Experimental Study of Engineering Properties of Kota Stone Slurry Powder and Fly Ash mixed Expansive soil.

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Abstract. Black Cotton soils have the properties to shrink and develop cracks without any warning when water content is reduced in hot season and expand when it comes in contact with water content in rainy season. So, for a civil engineer it is very difficult task to design a foundation on black cotton soil. The properties of black cotton soils can also be improved by stabilizing the soils by mechanical means or by mixing of additives in different proportions by weight. The present study explores the behavior of black cotton soil when it is stabilized with Kota stone slurry powder (KSSP) and fly Ash. Kota stone slurry powder and fly ash are locally available materials in abundance in Kota district in Rajasthan state. Kota stone slurry powder is generated during cutting, sawing and polishing process in Kota stone industries. Fly Ash is generated during thermal electricity production. Due to improper disposal, it considerably affects prime land, vegetations, surface and underground water. There should be great priority to dispose these generating waste materials in scientific manner. The study reveals that mixing of KSSP with black cotton soil as a stabilizing agent to improves the properties of the soil due to presence of silica and lime in it. The present study deals with determination of optimum percentage of utilization of KSSP and fly ash to improve the expansive soil. Index properties, Proctor test and swelling index test were conducted to evaluate the magnitude of KSSP and fly ash mixed expansive soil.

Keywords: Black Cotton Soil (BCS), Kota Stone Slurry Powder (KSSP), Fly Ash (FA), Stabilization.

1 Introduction

Black cotton soil found in western part of Madhya Pradesh, some part of Andhra Pradesh, Karnataka, Southern part of Rajasthan, almost entire part of Deccan plateau and Utter Pradesh. Land area covered with black cotton /expansive soil is about 20%-25% of total land area of India. Black cotton soil is highly problematic due to it detrimental volume changes corresponding to change in moisture content, swells, when contact with moisture in rainy season and shrinks in hot/dry season when it is dried (Navels 2001, Walsh et al. 1993). Black cotton soil is very dangerous for construction over it because of its swelling and shrinkage behavior but very fruitful for farmers because of its fertility. Lightly loaded civil engineering structures like residential buildings, pavements and linings founded on expansive soil are severely damaged due to its swelling and shrinkage behavior.

Kota stone has been commonly used as a building material since the ancient times. Kota stone slurry powder contains siliceous and also having free lime to react chemically and forms cementitious compound (Bell 1993). It is very fine powder generated from Kota stone industries during the process of cutting, sawing and polishing. Still a proper disposal system of Kota stone slurry powder is not developed. In present time, it is disposed to any convenient places like nearby nallah, river, pasture land, forest land and nearby roads. During the stormy days this fine powder particles transfer from one place to another place and also available in suspension state in environment, which hazardous to health for living beings and affect the fertility of the nearby soil areas. Disposed quantities can be reduced by using the KSSP in various engineering applications and give solution to the problems of disposal. This will help in reduction to pollute the environment and also reduce the bad effects on fertility of nearby fertile soils (Martin et al. 1990, Misra et al. 2005). Kota stone is basically a calcareous sedimentary rock available in different colors and texture (blue, brown, green, gray etc.) and fine-grained lime stone (Jitesh Mehta et al. 2016).

Need one of the major environmental problems around the world. It can be used to improve strength and durability parameters (Aman Jain, 2016).

Fly-ash is a byproduct from burning pulverized coal in electric generating plant. Fly ash available in district Kota in Rajasthan till dated May31, 2019 is 500 MT and stock in ash pond 0.67 Lac Metric Ton. Fly ash is defined as the material extracted from the flue gases of a furnace fired with coal. During stormy weather if fly ash is not disposed in proper manner, fine particles transfer from one place to another place and some particles are in suspension also, create the bad effects like damage lungs, damage nervous system, Kidney disease, swelling of the brain and hearing impairment. So, there is a need to dispose it in proper manner and used as an engineering material to improve the engineering properties of expansive soils. Several studies have shown that use of industrial waste materials like fly ash, pond ash etc. to improve the engineering behavior and also suppress the swelling-shrinkage characteristics of expansive soil (Khattab et al. 2007, Babu et al. 2008, Kumar and Singh 2008). Fly ash is also used in stabilization of expansive soils (Reddy et al. 2015). Many researchers have shown that fly ash and stone dust are additives have great potential to stabilize the expansive soil (Chen 1975, Schaefer et al.1997). Experimentation to

