Evaluating the Swelling Potential Tests With CBR For Soil Stabilization using Fly Ash and Steel Slag

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ABSTARCT

Steelmaking and power plant operations in Indiana generate massive annual amounts of metal slag, blast furnace slag, and fly ash. Such surplus firm by-products are kept in storage facilities until being disposed of at disposal facilities. Steel slag, fly ash, and blast furnace slag may occasionally be a more cost-effective substitute for lime stabilization in road packages that may also include sub grade stabilization operations. These kinds of packages utilize a lot of unused business by-products, which reduces the need for additional disposal facilities and promotes the preservation of natural resources, both of which are advantageous.

Those objectives were met by characterizing in situ clayey soils, which were collected via a potential implementation web page and subjected to a series of laboratory examinations that safeguarded unique gravity, grain length distribution, Atterberg limits, compaction, and unconfined compressive energy. In order to be employed in sub grade stabilization programmers, two types of metallic slag combinations were evaluated: I metallic slag and Class-C fly ash combinations; and (ii) metallic slag and blast furnace slag combinations. Using compaction and unconfined compression tests, researchers determined the mechanical properties of soil-five percent metallic slag-5 percent Class-C fly ash, soil-7 percent steel slag-3 percent Class-C fly ash, soil-8 percent metal slag-2 percent Class-C fly ash, soil-eight percent metal slag-2 percent Class-C fly, and soil-7 percent steel slag-3 percent blast furnace slag mixtures. Swelling tests with CBR were also carried out in order to evaluate the swelling potential of the combinations.

Key Words: Steel slag, fly ash, sustainability, subgrade stabilization, implementation

INTRODUCTION

1.1. Soil Stabilization

Each year in Indiana, a number of enterprises generate a sizable amount of recyclable materials from the sale of their goods, including metallic slag, blast furnace slag, and fly ash. In the steel sector, this is especially true. These waste items from industry can be repurposed to create useful civil engineering solutions. The use of recyclable materials in geotechnical projects has several advantages. A cost-effective solution that might help you buy herbal sources is to replace traditional ingredients with industrial by-products. Additionally, land filling requires less room and costs less money.

The American Coal Ash Association (ACAA) estimates that the U.S. Produced 130 million heaps of coal combustion merchandise (CCBP's) in 2010 (ACAA 2010). Of this overall manufacturing, only 43 percent was used beneficially, even as nearly seventy five MT (million metric tons) were disposed of in landfills. Large amounts of fly ash are still being disposed of in landfills or stored for future use. Similarly, the iron and steelmaking industries inside the U.S. Generate 9-14 MT of blast furnace slag and 10-15 MT of metallic slag each year. Typically, the amount of blast furnace slag generated each yr from the ironmaking tactics within the U.S. Is absolutely applied in beneficial applications. However, this is not the case for metallic slag. In 2009, the steel slag era after metal recovery become anticipated to be 6-9 MT inside the U.S. And 120-one hundred eighty MT in the global (Oss 2009, USGS 2010). The steel slag produced within the U.S. Is used as mixture for street and pavement production (~50 to 70%) and in other miscellaneous packages (~10 to fifteen%).

A portion of the closing steel slag that cannot be reutilized (between 15 and 40 percent) is stored in steel flora before being sent to slag disposal locations.

This metal slag further we can used to stabilities the vulnerable bearing potential soils like excessive plasticity clayee soils and black cotton soils like expansive soils and laterite soils.

In Indiana, numerous metal flora and power flora are in continuous production, producing blast furnace slag, metal slag and fly ash as through-merchandise on a every day foundation. Use of metal slag and fly ash in geotechnical packages, along with subgrade stabilization, will assist with the recycling of big quantities of those underutilized industrial by means of-merchandise. Beneficial use of fly ash and metal slag in avenue stabilization initiatives will now not handiest create a value-powerful alternative to lime stabilization, but also lessen the need for brand new disposal web sites. With successful implementation of those recyclable materials in geotechnical programs, the Indiana Department of Transportation (INDOT) has the opportunity to sell comparable sustainable packages inside the destiny.

