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A Literature Review- Black Cotton Soil Reinforced with Solid Waste

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Abstract - Expansive soils have swelling properties which gives rise to problems in civil engineering. These soils have poor volume stability in the presence of water. Due to their poor geotechnical properties like swelling, shear strength, compressibility, change in moisture content these soil posse's danger to the projects. In order to build safe structures, these characteristics of black cotton soil need to be modified and improved. However, due to increasing urbanization and based on availability of land for any mega project, it is unavoidable to do construction on expansive soils which are susceptible to damage due to various properties mentioned above. In order to mitigate such damage, it is essential to stabilize such soils using various techniques. Several methods for improving the above-mentioned properties have been investigated in this literature review study.

Keywords: Expansive soil, Silica fume, geocell, stone dust, black cotton soil, lime.

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INTRODUCTION

Expansive Soil

India is one of the world's fastest rising economy, where in a vast amount of development going on in the construction sector. Every year many new infrastructure projects, real estate projects get started in the country. Nearly 20% area in the country is covered with expansive Black cotton soil mainly in the central and southern part of the country like Madhya Pradesh, Maharashtra Rajasthan and Gujarat. It is also available in some sections of Karnataka, Telangana, Andhra Pradesh, and Tamil Nadu. Lava and Volcanic rocks are the major constituents of this class of soil. For the production of cotton, wheat, linseed, millets, and tobacco Black soil is the best suitable and so is popular with the name black cotton soil. Wadia (1975) has reported that the clay fragment of black cotton soil is highly rich in silica (60%), iron (15%) and just 25% of alumina. The classic black cotton soils, which are incorporated in clay, shale, or marl, have a high plasticity index, over swelling, and shrinkage properties. Ackroyd and Husain (1986) declared as montmorillonite is the mineral causing the extensive nature of black cotton soil dominating the content of clay. On account of the unfavorable nature of black cotton soil, geotechnical researchers are constantly looking ways to reduce the undesirable properties using soil stabilization techniques. The focus of the researchers in improving of the properties of black soil is close to synthesize, the swell-shrink capacity, plasticity index and particularly improving the characteristics of strength. The influence of various materials and methodologies on engineering properties of the improved soil is regarded as part of the state-of-the-art in black soil improvement application.

Physical Properties of B.C. Soil

Black cotton soils are usually greyish in color and available from 0.5m to 10m far down and also highly compressible in nature. The attributes of generally observed black cotton soils are listed below:-

Table1: Physical Properties of Black Cotton Soils

Sr.No.	Property	Value
1	Soil Classification	CH or MH
2	Liquid Limit (L.L.)	40 to 120 %
3	Plastic Limit (P.L.)	20 to 60 %
4	Dry Density (γd)	1300 to 1800 kg/m³
5	Optimum Moisture Content	20 to 35 %.
6	C.B.R. (Soaked)	1.2 to 4.0
7	Compression Index	0.2 to 0.5
8	Specific Gravity (G)	2.60 to 2.75
9	Free Swell Index	40 to 180%
10	Swelling Pressure	50 to 800 KN/m²
11	Fines (<75μ)	70 to 100%
12	2μ Fraction	20 to 60 %
13	Activity	0.8 to 18%

Chemical Properties of B. C. Soil

The following are the chemical properties of B.C.Soil as listed below :-

Table 2: Chemical Properties of B. C. Soil

Sr.No.	Property	Range
1	SiO_2,Al_2O_3	3 to 5%
2	Organic Content	0.4 to 204 %
3	Montmorrilonite Mineral	30 o 50%
4	SiO_2	50 to 55%
5	$CaCO_3$	5 to 15%
6	pH Value	>7(Alkaline)

LITERATURE REVIEW

Ekrem Kalkan et al (2004), investigated, the beneficial impact of micro silica on natural clay liners' swelling friction, permeability, and compression. Its aim was to see how silica fume influenced the swelling strain, permeability, and strength of compressive soil liners used as a hydraulic system. Although compressive soil liners have several benefits, such as high attenuation power, and less permeable, they also have a large swelling-shrinkage characteristics, which causes inconsistency.

