Stabilization of Expansive soil using Eggshell powder and Kota stone dust

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Abstract
Expansive soils represent a potential danger for the structures. The association of clay minerals, such as, smectite family, other silicate minerals and soils rich with sulfate salts forms expansive soil. The addition and removal of moisture causes expansion and shrinkage respectively for expansive soils. Since long, improvement in qualities of expansive soil by utilizing various materials has been a testing work for engineers. Considering millions of tons of waste produced annually across the country, which leads to the issue of disposal as well as adds to health risks. Use of such refuse and industrial waste as options to stabilizing materials may adequately contribute to environmental preservation and can minimize their unfriendly consequences on environment. In the present paper, eggshell powder and Kota stone dust is used as combination to examine the effects on strength of expansive soil. The soil samples are prepared with different proportions of eggshell powder (4%, 8%, 12%, and 16%) and Kota stone dust (5%, 10%, 15%, and 20%). A series of tests are conducted and the plausible variations in the strength of specimens are observed and recorded. By adding eggshell powder and Kota stone dust, the behavior of the soil properties is improved. The combination is found to be more effective rather than the addition of eggshell powder and Kota stone dust separately.

Key words: *Clay minerals**,** expansive soil, stabilizing materials, eggshell powder, Kota stone dust.*

1. Introduction

The expansive soil exists all over the world. India has large tracks of expansive soil known as black cotton soil that covers an area of 0.8 million square kilometers, which is about 20% of total land area. The expansive soil occurring above water table bear volume changes with change in moisture content which causes swelling of the soil and loss of strength. The decrease in moisture content brings the shrinkage of the soil. Swelling and shrinkage of expansive soil cause differential settlement leading to severe damage to the buildings, foundations, roads etc. The construction of structural foundation on black cotton soils falls as a challenge to the civil engineers. The swelling characteristics of black cotton soils & other expansive soils have been a matter of interest for number of researchers. Various empirical techniques and models for assessing the swell potential of the expansive soils by relating the physical properties of soil have been developed. It is considered that sometimes, the empirical techniques cannot be applied appropriately to all soils due to different soil conditions. Therefore, the idea of stabilization of soil by blending it with other materials was introduced.

2. Literature Review

O.O. Amu et. al. (2005)[1] studied the effect of eggshell powder on the stabilizing potential of lime on an expansive clay soil. The sample stabilized with 3% lime and 4% eggshell powder is found better than 7% lime only, as OMC is lower in latter case. The addition of 7% lime increased the unsoaked CBR value to 45.5%, while 3% lime+4% eggshell powder reduced the CBR value to 4.1%. The addition of 7% lime raised the UCS value from 59.64 KN/m^2 to 187.28 KN/m^2. The addition of 3% lime+4% eggshell powder reduced this strength to 93.5 KN/m^2.

Arash Barazesh et. al. (2012)[2] used expansive soil and different percentages of eggshell powder materials in the experiments. The changes in the Atterberg's limits were observed. It was found that the increased proportions of eggshell powder in the specimen resulted in sharper decrease in the respective index. Soil-eggshell powder mixture resulted in decrease of plasticity indices the largest decrease was noticed in the specimen with 16% of eggshell powder addition.

Ankur Mudgal et. al. (2014)[3] presented the stabilization of black cotton soil with a mixture of lime and stone dust. Stone dust was mixed up to 25% by weight. It was observed that MDD of the lime stabilized black cotton soil increases, up to the addition of 20% stone dust and further increment decreases the value. The UCS and CBR value increases up to 20% addition of stone dust in lime stabilized soil.

Ms. M. Yogeshkumari et. al. (2016)[4] described the study of properties of soil replacement of eggshell powder in various proportions. It is observed that the addition of eggshell powder shows noticeable improvement in soil properties. 20% replacement of soil by eggshell powder can be utilized as a soil stabilizer which minimizes the settlement problems and the same can reduce the environmental issues.

Diana Johns et. al. (2017)[5] showed in the research work the treatment of black cotton soil with eggshell powder and lime separately. A comparative research is being done which showed that eggshell powder can be replaced by 4% lime by adding 12% eggshell powder.

Birundha P. et. al. (2017)[6] presented the stabilization of clay soil using eggshell powder and quarry dust. Series of tests were conducted to determine the effect of eggshell powder and quarry dust on clay soil. The percentage of eggshell powder was taken to be 20% and the percentage of quarry dust was varied (10%, 20%, 30%, 40%). Results indicated that the combination of 20% eggshell powder and 30% quarry dust gave the best results.