analyze compaction and swelling behavior of black cotton soil mixed with different non-cementitious materials like fly ash and stone dust is presented (Vikash Malik, AkashPriyadarshee 2017). Present paper deals a comprehensive experimental work to analyze the index properties, swell behavior, and compaction characteristics of black cotton soil mixed with KSSP and fly ash.

Many researchers did work on stabilization of black cotton soil with different cementitious and non-cementitious materials in the past to analyse the improvement in black cotton soil mixed with different materials like stone dust, fly ash, marble dust, Kota stone slurry powder etc. The test results revealed that there is a significant improvement in engineering properties of expansive soils.

Tak, D, Sharma J.K. and Grover K.S (2018) presented the use of Kota stone powder to improve properties of black cotton soil and value of consistency limits, swelling pressure, standard proctor and UCS.

Shalendra Singh et al. (2013) analyzed black cotton soil mix with lime by different proportions and found that properties of soil such as plasticity index, shrinkage limit and CBR value are improved.

Parte, Shyam Singh and Yadav R K (2014) founded that marble dust has a potential to modify the characteristics of black cotton soil.

Anu K. et al. (2016) perform experiments on soft soil mixed with fly ash and lime and found improvement in engineering properties like dry density and strength of soft soil.

Shaik Khader Vali Baba et al. (2017) presented the effect of granite dust and lime which mixed with different proportions with black cotton soil and found improvement in the engineering properties of the black cotton soil.

Materials:

- soil:-Soil was collected from Amrit Nagar, near Bohr Khera, district Kota in Rajasthan state. Soil engineering properties listed in tables.

- **Kota stone slurry powder:**-The KSSP was collected from Inderprasth Industrial area dumped behind Mittal Factory, Road No. 5, district Kota in Rajasthan state.

- **Fly ash:-**Fly ash was collected from brick manufacturing yard near Nanta, generated during thermal power generation at district Kota in Rajasthan state.

2. Experimental program:

Objectives

- To stabilize and study the behavior of the Black cotton soil using KSSP and fly ash as a stabilizer.
- To mix KSSP and fly ash as a stabilizer at an interval of 5% from 0-20%.

Experimental details:

Properties of the black cotton soil studied by using varying percentage of Kota stone slurry powder and fly ash:

Atterberg,s limit, IS: 2720 (Part V).
Shrinkage limit, I.S: 2720 (Part VI).
Free swell index, IS: 2720 (Part XL).
Specific gravity test, IS: 2720 (Part III).
Proctor compaction test. IS: 2720 (Part VII).

Table 1.Test result values of black cotton soil, Kota stone slurry powder and fly ash

Descriptions	Black cotton soil	Kota Stone Slurry Powder	Fly Ash
Specific gravity	2.57	2.63	2.1
Liquid limit (%)	55	32..8	35.5
Plastic limit (%)	26.62	NP	NP
Plasticity index (%)	28.38	-	-
Shrinkage limit (%)	9.20	22.49	35.5
Unified soil classification Symbol	CH	CI	CI
Maximum dry density(g/cm^3)	1.67	1.69	1.23
Optimum moisture content (%)	19.4	18.3	23.4

Table 2.Chemical composition of Kota thermal fly ash –

Constituents of fly ash	Value – II (%)	As per IS: 3812 (Part 1); 2003
Silica (SiO2)	60.9	35.0
Alumina (Al2O3)	26.5	
Ferric Oxide (Fe2O3)	5.50	
Calcium Oxide (CaO)	5.98	
Magnesium Oxide (MgO)	0.62	5.0
Titanium Oxide (TiO2)	0.24	
Free lime content	2.75	
Moisture	0.76	
LOI (Loss On Ignition)	0.28	5.0
SiO2 + Al2O3 + Fe2O3	92.9	70.0

2.1 Liquid limit:

The object of the test is to determine the liquid limit that shows the lowest water content at which the sample is in liquid state.