Testing Materials and Representative Sampling

The following testing materials were used in this research:

1. Clayey soil
2. Steel Slag (i.e.; electric-arc-furnace steel slag fines)
3. Blast furnace slag (i.e.; blast furnace slag fines)
4. Class-C Fly ash

The implementation assignment becomes positioned in Crown Point, Indiana (see Figure 2.1). Clayey soil samples were collected from the crossroads of I-65 and 109th Avenue in the southwest (SW) and northwest (NW) quadrants (see Figure 2.2).

Edward C. Levy Co., which is a slag-processer organization with many places within the U.S., supplied the samples of metallic slag and blast furnace slag used on this studies. Northern Indiana Public Service Company (NIPSCO) furnished the Class-C fly ash.

The water content of the clayey soil samples at their natural nation become very high considering that they had been accrued after a blizzard. Initially, the soil samples had been air-dried for at the very least 24 hours. The drying technique turned into facilitated by means of using a ventilator. Clayey soils have a tendency to form clusters whilst dried. The big dried clusters of soil have been first beaten with a plastic hammer before intending with the trying out. Blast furnace slag, metallic slag and Class-C fly ash samples have been stored in air-tight buckets. Whenever a smaller component of these samples changed into required for testing, a pattern splitter changed into used to reap consultant samples, as shown in Figure.

Figure. 1 Soil splitter used to obtain representative samples

III. DESIGN OF MIXTURES FOR SUBGRADE STABILIZATION

EXPERIMEENTAL INVESTIGATION

the results of laboratory tests performed on the in situ soil, the soil-metal slag-Class-C fly ash combo, and the soil-metal slag-blast furnace slag combo have been presented. Prior to stabilisation, a number of tests were performed on the in situ clayey soil to determine its qualities and determine whether it could be stabilised. Special gravity, grain length distribution, Atterberg limits, compaction, and unconfined compressive strength were all determined in the laboratory after the in situ clayey soil was sampled. In order to determine whether or not metal slag combinations could be used as a potential replacement for lime in subgrade stabilization programmes, two types of metal slag combinations were investigated: 1) metallic slag-Class C fly ash combinations, and 2) metallic slag-blast furnace slag combinations. A determination of the mechanical houses of soil-steel slag–Class C fly ash and soil–metallic slag–blast furnace slag combination by compaction and unconfined compression tests was made for the mixes of soil-steel slag–Class C fly ash. CBR swelling tests have also been carried out in order to determine the possible swelling potential of the combination drugs and combinations. The following key parts of this Chapter provide an overview of the consequences of the tests:

1. In situ soil
2. Soil-steel slag-fly ash mixtures
3. Soil-steel slag-blast furnace slag mixture

Long-Term Swelling Behaviour of the Soil-Steel Slag- Blast Furnace Slag Mixture

Two lengthy-time period swelling tests have been performed at the soil-7% steel slag-3% blast furnace slag combination. The soil-metallic slag-blast furnace slag samples have been compacted at a moisture content of about 16.7% to a hundred% relative compaction in CBR molds. The one-dimensional swelling of the soil-metal slag-blast furnace slag combination become monitored for more than three months at room temperature. Figure indicates the time vs. Volumetric pressure curves acquired from the lengthy-time period swelling exams carried out at the soil-7% metallic slag-3% blast furnace mixtures together with that from the take a look at executed at the in situ clayey soil.

One of the compacted soil-7% steel slag-three% blast furnace slag mixture reached a most swelling strain of 0.052% after about 6 days of soaking. The swelling traces measured for the second pattern had been negligible (i.E.; much less than 0.01%) during the take a look at period. The swelling of the soil-7% metal slag-3% blast furnace slag pattern stabilized faster and at a good deal smaller most swelling lines than the in situ clayey soil. Figure certainly indicates that mixing of soil with metal slag-blast furnace slag mixture allows in reducing considerably the swelling of the clayey soil examined in this look at implementation assignment. The price and availability of each mixture tested on this observe within the region of the proposed implementation website online changed into also considered on this decision.

These results suggest the incidence of stronger cementations reactions inside the soil-metallic slag-Class-C fly ash aggregate. The maximum swelling strains of the soil-7% metallic slag-3% Class-C fly ash and soil-7% steel slag-3% blast furnace slag combinations were 0. Thirteen % and zero.052%, respectively, primarily based on the lengthy-time period swelling exams. These outcomes imply that the soil-7% steel slag-3% blast furnace slag turned into relatively more powerful in stabilizing the in situ clayey soil. Nonetheless, the lengthy-time period swelling exams effects showed that both combinations had been powerful in lowering the swelling of the in situ clayey soil to negligible tiers.