3. Methodology

The soil sample used for this work was collected from Borkheda region (Kota) Rajasthan, India. The sample was collected from the depth of 2 - 2.5 m to neglect the top soil. Eggshell powder and Kota stone dust were used as binders. Materials were mixed using normal tap water. The eggshells were collected from local restaurants, hatcheries, domestic wastes and were dried at a temperature of 180*C for 1 hour. These were later powdered by using mechanical means and sieved through IS Sieve No. 18 (1 mm). The Kota stone is a siliceous calcium carbonate rock and is readily available in Rajasthan. During the process of cutting, the original stone mass is lost by 25 – 30% in the form of dust which is Kota stone dust. The work has been done on various percentages of mixtures.

The stabilized mixtures were prepared by first of all mixing thoroughly the dry eggshell powder in various proportions to the black cotton soil. The eggshell powder contents of 4%, 8%, 12%, 16% by weight were added in the soil. Then, eggshell powder content of 12% was ceased and mixed with the various percentages of Kota stone dust in the soil. The Kota stone dust contents of 5%, 10%, 15%, 20% by weight were added.

4. Experimental Details

Study on soil properties using varying percentages of eggshell powder and Kota stone dust consisted of

- Proctor Compaction Test (IS: 2720 Part VIII – 1983)
- Atterberg’s Limit Test (IS: 2720 Part V – 1985)
- Unconfined Compressive Strength Test (IS: 2720 Part X – 1991)
- California Bearing Ratio Test (IS: 2720 Part XVI – 1987)

Table 1. Properties of virgin black cotton soil

S.no.	Properties	Values
1	Specific Gravity (G)	2.46
2	Soil Classification	CH
3	Liquid Limit (LL)	54.52%
4	Plastic Limit (PL)	34.705%
5	Plasticity Index (PI)	19.81%
6	Optimum Moisture Content (OMC)	21.2%
7	Maximum Dry Density (ρ)	1.765 g/cc
8	Free Swell Index	58.82%
9	Unconfined Compressive Strength (UCS)	1.097 kg/cm2
10	California Bearing Ratio (CBR)	1.21%

5. Results and Discussion

5.1 Compaction characteristics

By addition of eggshell powder and Kota stone dust to the soil, the maximum dry density and optimum moisture content was found by Standard Proctor Compaction test as per IS 2720 – Part VIII - 1983.

A. Black cotton soil (BC) + Eggshell powder (ESP)

Table 2. Influence of eggshell powder with black cotton soil on compaction characteristics

Mix Specimen	OMC (%)	MDD (g/cc)
BC	21.23	1.769
BC + 4% ESP	19.17	1.777
BC + 8% ESP	16.41	1.801
BC + 12% ESP	14.73	1.855
BC + 14% ESP	14.86	1.844

BC + 16% ESP	15.25	1.842

From table 2, it is observed that the MDD of BC soil is 1.769 g/cc. With the increasing percentage of ESP in BC soil, the MDD increases up to 1.855 g/cc and then decreases with further addition of ESP. The increment in MDD is found to be 4.86%. The representation of the table is shown in Fig 1.

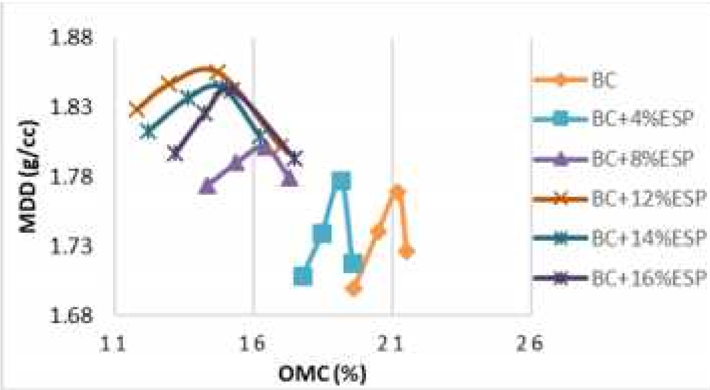

Fig.1. Variation in OMC and MDD with varying percentage of eggshell powder

B. Black cotton soil + Kota stone dust (KSD)

Table 3. Influence of Kota stone dust with black cotton soil on compaction characteristics

Mix specimen	**OMC (%)**	**MDD (g/cc)**
BC soil	21.23	1.769
BC + 5% KSD	19.79	1.78
BC + 10% KSD	18.14	1.802
BC + 15% KSD	16.65	1.835
BC + 20% KSD	17.73	1.817

From table 2, it has been observed that the addition of KSD up to 15% increases the MDD by 3.73%. The OMC is found to be decreasing up to 16.65% with the addition of KSD in BC soil. Further addition increases the OMC which is shown in Fig 2.