Table 3. Liquid limit of Mixed Specimens

Descriptions	Liquid limit (%)	Percentage decreasing (%)
BCS + 05% Fly ash + 15% KSSP	49.81	9.43
BCS + 10% Fly ash + 15% KSSP	47.95	12.82
BCS + 15% Fly ash + 15% KSS	46.80	14.91
BCS + 20% Fly ash + 15% KSSP	45.50	17.27

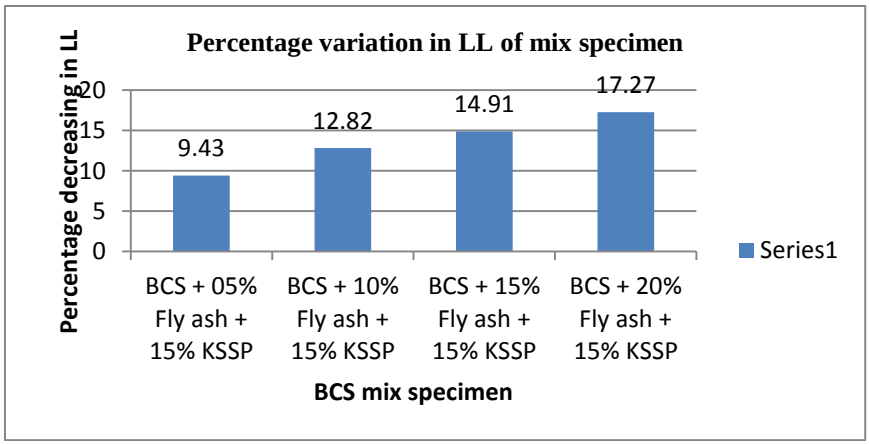

Figure 1. Percentage variations in liquid limit of BCS mixed specimen

Fig. 1 Show continuous decreasing liquid limit of the black cotton soil mixed specimens. Liquid limit of the Black cotton soil was 55%, it decreases upto 45.50%. Proportions of fly ash and Kota stone slurry powder in the Black cotton soil by dry weight of the soil. Specimens having fixed 15% Kota stone slurry powder but fly ash varying from 5% to 20% at the interval of 5%. Decreasing in liquid limit shows reduction in volume. This behavior indicates improvement in the engineering characteristics of the soil. Proportion of 15% Kota stone slurry powder is the optimum dose in the soil. Liquid limit test performed by the Uppal Cone Penetrometer (IS: 2720-V).

Table 4.Liquid Limit of Mixed Specimens

Particulars	Liquid limit (%)	Percentage decreasing (%)
BCS	55	-
Fly-ash	35.5	-
BCS + 10% Fly ash + 05% KSSP	51.06	7.16
BCS + 10% Fly ash + 10% KSSP	50.11	8.90
BCS + 10% Fly ash + 15% KSSP	47.95	12.82
BCS + 10% Fly ash + 20% KSSP	45.92	16.51
BCS + 10% Fly ash + 25% KSSP	44.51	19.07

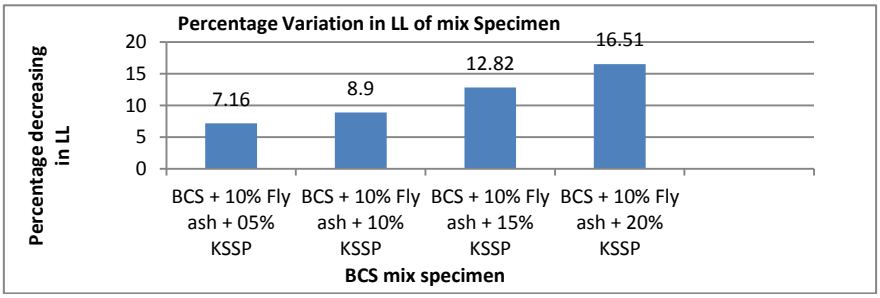

Figure 2. Percentage variations in liquid limit BCS mixed specimen

Fig. 1 Shows continuous decreasing the liquid limit of mixed of the black cotton soil specimens. Liquid limit of the black cotton soil is 55%, it decreases upto 44.51%. Proportions of fly ash and Kota stone slurry powder in the black cotton soil by dry weight of the soil. Specimens having fixed 10% fly ash but Kota stone slurry powder varying from 5% to 20% at the interval of 5%. Decreasing in liquid limit shows reduction in volume. This behavior indicates improvement in the engineering characteristics of the soil. Proportion of 10% fly ash is the optimum dose in the soil.