Based on the laboratory tests executed on diverse mixtures, soil-steel slag-Class-C fly ash combos had been observed to be suitable for subgrade programs. Since Class-C fly ash is extra costly than steel slag, minimizing the proportion of Class-C fly ash inside the mixture turned into suitable on the way to provide a price-effective alternative to lime. The soil-7% metallic slag-three% Class-C fly ash mixture changed into decided on as the maximum suitable subgrade cloth for the implementation mission.

The soil-metal slag-Class-C fly ash aggregate decided on based totally at the laboratory check results executed on this study turned into implemented as a subgrade fabric in an INDOT challenge. The implementation challenge for the soil-metallic slag-Class-C fly ash combination became executed at the intersection of 109th Avenue and I-sixty-five, close to Crown Point, Indiana.

The metal slag-Class-C fly ash combination become used to stabilize the in situ subgrade soil of a few sections of the I-65 ramps on the intersection of 109th Avenue and I-65. This bankruptcy explains the info of the implementation project and the development series in addition to the sector first-rate manipulate assessments achieved at the stabilized subgrade soils.

FIELD IMPLEMENTATION OF SOIL STEEL SLAG CLASS C FLY ASH MIXTURE AS A SUB GRADE MATERIAL

IMPLEMENTATION PROJECT

Based on the effects of the laboratory exams performed on various combos, the 7% metallic slag-three% Class-C fly ash mixture became selected because the maximum suitable and value-powerful mixture to stabilize the in situ soils on the proposed implementation website. The implementation venture for the soil-metallic slag-fly ash mixture was accomplished on the intersection of 109th Avenue and I-sixty-five. As explained in Chapter 2, the soil samples used inside the laboratory assessments had been collected from the SW and NW quadrants of the intersection of 109th Avenue and I-sixty-five. The steel slag-Class-C fly ash combination became used to stabilize the in-situ subgrade soils of some sections of the ramps in NW and SW of the 109th Avenue and I-65 intersection. The following sections provide details of the construction sequence and preferred hints for subgrade stabilization.

CONSTRUCTION GUIDELINES FOR SUBGRADE STABILIZATION

Based on the consequences of the laboratory check finished on the compacted soil-7% steel slag-3% Class-C fly ash aggregate, the subsequent hints have been proposed for the subgrade stabilization field work:

•The subgrade stabilization should be completed by way of in-vicinity mixing of the in situ soils with the pre-blended 7% metal slag-three% Class-C fly ash aggregate;

•The amount of metal slag-Class-C fly ash aggregate must be maintained at at least 10% (by using weight) of dry mass of soil in all of the sections dealt with with the 7 % steel slag-three% Class-C fly ash combination.

•The impact of mellowing on the residences of the soil-7% metal slag-three% Class-C fly ash aggregate became no longer considered, and consequently, the values of the unconfined compressive strength supplied in this report are for samples compacted right after mixing. Therefore, compaction of the mixture inside the discipline need to start without delay and be completed inside 3 to four hours after mixing;

•The soil-7% metal slag-3% Class-C fly ash aggregate shall be compacted inside a moisture content range of 14 to 18%. A moisture content material of one to a few% above the foremost moisture content material is ultimate to make certain that the unfastened lime gift within the Class-C fly ash and metallic slag has sufficient water for finishing touch of the cementitious reactions.

•If the dry steel slag-Class-C fly ash combination is mixed with the in situ clayey soil with out water spraying or aeration, the moisture content of the in situ clayey soil have to be inside 16-19% before the begin of the stabilization paintings in order for the soil-steel slag-Class-C fly ash combination to gain an most beneficial moisture content within the range of 14-18%;

•A minimum relative compaction of 100% need to be targeted for the stabilized subgrade soils (i.E.; soil-7% steel slag-three% Class-C fly ash combination). The maximum dry unit weight and moisture content of the compacted soil-7% metallic slag-3% Class-C fly ash mixture need to be within the ranges of 17. Nine-18.1 kN/m3 and 14-18%, respectively, to obtain 100% relative compaction;

•Construction traffic or gadget shall not traffic on the treated soil within seventy-two hours after compaction.