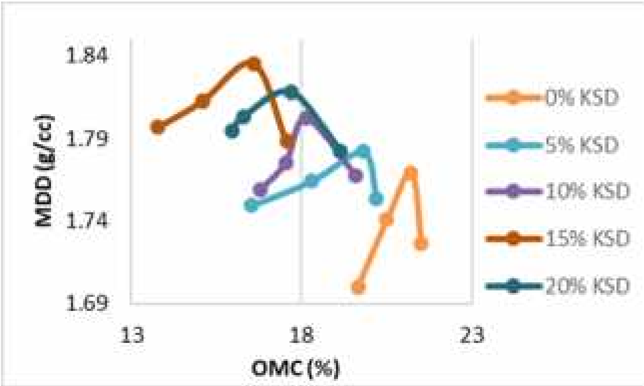

Fig. 2. Variation in OMC and MDD with varying percentage of Kota stone dust

C. Black cotton soil + Eggshell powder + Kota stone dust

Table 4. Influence of ESP & KSD on compaction characteristics

Mix Specimen	OMC (%)	MDD (g/cc)
BC soil	21.23	1.769
BC+12%ESP+5%KSD	14.41	1.87
BC+12%ESP+10%KSD	15.59	1.851
BC+12%ESP+15%KSD	17.07	1.791

It is observed from Table 4 that with the increase in the percentage of KSD in 12% ESP, the MDD decreases and the OMC content increases. At 12% ESP and 5% KSD mixed with BC soil, the MDD increases about 5.71%. Fig 3 shows the variation in OMC and MDD with the addition of ESP and KSD in BC soil.

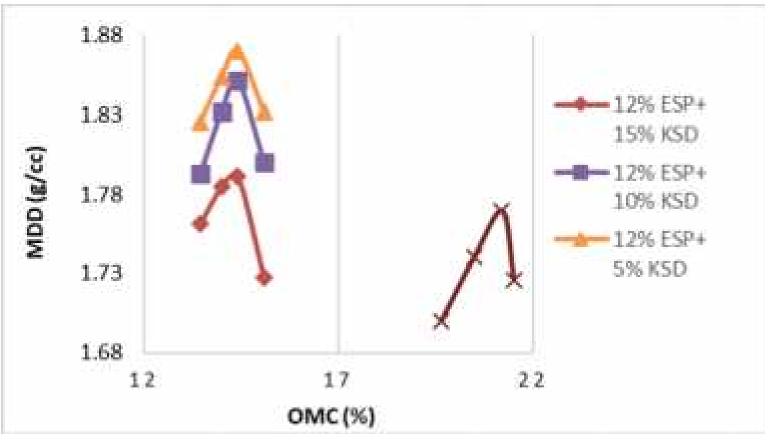

Fig. 3. Variation on OMC and MDD with varying percentage of ESP and KSD

5.2 Unconfined Compressive Strength test

The UCS value of BC soil was found to be 1.09 Kg/cm^2. The soil was treated with different percentages of eggshell powder and Kota stone dust and the results have been shown below.

A. Black cotton soil + Eggshell powder

Table 5. Influence of eggshell powder on UCS value

Soil mix	UCS, q_u (Kg/cm^2)
BC + 4% ESP	1.33
BC + 8% ESP	1.81
BC + 12% ESP	3.02
BC + 16% ESP	2.83

Table 5 shows that the maximum UCS value is observed when BC soil was added with 12% ESP. The total increment of 175.29% was observed at 12% ESP. Further increment decreases the UCS value due to rearrangement of soil crystalline structure. The results are shown in Fig 4.