2.2 Plastic limit test:

Table 5.Plastic limit of specimens

Descriptions	Plastic limit (%)	Percentage decreasing (%)
BCS + 05% Fly ash + 15% KSSP	25.05	5.90
BCS + 10% Fly ash + 15% KSSP	23.76	10.74
BCS + 15% Fly ash + 15% KSSP	23.05	13.41
BCS + 20% Fly ash + 15% KSSP	22.10	17.0

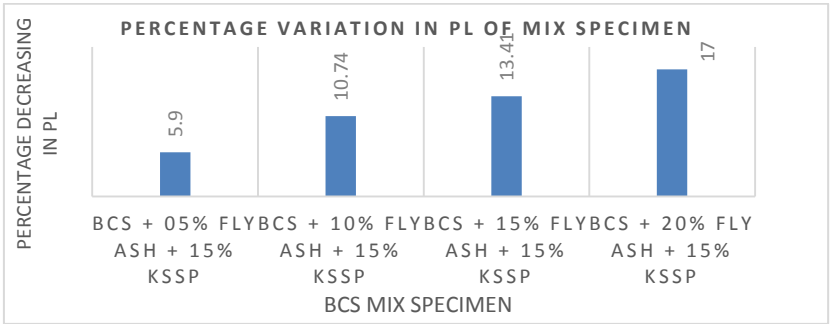

Figure3. Percentage variations in plastic limit (PL)

Fig. 3 representing the relationship of mixed specimens with variation in the plastic limit. Plastic limit of the Black cotton soil is 26.62% but mixing fly ash and Kota stone slurry powder are non-plastic (NP). Decreasing in plastic limit of the Black cotton and it mixed specimens from 26.62% to 22.10%. Mixed specimens having 15% Kota stone slurry powder but other admixture material was fly ash percentage varying from 5% to 20% at the interval of 5%. Decreasing in plastic limit showed reducing the volume change behavior that indicated improvement in the characteristics of the soil.

Table 6.Plastic limit of specimens

Descriptions	Plastic limit (%)	Percentage decreasing (%)
Black cotton soil	26.62	-
BCS + 10% Fly ash + 05% KSSP	25.05	5.90
BCS + 10% Fly ash + 10% KSSP	24.25	8.90
BCS + 10% Fly ash + 15% KSSP	23.76	10.74
BCS + 10% Fly ash + 20% KSSP	22.88	14.05

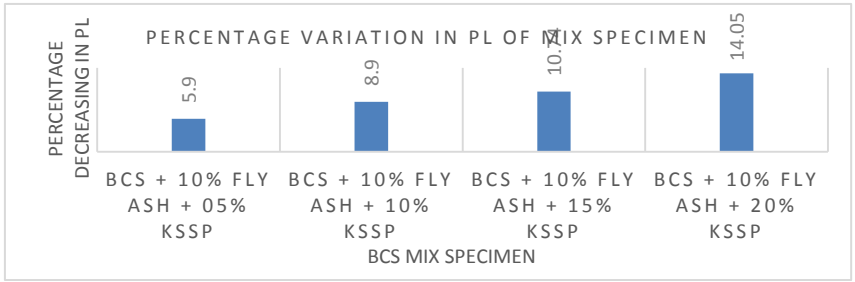

Figure 4.Percentage variations in Plastic limit (PL).