4.4 SUBGRADE STABILIZATION CONSTRUCTION SEQUENCE

As defined inside the preceding chapters, the subgrade soils in some sections of the NW and SW ramps on the intersection of 109th Avenue and I-65 have been stabilized with a 7% metallic slag-3% Class-C fly ash combination. Figure 4.1 shows a picture of the soil within the SW ramp earlier than stabilization. The following steps, which can be described in detail in the next section, had been followed during the stabilization paintings:

Spreading

Mixing and Water Spraying
Compaction

4.4.1 SPREADING

The pre-combined 7% metal slag-3% Class-C fly ash aggregate was transported to the website online the use of a self-unloading bulk tanker truck, which is also called a spreader truck. Figure four.2 indicates the spreader truck used on this demonstration venture. The pre-mixed 7% metallic slag-3% Class-C fly ash combination changed into spread uniformly at the subgrade soil using the spreader truck. Figure four. Three suggests the spreading of the metal slag-Class-C fly ash mixture at the in-situ soil. Figure four.4 is a photograph of a section of the ramp after the initial spreading operation.

Figure 10. In situ subgrade soil of the SW ramp before soil stabilization

Figure 11 Spreader truck

Figure 12. Spreading of the steel slag-Class-C fly ash mixture on the subgrade soil

V. RESULT ANALYSIS AND DISCUSSION

5.1 Properties of clay visual characteristics of soil:

The following properties observed from visual classification in dry condition
Colour - Black colour
Odour - odour of decaying vegetation
Texture – Fine grained
To study the behaviour of clay when it was untreated, treated (with binders and reinforcement techniques) for the modal flexible pavements and also for the foundation soil beds.
The following tests for conducting as per IS code of practice:
Grain size distribution
Index properties – Liquid limit -Plastic limit
Shrinkage limit
3 Strength test - California bearing ratio

5.2 Visual characteristics of soil:

The following properties were observed from Visual classification in dry condition.
Colour - Black colour
Odour - odour of decaying vegetation
Texture - Fine grained
Dry strength - medium
Plasticity - highly plastic
Classification - highly compressive clay (CH)

Specific gravity	2.60
Percent finer (%)	65.92
IS Classification	CI
Liquid limit (%)	47.70
Plastic limit (%)	25.65

Plasticity index (%)	22.05
OMC (%)	15.80
MDD (kN/m³)	18.04
CBR Soaked (%)	1.82
CBR Unsoaked (%)	3.46

Table 2.1: Properties of Unmodified Soil

5.3 Steel slag and Fly ash

Stainless steel slag was procured from Concast Ferro Inc., Dusipeta, Srikakulam district, Andhra Pradesh, for use in this research. It is mostly composed of sand-sized particles (95 percent).The fly ash used in the study is obtained from the Sri Vishnu Sai Saravana Enterprises, Visakhapatnam, Andhra Pradesh. The grade of fly ash used in the experimental work is “F” grade. Fly ash consists of Sand size particles (27%) and Fine size particles of (73%).

The proportions of Steel slag and Fly ash utilised in the study with the unaltered soil were 0%, 10%, 20%, 30%, 40%, and 50%. The following tests were carried out on soil samples containing various amounts of Steel slag and Fly ash. The liquid and plastic limit tests were carried out in accordance with IS: 2720 (Part 5) - 1995. IS: 2720(Part 7)-1997 was used to conduct a standard compaction test. The CBR tests were performed at OMC and MDD in accordance with IS: 2720 (Part 16) – 1997.

5.4 Atterberg’s limit test:

(Soil+ Admixtures) in (%)	Steel slag		Flyash	
	L.L	P.I	L.L	P.I
100+0	47.70	47.70	22.05	22.05
90+10	45.80	46.90	18.96	21.16
80+20	43.30	45.50	16.10	20.36
70+30	40.70	42.80	12.77	18.43
60+40	38.90	40.70	10.51	16.75
50+50	36.75	39.5	7.55	16.39

Table 3.1: Effects of Steel Slag and Fly Ash on L.L and P.I

From the Fig.3.1 & Fig.3.2, it is observed that as the percentage of Steel slag and fly ash increases, there is a marked reduction in liquid limit and plasticity index of clay that was tested.