Ekrem Kalkan et.al, in this paper has examined the impact of micro silica on permeability, and compression, swelling pressure and strength of compressive soil liners used as a hydraulic system. Compacted soil samples with micro silica in various ratios i.e. 0%, 5%, 10%, 15%, 20%, 25%, 30% and 50% has been prepared. The experiments were done as per ASTM standards; Atterberg test as per ASTM-D-4318, SPT test as per ASTM D 698, compressive tests (ASTM-2166), Falling-head permeability applied as per ASTM-D-5084, standard Odometer test as per ASTM-D-2435, cracking tests was performed in falling-head permeability equipment as per ASTM-D-5084. The results of experiments are presented in Table below-

Table 3: Impact of Micro Silica on Geotechnical Properties

	Parameters	Results
GEOTECHNICAL PROPERTIES	Atterberg's limits	Plasticity Index and Liquid limit values of black cotton soil show a slight decrement, while there is an increment in the values of micro silica value till 50% replacement with dry soil.
	Compaction parameters	When silica fumes were added to clay samples improvement was seen in moisture content and reduction was seen in Dry Density Value for similar compaction effort was found.
	Swelling Potential & Permeablity	Swelling Potential and Permeability were found to have been steadily decreased with an increase in micro silica content values then slowly decrement in the values in seen at and at compound soil with 30% and 50% admixture value.
	Compression strength	Significant increase in the compression strength content was found with silica fume content till 25%
	Scanning electron microscope (SEM)	Soil with 30% content of micro silica shows dense material in comparison to those soil with 0%, 10% and 20% additives value

Ekrem Kalkan et al(2008), Studied that the Impact of micro silica on the desiccate crack on compressed expansive soil. Due to low permeable value and maximum CEC, expansive soils are used widely in geotechnical applications, for example, in construction of liner and cover systems. Since, the compressed expansive soil shows cracking at dry state due to its high value of free- swell, and increased value of hydraulic conductivity is also seen.

Ekrem Kalkan, in his study, he examined the potentially use of silica ash as a stabilizing material to minimize the desiccation crack in compressed soil liners and covers. For experiments, the expansive soil and micro silica were mixed in dry state. The content of silica powder were used at the percentage of 5, 10, 15, 20, 25, 30, and 50 by the total dry weight of silica fume -clayey soil mixtures. The experiments were done as per ASTM standards; SPT test as per ASTM-D-698, standard Odometer test as per ASTM-D-2435. Cracking experiments were used to observe the formation of desiccation cracks in established samples of expansive soil and soil–silica powder admixture. Before the cracking checks, soil was compacted to the ideal water content at compression testing machine. To achieve optimum moisture of the compressed soil, cracking test were attempted to calculate the permeability undergoing hydrostatic pressure as per ASTM-D-5084. Few other properties like, the specific surface area (SSA) and cation exchange capacity (CEC) of expansive soil and soil–silica additive were established with the help of ethylene glycol and ammonium acetate.

Table 4: Impact of micro Silica fume on engineering properties of clayey soil

	Parameters	Results
GEOTECHNICAL PROPERTIES	CEC and SSA	With the increment in content of silica, CEC and SSA decrease reason being the decrement in content of relative clay minerals in the samples. Silica content's optimal value is 25 percent
	Compactions parameters	For same compaction effort, a decrement in the MDD is seen in the mixture of expansive soil due to silica fumes
	Dessication crack development	A decrement in the development of dessication cracks was found at the surface of the mixture of clayey soil and silica fumes due to silica fumes. Silica content's optimal value is 25 percent
	Void-ratio effective stress relationship	Due to reaction silica fume with clay content, and addition materials of low plastic a decrement in the compressiblity of composite samples was found
	Swelling percentage	For the mixture of clayey soil and silica fumes conatining 30 and 50 percent contents of silica fume a decrement from 18.7 to 2.7 percent was found in the vertical swelling percentagein the sample mixture of clayey soil and silica fumes
	Hydraulic conductivity	With increment in silica fume content a decrement in values of hydraulic conductivity was found, and in composite soil whi contain 25 & 30 percent silica contents low values were finally reached

Ekrem Kalkan et al(2009),studied the impact of micro silica on the geo-technic properties of granulated soil exposed to freezing and thawing. As compared to granulated soil samples, the test results indicate that stabilised granulated soil samples containing micro-silica have a higher tolerance to freeze and thaw effects. The silica fume decreases the effects of freezing and thawing cycles on the unconfined compressive strength and permeability.