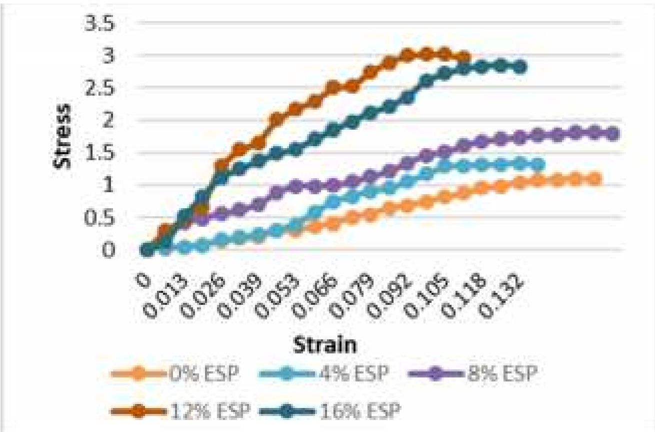

Fig. 4. Variation in UCS value with varying percentage of eggshell powder

B. Black cotton soil + Kota stone dust

Table 6. Influence of Kota stone dust on UCS value

Soil Mix	UCS, q_u (Kg/cm^2)

BC + 5% KSD	1.29
BC + 10% KSD	1.64
BC + 15% KSD	1.86
BC + 20% KSD	1.96

From table 6, it is observed that by increasing the percentage of KSD, the UCS value increased from 1.09 Kg/cm2 to 1.96 Kg/cm2. The total increment is observed to be 78.83%. The UCS value of each sample is shown in Fig 5.

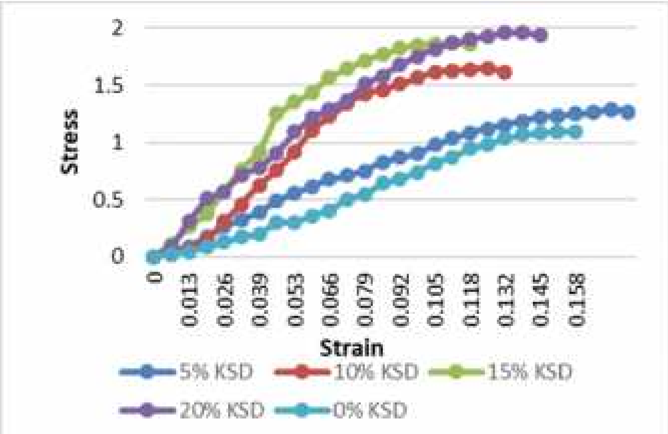

Fig. 5. Variation in UCS value with varying percentage of Kota stone dust

C. Black cotton soil + Eggshell powder + Kota stone dust

Table 7. Influence of ESP & KSD on UCS value

Soil mix	**UCS, q_u(Kg/cm^2)**
BC + 12% ESP + 5% KSD	3.22
BC + 12% ESP + 10% KSD	2.75
BC + 12% ESP + 15% KSD	2.54

By increasing the percentage of KSD in BC soil and 12% ESP, it is observed from table 7 that the UCS value keeps on decreasing. The unconfined compressive strength of BC soil when mixed with 12% ESP and 5% KSD is observed to be 3.23 and there is a percentage increase of 194.12%. The stress- strain curve for the above table is shown in Fig 6.

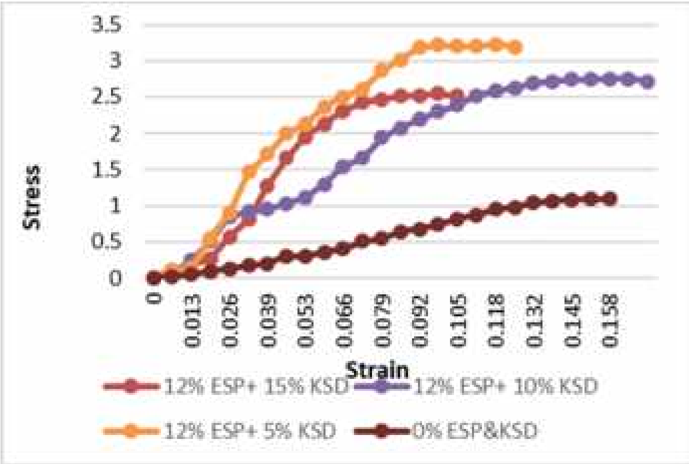

Fig. 6. Variation in UCS value with varying percentage of KSD & 12% ESP

5.3 California Bearing Ratio test

The CBR test was performed as per IS: 2720 (Part – XVI) 1987. The CBR value of BC soil was found as 1.21%.

A. Black cotton soil + Eggshell powder

Table 8. Influence of Eggshell powder on CBR value

Test Specimen	**CBR (%)**	**% Increase**
BC Soil	1.21	-
BC+ 4% ESP	1.75	44.62
BC+ 8% ESP	2.43	100.82
BC+ 12% ESP	3.95	226.44
BC+ 16% ESP	3.19	163.63

From Table 8, it is found that 12% ESP when added to BC soil gave the best results. It shows an increment of 226.44% and on further increment, the CBR value decreases. The load v/s penetration graph is plotted and is shown in Fig 7.