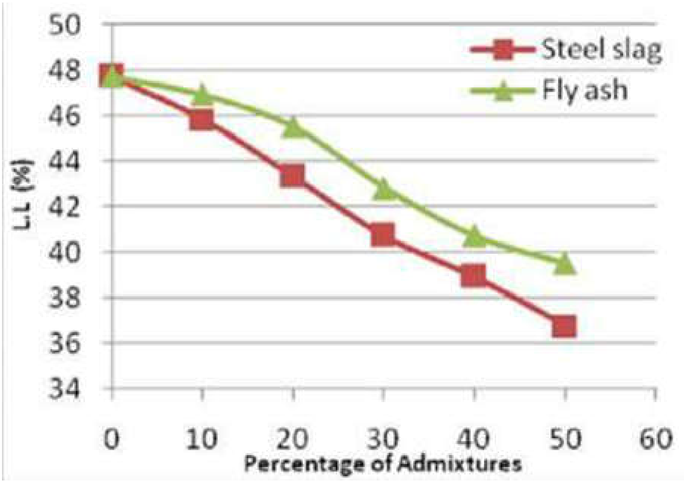

Fig.3.1: Influence of Steel Slag and Fly Ash on Liquid Limit

The addition of the Steel slag to the unmodified soil reduces the clay content material and consequently increases the proportion of coarser debris, in flip lowering the Liquid restrict and Plasticity index of soil. The liquid restrict of the modified soil at 50% addition of fly ash and Steel slag is decreased to 36. Seventy five% and 39. Five% respectively.

Plasticity characteristics of the soil pattern are gradually lowering with increase in the share of Steel slag and fly ash. The plasticity index of modified soil is reduced to 16.39% and 7.Fifty five% respectively with addition of (50%) of Fly ash and (50%) metal slag.

It may be seen that there may be a lower in OMC and growth in MDD value with boom in percent of Steel slag.

High percentages of discount in voids affect the density of soil+ Steel slag mixes.

It is located that the clay pattern when changed with 50% of Steel slag yielded maximum dry density of 19.75kN/m³ at superior moisture content material of 14.50%.

In case of Fly ash it's miles located that there may be a lower in MDD of modified soil with boom in percentage of Fly ash, because of the lower precise gravity of Fly ash compared to the unmodified soil and OMC of modified soil is increase as the percentages of Fly ash will increase, because of the boom in cohesive assets of soil.

5.5 Compaction test:

(Soil+ Admixtures) in (%)	Steel slag		Flyash	
	OMC (%)	MDD (kN/m³)	OMC (%)	MDD (kN/m³)
100+0	15.80	18.04	15.80	18.04
90+10	14.2	18.38	17.5	16.85
80+20	12.9	18.68	18.8	16.02
70+30	11.4	19.10	20.6	15.2
60+40	10.05	19.70	21.2	14.8
50+50	9.6	19.75	21.4	14.50

Table 3.2: Effects of Steel Slag and Fly Ash on OMC and MDD

The variations of compaction characteristics such as OMC and MDD for the clay treated with fly ash and Steel slag are presented in Fig.3.3 & Fig.3.4.