For compressed granulated soil in landfill liner and covering system, freez-thaw damage is one of the most serious issues. Freeze thaw processes limit the strength and longevity of the material. The most frequent effects of freeze thaw disruption are cracking and spalling. Ekrem Kalkan, in this paper, presents the impact of addition of micro silica in geo-technic properties of granulated soil such as hydraulic conductivity and compression strength. The research samples were made by combining dry granulated soil and micro silica with the appropriate amount of water to achieve the desired moisture content. Five samples at the percentage of 0, 10, 20, 25 and 30, micro silica content in fine-grained soils were prepared. The experiments were done as per ASTM standards; SPT test as per ASTM-D-698, The research samples were made by combining dry granulated soil and micro silica with the appropriate amount of water to achieve the desired moisture content, Atterbergs limit as per ASTM-D-4318, compression strength as per ASTM-D-2166. Plasticity index and liquid limit values were observed to reduce, on both stabilised samples, the plastic limit values rise as the silica fume content rises. Freeze-thaw tests were attempted on a programmable apparatus. Freeze thaw experiments were performed on the natural and stabilised granulated soil samples in compliance with ASTM-C-666. Both samples were put in the freezing chamber and conditioned for 2.30 hours at 18 °C. After the samples were frozen, they were moved from the freezing apparatus to a control room where they were held at temperature of 20 °C for 2.30 hours. Freeze-thaw cycle will be performed 20 times.

There were an increment in the optimum water content and reduction is seen in maximum value dry density with the added value of micro silica. Optimal micro silica amount was seen at 30percent of silica powder. Tests for different samples were also performed for before and after freeze-thaw cycle. Summary of results presented in Table-5 –

Table 5: Impact of Micro- Silica on UCS and Permeability

Parameters	Unconfined Compressive Strengths(UCS)	Permeablity
Before freez and thaw cycle	when amount of Micro silica content increases, the value of UCS also increases. Silica content's optimal value is 30 percent.	With increase in amount of silica content there is a reduction in permeablity. Silica content's optimal value is 30 percent.
After freez and thaw cycle	when amount of micro silica content increases UCS also increases. Silica content's optimal value is 30 percent.	With increase in amount of silica content there is a reduction in permeablity. Silica content's optimal value is 30 percent.

Ekrem Kalkan (2011), investigated the adjustment of black clayey soil by means of a valuable admixture which shows the impact on swelling characteristics by drying and wetting cycles. All prepared samples of soil-silica mixture and soil were compressed at the optimum value of water and were lay open for wetting and drying cycles along with swelling tendency. Silica was used at the dosages of 10%, 20%, 25% and 30% by the total weight of silica-clayey soil blend. The samples were kept in water for 48h. After draining the water, prepared samples were shifted to the laboratory for testing from the odometer apparatus. The samples were air-dried at 22 °C to acquire initial water content. The prepared samples were dry for five days after they prepared and collected by weight. The odometer apparatus was refilled with the cured clayey soil and natural dried soil samples from the consolidation cells, and then soaked in water for 48 hours to swell. Inside consolidation cells, consolidated expansive soil and natural soil were imposed to five cycles of alternative drying and wetting in these experiments. The results showed that increasing silica fume by about 30% decreased the plasticity index and liquid limit values. On the other side, the plastic limit to some extent shows increment on adding silica content. Under the same compression effort, adding silica-fume decreased maximal dry weight contents while increasing optimum moisture values. The swelling potential and swelling pressure values decreased with rising silica fume amount, finally reaching less values in stable sample with 25% - 30% silica fume amount.

Ekrem Kalkan et al(2013), has investigated the adaptability of materials like scrap tire rubber in the form of fiber and silica fume in geotechnical area where he evaluated the impacts of mix of materials on unconfined compressive strength (UCS) and other factors like swelling pressure, hydraulic conductivity, cohesion, and internal friction angle of clayey soils. Silica fume used was about 10 and 20 % by the total weight of mixture. The scrap tier fiber was taken as 1.0%, 2.0%, 3.0%, 4.0% of total weight of mixture. Then, soil sample and mixture to be added at the ideal humidity content. The outcomes showed that the mixture of materials improved the compression strength (UCS) and related strength constraints. Though the increase in content of fiber will decrease the swelling and increase the Hydraulic gradient. It was also found that the Micro Silica-fiber mixture and modified silica diminished the swelling pressure and hydraulic conductivity. The extreme UCS value was found at 2% fiber mixture- 20% silica fume. The highest internal angle of friction and cohesion values was reached by adding 2% fiber mixture-20% silica fume. The swelling and hydraulic gradient diminished on increasing the fiber-silica mixture. Scanning electron microscopy observations shows possible improvement in raw soil with comparison of modified clay sample.