Fig. 4 representing the relationship of mixed specimens with varying in the plastic limit. Plastic limit of the black cotton soil is 26.62% but mixing fly ash and Kota stone slurry powder are non-plastic (NP). Decreasing in plastic limit of the black

cotton and it mixed specimens from 26.62% to 22.28%. Mixed specimens having 10% fly ash but other mixing material was Kota stone slurry powder and percentage was varying from 5% to 20% at the interval of 5%. Decreasing plastic limit shows reducing the volume change behaviour that indicated improvement in characteristics of the soil.

2.3. Plasticity Index:

Table 7.Plasticity Index of mixed specimens

Descriptions	Plasticity index (%)	Percentage decreasing (%)
BCS + 05% Fly ash + 15% KSSP	24.76	12.76
BCS + 10% Fly ash + 15% KSSP	24.49	13.71
BCS + 15% Fly ash + 15% KSSP	23.75	16.31
BCS + 20% Fly ash + 15% KSSP	23.40	17.55

Table 8. Plasticity index of mixed specimens

Particulars	Plasticity index (%)	Percentage decreasing (%)
BCS	28.38	-
BCS + 10% Fly ash + 05% KSSP	26.01	8.35
BCS + 10% Fly ash + 10% KSSP	25.86	8.88
BCS + 10% Fly ash + 15% KSSP	24.49	13.71
BCS + 10% Fly ash + 20% KSSP	23.04 `	18.82

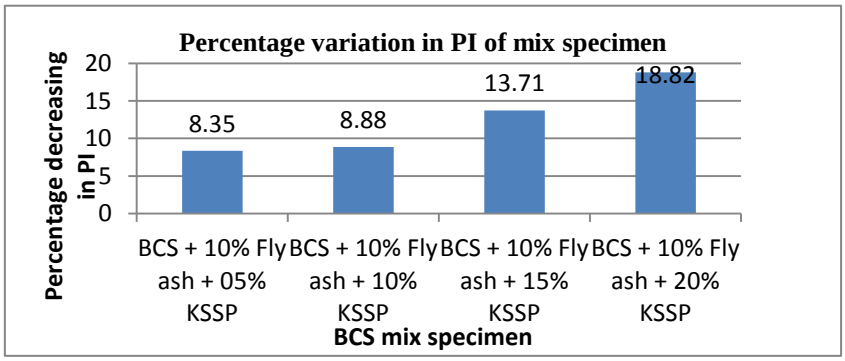

Figure5. Percentage variation in Plasticity index (PI)

Fig. 5 representing the plasticity index variations in different mixed specimens and found decreasing in plasticity index of different mixed as compare to the black cotton soil. Mixed specimens of the black cotton soil having different percentage of fly ash

but Kota stone slurry powder was fixed. Proportion of the admixtures in the mixed specimens was by weight of the dry soil. Fig. 6 shows mixed specimens having 15% KSSP but varying the percentage of fly ash from 5% to 20% at the interval of 5%. Mixing of 15% Kota stone slurry powder is the optimum dose. The plasticity index of the Black cotton soil is 28.38% and decreases upto 23.04%. Decreasing in plasticity index, indicate improvement in strength of the soil.

2.4 Shrinkage limit:

Table 9. Shrinkage limit of mixed specimen

Descriptions	Shrinkage limit (%)	Percentage increasing (%)
BCS + 05% Fly ash + 15% KSSP	10.78	17.18
BCS + 10% Fly ash + 15% KSSP	11.20	21.74
BCS + 15% Fly ash + 15% KSSP	12.16	32.17
BCS + 20% Fly ash + 15% KSSP	13.08	42.17

Table 9 representing a comparison of mixed specimens shrinkage limits and shrinkage limit of the black cotton. Shrinkage limit of the black cotton soil was 9.20% and 22.49%, 35.5% for Kota stone slurry powder and fly ash respectively. Increasing in shrinkage limit was from 9.20% to 13.08%. Percentage of Kota stone slurry powder was remained 15% but percentage of fly ash varying from 5% to 20% at the interval of 5%. Percentage increasing in shrinkage limit was 42.17%. Presence of more percentage of fly ash founded more variations in mixed specimens.