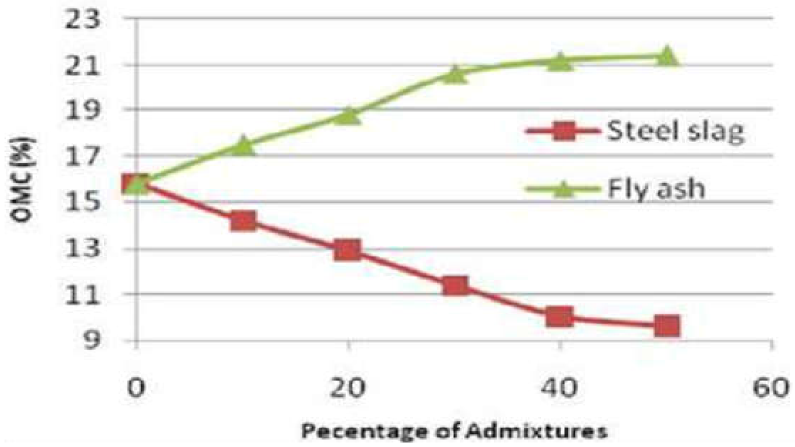

Fig.3.3: Influence of Steel Slag and Fly Ash on OMC

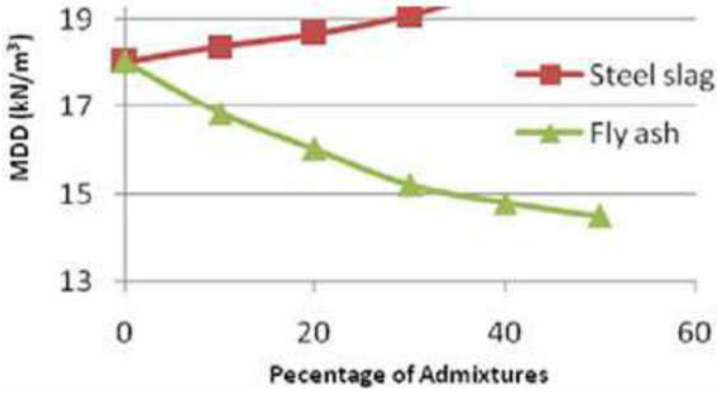

Fig.3.4: Influence of Steel Slag and Fly Ash on MDD

5.6 CBR TEST:

Soaked CBR test consequences of Steel slag and Fly ash handled soil are presented in Fig.Three.Five. From this plot, it's far located that as the share admixture along with Steel slag will increase, the CBR value also growing in an affordable trend. The optimal price of CBR is found at 30% of fly ash and 50% of Steel slag. The CBR value of modified soil increases from 1.82% to five.20% with 50% addition of Steel slag and for 30% fly ash CBR is extended to a few.01%.

(Soil+ Admixtures) in (%)	Steel slag	Flyash
100+0	1.82	1.82
90+10	2.91	2
80+20	4.02	2.64
70+30	4.83	3.01
60+40	5.10	2.64
50+50	5.20	2.3

Table 3.3: Effects of Steel Slag and Fly Ash on Soaked CBR

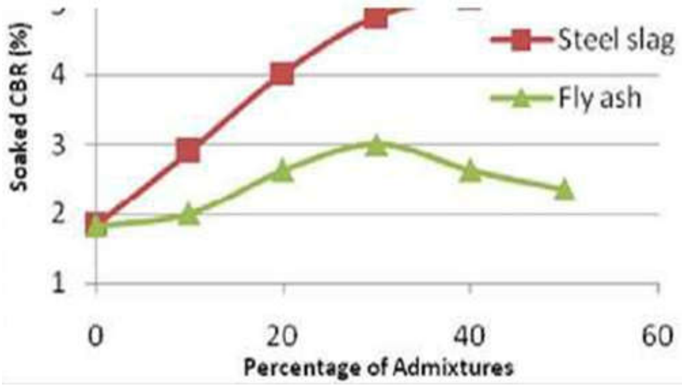

Fig.3.5: Influence of Steel Slag and Fly Ash on Soaked CBR

(Soil+ Admixtures) in (%)	Steel slag	Fly ash
100+0	3.46	3.46
90+10	4.52	3.82
80+20	5.78	4.34
70+30	6.74	5.02
60+40	7.55	4.02
50+50	7.7	3.44

Table 3.4: Effects of Steel Slag and Fly Ash on Unsoaked CBR

The optimum value of CBR is found at 30% of fly ash and 50% of Steel slag. The CBR value of modified soil increases from 3.46% to 7.70% with 50% addition of Steel slag and for 30% fly ash CBR increased to 5.02%.

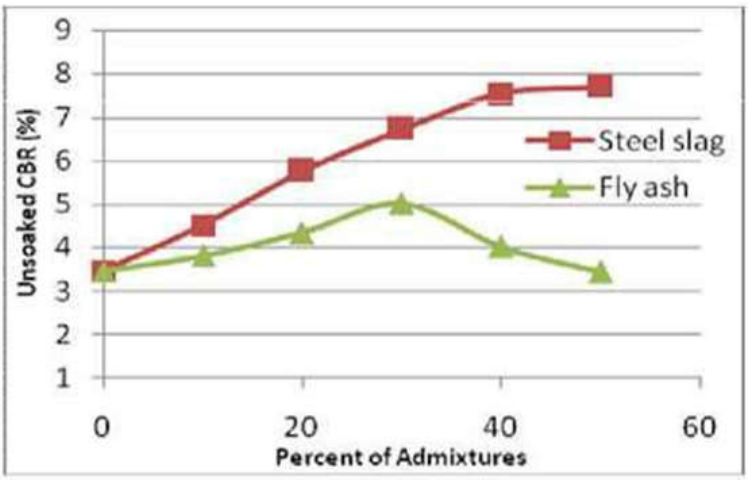

Fig.3.6: Influence of Steel Slag and Fly Ash on Unsoaked CBR

Unsoaked CBR test results of Steel slag and Fly ash treated soil are presented in Figure 3.6. The most appropriate fee of CBR is located at 30% of fly ash and 50% of Steel slag. The CBR fee of changed soil increases from 3.Forty six% to 7.70% with 50% addition of Steel slag and for 30% fly ash CBR expanded to 5.02%.