Ankur Mudgal, A.K.Sahu (2014), examined the influence of stone dust and Lime in the Clayey soil. A combination of Stone dust and Lime were used to enhance the strength of black clayey soil. First an optimum value of lime was discovered, standard proctor test was done on soil samples mixed with lime (by weight percentage of lime 3,6,9,12 %) and Maximum Dry Density was found to estimate the optimum percentage of lime which was found out to be 9%. After the stone dust was added 5,10,15,20,25 % by weight to black soil-lime mix. After this MDD, OMC, Unconfined Compaction Test, California Bearing Test tests were done. To study the morphological and mineralogical characterization Scanning Electron Microscopic (SEM) and X-Ray Diffractometer (XRD-analysis) was done respectively. During the experiment it was found out that with varying stone dust mix (5,10,15,20,25%) the MDD value increases till 20% beyond that the in increase in stone dust had a negative effect on mix sample. Same results were reported for CBR and UCS test. It was concluded that the optimum value for lime mix was at 9% and for stone dust was at 20%. SEM test results reported that the sample mix had undergone pozzolanic reaction and cementitious compounds were formed, XRD-analysis results reported the formation of ettringite which reduced swelling tendency of the soil.

Similarly, other studies has been listed in the table below:-

Sr. No.	Sources	Material (Content (%)	Optimal Content (%)	Findings
1	Kalkan & Akbulut (2004)	Silica Fume	25	Reduced Permeability, increased UCS, Liquid limit Increased,Plastic Limit Increased,OMC increased, MDD decreased
2	Ekrem Kalkan et al(2008)	Silica Fume	25	CEC,SSA incresed,Compressibility decresed,swelling decreased
3	Ekrem Kalkan et al(2009)	Silica Fume	25	Freezing and thawing resistance increased
4	Ekrem Kalkan (2011)	Silica Fume	25	pH increased and specific surface area,Cation exchange capacity Reduced, LL,PI decreased whereas PL increased, MDD decreased,OMC increased,swelling potential and swelling pressure decreased
5	Ekrem Kalkan (2013)	Scrap tire rubber fibre-silica fume (2%-20%)	20	Swelling Pressure reduced,Maximum UCS obtained by adding 20% silica fume-2% fibre, Shear strength Increased, internal friction angle and cohesion maximum values at 2% fibre -20 % silica Fume
6	Ankur,Rju,Sahu (2014)	Lime and Stone Dust	9	MDD Increased,UCS and CBR Increased,SEM shows Coarser bonded particles,X-Ray Diffraction shows montmorillonite, vermiculite in Black soil, , Dolomite calcite - lime, Quartz and Whewellite- stone dust
7	Dharan et al 2016	Waste Paper Sludge ash (4 to 12)	8	CBR increased by 5% - 25% at 14D, UCS increased from 150 Kpa - 450 KPa at 28D.
8	Latifi et al (2017)	Calcium Carbide Residue (3 to 15)	9	At respective curing time of 7D, 28D, and 90D, the UCS of natural soil increased by around 250 percent, 1000 percent, and 1800 percent.
9	Siva-subramani (2017)	Egg Shell Powder (3) , Sugarcane bagasse ash (5-25)	25	After a comparative study of subgrade using improved and unimproved soils, CBR rose from 0.58 percent to 12.23 percent, and cost savings of 23.4 percent was achieved.
10	Shukla et al (2016)	Micro Fine Slag (3 to 15)	6	UCS enhanced upto 325 percent, unsoaked CBR improved till 186 percent, at 7 days, therefore Very less improvement seen in soaked CBR value.
11	Gobinat et al(2016)	Amorphous Silica (10 to 70)		At 10% Silica content, UCS reached to its maximum value, unsoaked CBR also enhanced, but soaked CBR attained its maximum value at 50% of silica content, and the consolidated value increased.
12	Butt (2016)	Saw-Dust Ash (4 to 12)	4	unsoaked CBR increased upto 103%, UCS improved upto 26%
13	Anupam (2014)	Rice Husk Ash (5 to 35)	25	The tests were carried out over a range of curing times (7, 14, 28, 56, and 128 days), and the findings all followed a similar pattern. Resilient modulus was improved by 94.5 percent while the stress strength ratio was 0.5 to 0.8, and the UCS improved upto 94 percent, cohesion enhanced upto 31 percent and angle of frictionenhanced by 150 percent, tensile strength was also improved from 15 to 23.5 KPa.,The CBR value improved from 2 to 13 percent at 28D.