Table 10. Shrinkage limit of mixed specimens

Descriptions	Shrinkage limit (%)	Percentage increasing (%)
BCS	9.20	-
BCS + 10% Fly ash + 05% KSSP	10.48	13.91
BCS + 10% Fly ash + 10% KSSP	10.87	18.15
BCS + 10% Fly ash + 15% KSSP	11.20	21.74
BCS + 10% Fly ash + 20% KSSP	12.10	31.52

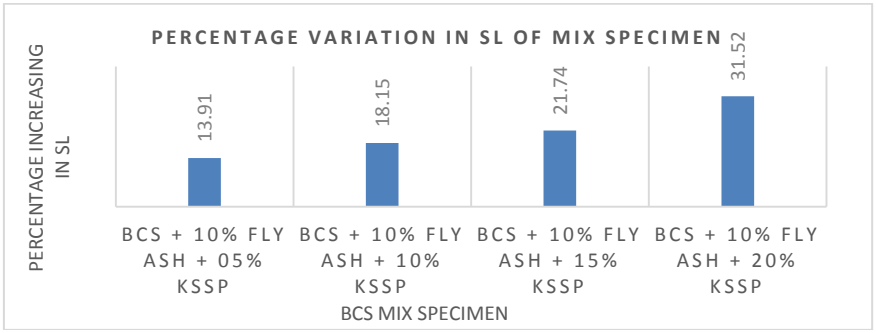

Figure6. Percentage variation in Shrinkage limit (SL)

Fig. 6 draws a relationship between mixed specimens shrinkage limit. Shrinkage limit of the Black cotton was 9.20% and 22.49%, 35.5% for Kota stone slurry powder and fly ash respectively. Increasing in shrinkage limit was from 9.20% to 12.10%. Percentage of fly ash was remained 10% but percentage of Kota stone slurry powder (KSSP) varying from 5% to 20% at the interval of 5%. Percentage increasing in shrinkage limit was 31.52%.

2.5. Specific gravity:

Table 11. Specific gravity of mixed specimens

Descriptions	Specific gravity	Percentage variation (%)
BCS + 05% Fly ash + 15% KSSP	2.59	+ 0.8
BCS + 10% Fly ash + 15% KSSP	2.57	0.00
BCS + 15% Fly ash + 15% KSSP	2.55	- 0.8
BCS + 20% Fly ash + 15% KSSP	2.52	- 1.95

Table 12. Specific gravity of mixed specimens

Descriptions	Specific gravity	Percentage variation (%)
BCS	2.57	-
BCS + 10% Fly ash + 05% KSSP	2.56	- 0.4
BCS + 10% Fly ash + 10% KSSP	2.56	- 0.4
BCS + 10% Fly ash + 15% KSSP	2.57	- 0.4
BCS + 10% Fly ash + 20% KSSP	2.59	+ 0.8

Table 11, 12 representing specific gravity of mixed specimens having varying percentage of Kota stone slurry powder and fly ash.

2.6. Swell index:

Table 13. Swell index of mixed specimens

Particulars	Swell index (%)	Percentage decreasing (%)
BCS + 05% Fly ash + 15% KSSP	40	20
BCS + 10% Fly ash + 15% KSSP	40	20
BCS + 15% Fly ash + 15% KSSP	35	30
BCS + 20% Fly ash + 15% KSSP	35	30

Table 14. Swell index of mixed specimens

Particulars	Swell index (%)	Percentage decreasing (%)
BCS	50	-
BCS + 10% Fly ash + 05% KSSP	45	10
BCS + 10% Fly ash + 10% KSSP	45	10
BCS + 10% Fly ash + 15% KSSP	40	20
BCS + 10% Fly ash + 20% KSSP	35	30

Table 11 and 12 representing swelling index of the black cotton soil and its mixed with different proportions of fly ash and Kota stone slurry powder. Swell index of the black cotton soil is 50% and reduced up to 30% in mix of 20% ash with 15% Kota stone slurry powder and 10% ash with 20% Kota stone slurry powder.