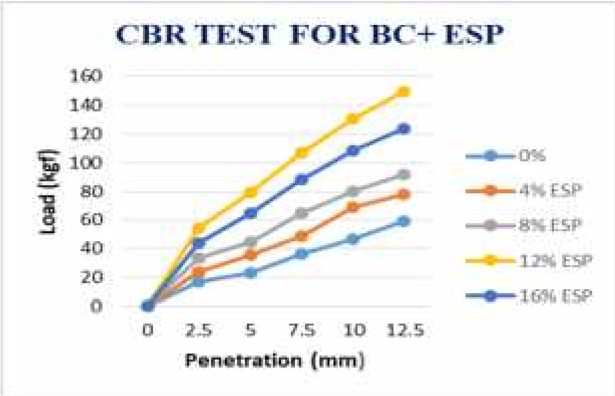

Fig.7. Variation in CBR value with varying percentage of eggshell powder in BC soil

B. Black cotton soil + Kota stone dust

Table 9. Influence of Kota stone dust on CBR value

Test Specimen	CBR (%)	% Increase
BC Soil	1.21	-
BC+ 5% KSD	1.97	62.81
BC+ 10% KSD	2.66	119.83
BC+ 15% KSD	3.49	188.43
BC+ 20% KSD	4.55	276.03

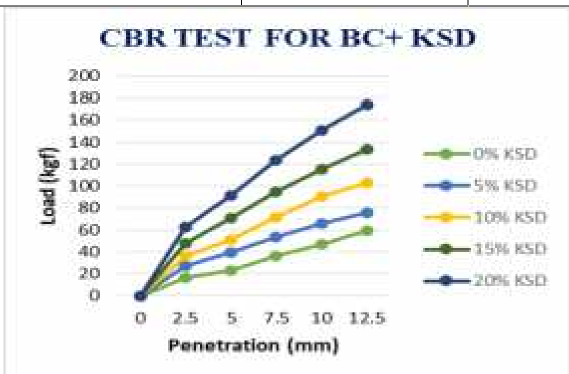

Fig.8. Variation in CBR value with varying percentages of Kota stone dust

It has been observed from Fig 8 that the CBR value keeps on increasing with the addition of KSD in BC soil up to 20% addition with an increment of 276.03%.

C. Black cotton soil + Eggshell powder + Kota stone dust

Table 10. Influence of ESP & KSD on CBR value

Test Specimen	CBR (%)	% Increase
BC Soil	1.21	-
BC+ 12% ESP+ 15% KSD	2.73	125.62
BC+ 12% ESP+ 10% KSD	3.34	176.03
BC+ 12% ESP+ 5% KSD	4.48	270.25

It has been observed from table 10 that the increment in the percentage of KSD in 12% ESP and BC soil decreases the CBR value. The 5% addition of KSD in BC soil with 12% ESP gave the maximum increment of 270.25%. Fig 9 shows the variation in CBR value with varying percentage of ESP and KSD.

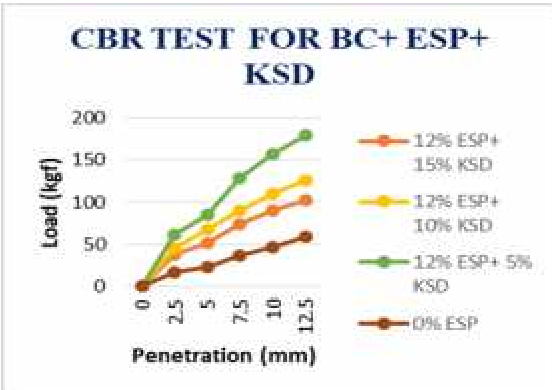

Fig. 9. Variation in CBR value with varying percentage of KSD & 12% ESP

5.4 Atterberg's Limit test

The Atterberg's limits such as liquid limit and plastic limit were determined as per IS: 2720 Part-V, 1985. The tests were performed by mixing ESP and KSD in BC soil in varying proportions. The combination of both in BC soil was also tested for the liquid limit and the plastic limit.