14	Negi (2013)	Silica Fume		Increased CBR,UCS,Differential Free Swell Reduced from 50% to 7%, MDD decreased,OMC increased
15	AL-Sharif et al (2000)	Sewage Sludge Ash (2.5 to 15)	7.5	7D curing raised UCS slightly, while swelling pressure decreased by 60%, and No changes in UCS are seen at 28 days.
16	Modak P.R. et al (2012)	Lime and Fly Ash		CBR and MDD is Increased
17	Sharma et al (2012)	Blast furnace slag (10 to 90)	20	The original tangent modulus improved from 20 Mpa - 60 MPa, and the UCS increased by around 100% at 28 D.
18	Nadgouda et al (2010)	Lime	3.5	CBR and Mdd incresed

The table provides a detailed summary of various studies focused on the effects of adding different materials to soil and their optimal content percentages to achieve improved geotechnical properties. For instance, Kalkan & Akbulut (2004) investigated the use of silica fume at an optimal content of 25%, finding that it significantly reduced soil permeability, increased unconfined compressive strength (UCS), liquid limit, and plastic limit, while also increasing the optimum moisture content (OMC) and decreasing the maximum dry density (MDD). Similarly, Ekrem Kalkan et al. (2008) observed that incorporating 25% silica fume led to increased cation exchange capacity (CEC), specific surface area (SSA), reduced compressibility, and decreased swelling. Another study by Ekrem Kalkan in 2009 found that the same 25% silica fume content enhanced soil's resistance to freezing and thawing cycles. In 2011, Ekrem Kalkan reported that 25% silica fume increased pH and specific surface area while reducing cation exchange capacity, liquid limit, and plasticity index, and simultaneously increasing plastic limit, OMC, and reducing MDD, swelling potential, and swelling pressure.

Further research by Ekrem Kalkan in 2013 examined a combination of scrap tire rubber fiber (2%-20%) and silica fume (20%) and discovered that this mixture reduced swelling pressure and achieved maximum UCS with 20% silica fume and 2% fiber, enhancing shear strength, internal friction angle, and cohesion. This comprehensive data underscores the diverse materials and optimal content percentages that can be employed to significantly improve soil properties for various geotechnical applications.

MATERIAL AND METHODOLOGY

The following flowchart shows the step by step process of material collection, selection determination of necessary properties and implement it using various percentage of additives.

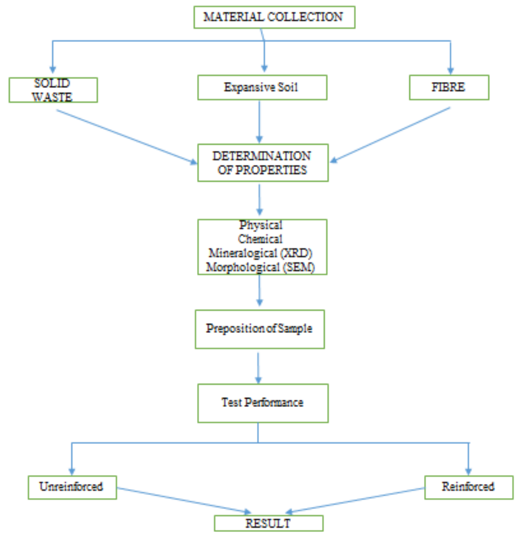

Figure 1: Flow Chart

CONCLUSION

Expansive soil is highly available in india but due to its swelling and shrinkage property it cannot be used directy in raw for making any structure. After applying several remedies to black

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CONFLICTS OF INTEREST

The authors declare no conflict of interest

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