2.7 Proctor test:

Table 15.Proctor test of mixed specimens

Descriptions	Optimum moisture content (%)	Maximum dry density (g/cm3)
BCS	19.4	1.67
BCS + 05% Fly ash + 15% KSSP	16.82	1.73
BCS + 10% Fly ash + 15% KSSP	17.23	1.73
BCS + 15% Fly ash + 15% KSSP	17.62	1.72
BCS + 20% Fly ash + 15% KSSP	17.90	1.71

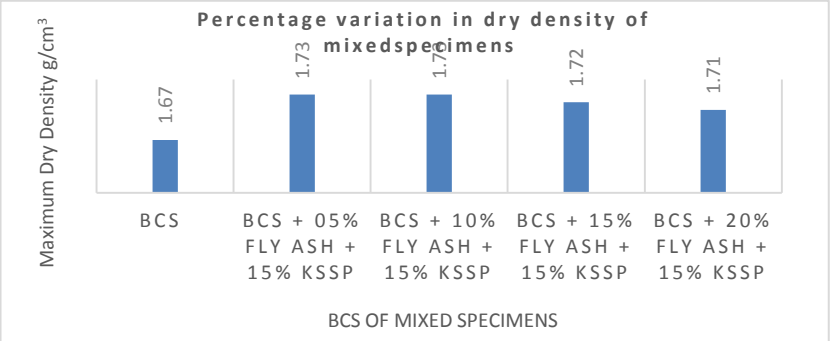

Figure 7. Percentage variations in dry density

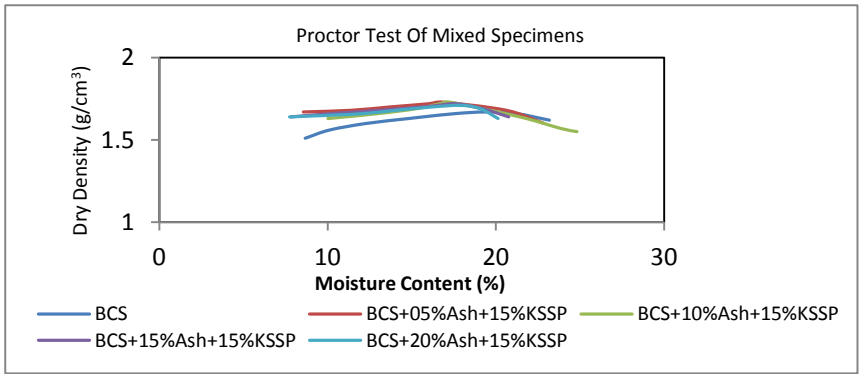

Figure 8. Variation of dry density with moisture content

Fig. 8 representing a relationship between dry density versus moisture content. The maximum dry density of the black cotton soil was found 1.67g/cm^3 corresponding to moisture content 19.4%. The maximum dry density obtained was 1.73g/cm3 of the mix having 10% fly ash and 15% KSSP corresponding to moisture content 17.23%. Percentage increasing in maximum dry founded was 3.6%. Percentage increasing in maximum dry density indicates improvement in the characteristics of the black cotton soil. Test specimens having 15% Kota stone slurry powder but varying percentage of fly ash varying from 5% to 20% at the interval of 5%. The rest was conducted as per IS: 2720-VII. This test equivalent to the standard Proctor test AASHO – American Association of State Highway officials.

Table 16.Proctor test of mixed specimens

Descriptions	Optimum moisture content (%)	Maximum dry density (g/cm3)
BCS	19.4	1.67
BCS + 10% Fly ash + 05% KSSP	18.96	1.71

BCS + 10% Fly ash + 10% KSSP	18.74	1.72
BCS + 10% Fly ash + 15% KSSP	18.43	1.73
BCS + 10% Fly ash + 20% KSSP	18.08	1.75

