and it increase to 2.11 times when Fly Ash 15% and Steel Slag 20% is added to untreated soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

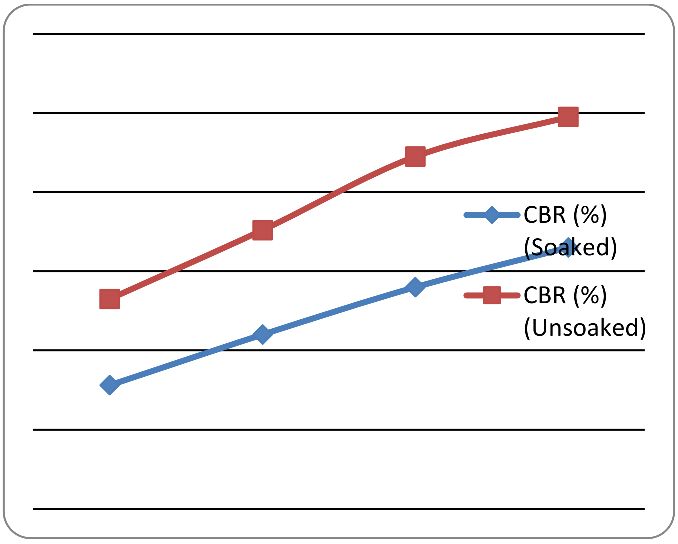


Fig:-11 Variations b/w CBR Values of Steel Slag mix with Fly Ash

4.8.3 UCS TEST:

- The UCS values of untreated soil also improve considerably with expansion of Steel Slag 20% and Fly Ash 15%. The value increases from 210 kN/m² to 635 kN/m² with addition of Steel Slag and Fly Ash.
- The reason behind of this when Steel Slag and Fly Ash comes in contact with water, pozzolanic reactions takes place during the curing period.

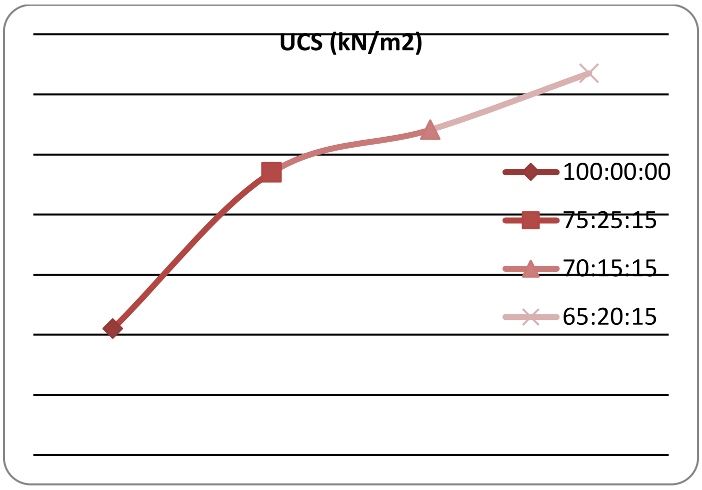


Fig:-12 Variations b/w UCS Values of Steel Slag mix with Fly Ash

CHAPTER 5

CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. From this study it is concluded that Steel Slag is waste product from industries that can be used as stabilizers to clay soil and this would help to solve the conventional problem of disposal of them. .
2. The optimum value of Fly Ash is used for this work was 15 % because of the optimum value of C.B.R. is found at 15% of Fly Ash when added to soil.
3. The C.B.R value increases with increase of Steel Slag along with fixed quantity of Fly Ash. It increased 2.11 times from the untreated soil.
4. The optimum value of Steel Slag and Fly Ash required for soil stabilization is 20 % and 15 % by weight of soil respectively.
5. Unconfined compressive strength increases with increase of quantity of Steel Slag and with fixed quantity of Fly Ash. The value of unconfined compressive strength is increased 3.02 times from the untreated soil.

Addition of Steel Slag and Fly Ash stabilizer makes the soil mixes durable, low cost and effective for soil improvement. If these two materials are easily available near to the site.

5.2 FUTURE SCOPE:

1. In this study, clayey soil is used for the work. Other soil can be used in the place of clayey soil.
2. In this study Standard proctor test , C.B.R. test and U.C.S. test are performed. Other tests can be used for further work like Direct shear test, Triaxial test, Durability test and Permeability test.
3. U.C.S. test is conducted with one week of curing period; curing period of work can be increased.
4. In place of Fly Ash, other binder material can be used with Steel Slag. Different types of materials can also be used with Steel Slag.
5. Different proportions of Steel Slag and Fly Ash can be used for getting better results.

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