CONCLUSIONS

The following conclusions have been made in light of the investigation's findings:

1) In accordance with the USCS classification machine, the soil collected from the implementation website was designated as lean clay (CL). The in situ soil's PI, LL, and PL values fell between the ranges of 12-33, 28-35, and 16-22, respectively.

2) The soil sampled from the implementation web page was categorized as A-6 by the AASHTO categorization machine, with a set index of 7. (AASHTO M145). AASHTO rates A-6 soils as subgrade fabric with a well-known score ranging from excellent to bad.

(3) The in situ clayey soil's most beneficial moisture content and dry unit weight, respectively, were 13% and 18.56 kN/m3 (118.2 pcf).

4)The compacted soil samples reached a most swelling stress of approximately zero.41% after approximately 13 days of soaking and started out shrinking after that. Eventually, the soil samples reached equilibrium at about 0.24% swelling pressure after 35 days of soaking.

5)The unconfined compressive power of the in situ soil samples compacted to ninety five to a hundred and one% relative compaction ranged among 214 and 329 kPa. The common unconfined compressive electricity of the samples examined became 282.9 kPa (forty one psi).

6)The unconfined compressive strength take a look at effects showed that the in situ clayey soil on the implementation web site required development to support the hundreds from the pavement considering INDOT requires a minimum unconfined compressive strength of 552 kPa (eighty psi) for subgrade soils.

7)The PI, LL and PL values of the soil-7% steel slag-3% Class-C fly ash mixture were 13, 35 and 22, respectively. These results indicated that blending the in situ soil with the 7% metallic slag-3% Class-C fly ash combination ended in an boom in LL and PL. No widespread alternate turned into located in the PI of the soil-7% metal slag-three% Class-C fly ash combination while as compared to that of the in situ clayey soil. Seventy four

8)The PI, LL and PL of the soil-7% metallic slag-three% blast furnace slag aggregate have been 14, 39 and 25, respectively. These consequences indicated that mixing the in situ soil with the 7% steel slag-three% blast furnace slag aggregate resulted in an boom in LL and PL. No substantial alternate changed into found inside the PI of the soil-7% steel slag-three% blast furnace slag aggregate whilst as compared to that of the in situ clayey soil.

9)The superior moisture content and most dry unit weight of the soil-7% metallic slag-3% fly ash aggregate have been 15% and 18.04 kN/m3 (114.Eight pcf), respectively.

10)The most suitable moisture content and most dry unit weight of the soil-7% metallic slag-3% blast furnace slag aggregate were sixteen% and sixteen.94 kN/m3 (107.7 pcf), respectively.

Eleven) Both the soil-steel slag-Class-C fly ash and soil-metal slag-blast furnace mixtures exhibited better most excellent moisture content material and lower maximum dry unit weight than the ones found for the in situ clayey soil.

12)The two-day unconfined compressive energy of the compacted soil-7% steel slag-3% Class-C fly ash and soil-7% metal slag-three% blast furnace slag combos have been 820 kPa (119 psi) and 602 kPa (87 psi), respectively.

13)The unconfined compressive strength advantage fee of the soil-7% metal slag-3% Class-C fly ash combination become higher than that of the soil-7% metal slag-3 % blast furnace slag combination. These consequences indicated the incidence of stronger cementitious reactions in the soil-metallic slag-Class-C fly ash combination.

14)The maximum swelling lines of the soil-7% metallic slag-three% Class-C fly ash and soil-7% metallic slag-three% blast furnace slag combos had been zero.13 % and 0.052%, respectively. These results confirmed that each the steel slag-Class-C fly ash and metallic slag-blast furnace slag mixtures had been powerful in decreasing the swelling capacity of the in situ clayey soil.

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