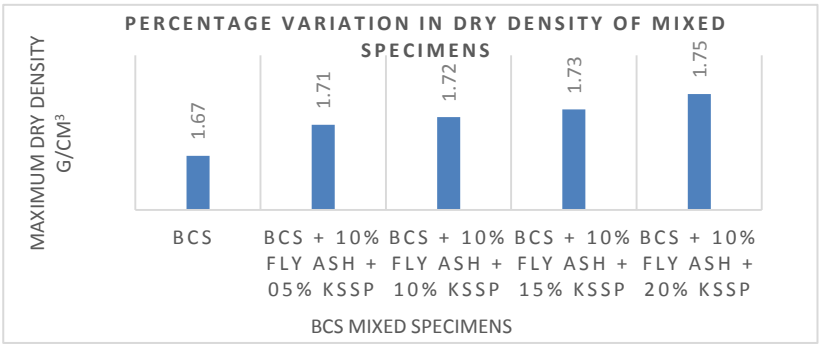

Figure 9. Variation of dry density with moisture content

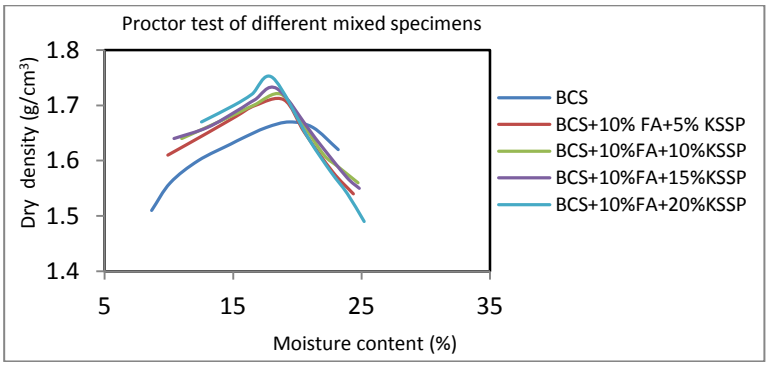

Figure 10. Variation in dry density of mixed specimens

Fig. 10 representing a relationship between dry density versus moisture content. The dry maximum density of the black cotton soil was found 1.67g/cm3 and the corresponding to moisture content was 19.4%. The maximum dry density obtained was 1.75g/cm^3 of the mix having 10% fly ash and 20% KSSP corresponding to moisture content 18.08%. Percentage increasing in maximum dry founded was 4.8%. Percentage increasing in maximum dry density indicates improvement in the characteristics of the black cotton soil. Test specimens having 10% fly ash but varying percentage of Kota stone slurry powder from 5% to 20% at the interval of 5%.

3. Conclusions

This experimental study investigates the incorporation of fly ash and Kota stone slurry powder to improve the characteristics of the Black cotton soil. Following conclusions are describe as bellow,

1. Liquid limit of the black cotton soil found 55%, it decreased at different proportions of fly ash and Kota stone slurry powder in the black cotton soil. 19.07% decreased in LL of the black cotton soil mixed having 10% fly ash and 25% KSSP, 17.27% decreased in LL mixed having 15% KSSP and 20% fly ash. The black cotton soil classification changed from CH (high compressible) to CI (medium compressible).
2. The plastic limit of the black cotton soil found 26.62%. Reduction in PL of mix having different proportions of KSSP and fly ash. 14.05% reduction in mixed having 20% KSSP and 10%% fly ash and 17% reduction in PL of mix having 15% KSSP and 20% fly ash.
3. Determined the plasticity index of the black cotton soil was 28.38%. Plasticity index is reduced in mixed having different proportions of KSSP and fly ash. Maximum reduction in PI of the specimen having 20%KSSP and 10% fly ash was 18.82%. Reduction in PI indicates improvement in strength characteristics of the BC soil.
4. Free swell index of the black cotton soil was 50%, it reduced upto 35%. Reduction in the swell index was 30%. Reduction in free swell index meant reduced in swell behavior of the BC soil. This behavior indicates improvement in the properties of the BC soil.
5. The maximum dry density (MDD) and optimum moisture content (OMC) of the black cotton soil is determined 1.67g/cm^3 and 19.4% respectively. The MDD increased at different proportions of mixed used KSSP and fly ash as an admixture. The dry density was at most of the specimen having 10% fly ash and 20% KSSP and found 1.75g/cm^3. Increased in the MDD also indicates improvement in the engineering properties of the BC soil.

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