A. Black cotton soil + Eggshell powder

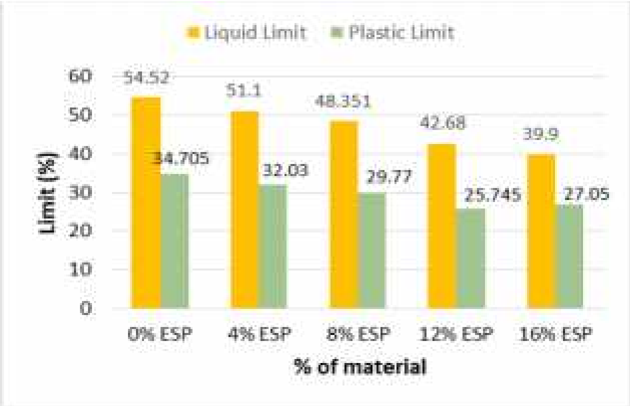

Fig. 10. Variation in Atterberg's limits with varying percentages of eggshell powder

From Fig 10, it is obtained that the soil is organic clay having high plasticity. With increase in the quantity of ESP in BC soil, the behavior of mix specimen changes from CH to CI. It is observed that the liquid limit and plastic limit decreases with increase in the percentage of ESP.

B. Black cotton soil + Kota stone dust

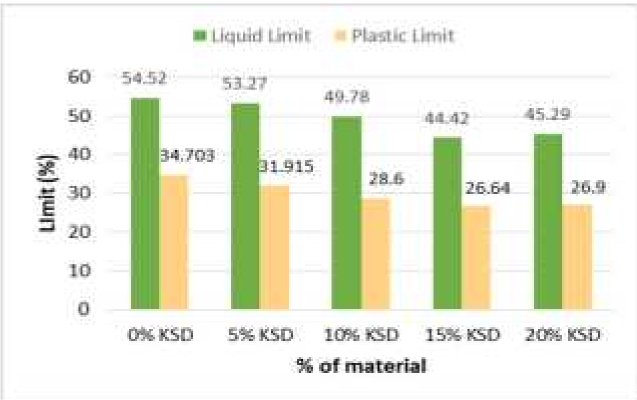

Fig. 11. Variation in Atterberg's limits with varying percentages of Kota stone dust

From Fig 11, it is observed that the liquid limit and plastic limit decreases with the increase in the percentage of KSD up to 15% addition. The liquid limit decreased from 54.52% to 44.42%. The plastic limit decreased up to 26.64%. The behavior of the BC soil changed from high plasticity clay to intermediate plasticity clay.

C. Black cotton soil + Eggshell powder + Kota stone dust

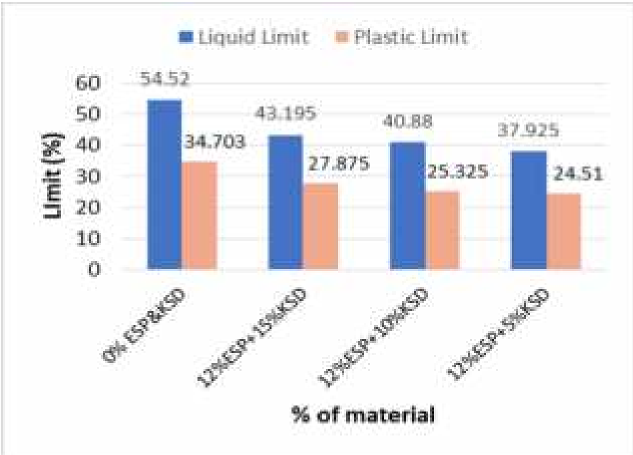

Fig. 12. Variation in Atterberg's limits with varying percentages of KSD and 12% ESP

From Fig 12, it has been observed that with the increase in the percentage of KSD with 12% ESP and BC soil, the percentage of liquid limit and plastic limit increases.

6. Conclusion

1. The dry density reaches 1.87 g/cc from 1.76 g/cc by the addition of 12% ESP & 5% KSD. There is an increase of 6% in MDD by adding ESP & KSD as stabilizing agents.

2. The UCS value is found to be 3.02 Kg/cm^2 with the addition of 12% ESP. Further addition decreased the value slightly. However, further addition of 5% KSD in the mixture of 12% ESP and BC soil, increased the UCS value up to 3.22 Kg/cm2. Here, a percentage increase of 6.62% has been observed.

3. The CBR value of pure black cotton soil was 1.21%, it is found to be increased by 270.25% by adding 12% ESP & 5% KSD.

4. The black cotton soil stabilized with 12% ESP reduced the liquid limit and plastic limit from 54.52% and 34.705% to 42.68% and 25.745% respectively. By further addition of 5% KSD, it reduced to 37.89% and 24.51% respectively. The nature of soil changed from CH to CI.

5. It is found that, the combination of ESP & KSD is more effective to stabilize the highly expansive black cotton soil rather than using them separately.

7. References

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