A Critical Review on Enhancing Soil Properties Using Quarry Dust and Sisal Fibre

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Abstract: With the advancement in industrialization various wastes have been generated as a by-product of advancement like fly ash, quarry dust, GGBFS, kiln dust, bagasse ash, rice husk and many more. The aim of the study was to review on the soil stabilization using various waste material and analyse qualitatively to reach at the optimum values (amount and percentages) of the waste materials along with using soil reinforcement techniques i.e. using various fibrous materials which enhance engineering properties of soil providing required reinforcement to the soil. This study helps in understanding the type and amount of various waste materials used for soil stabilization without compromising on the strength parameters and cost effectiveness.

IndexTerms **- Soil stabilization, Fly ash, Quarry dust, Sisal fibre, GGBFS, CBR, OMC and MDD.**

I. Introduction

Due to exponential growth in urbanization, industrialization and technological advancement makes the world a better place to live in while on the other hand poses various problems to the human beings. Like due to population growth, the need for their shelters booms the civil engineering and different structures have been built for their needs, due to which land scarcity problem occurs. While dealing with soil and foundation engineering we encountered with expansive soil which have low strength and shows swelling and shrinkage behaviour when comes in contact with water. Having working with such soil we left with two options i.e. either replace the soil with some good quality soil (which itself is a tedious work) or enhance the in-situ soil properties. So there comes a need to use any of the industrial wastes along with the soil to enhance its engineering property which serves the two way purpose of soil stabilization and optimum utilization of industrial wastes. Soil stabilization can be done by any of the following methods i.e. Physical, Mechanical and Chemical method. Physical method reduces the swell potential without effecting the soil chemistry while other methods chemically and structurally changes in the soil geometry.

Soil stabilization: Stabilization is defined as the process of improving soil aggregate properties by blending in the materials that increases the load carrying capacity, firmness and resistance to weathering or displacement. It can be defined as the process of altering soil properties by mechanical or chemical means thereby improving the desired engineering properties of such soils. It has been used from many years to improve the characteristics of the sub grade having problematic soil. Different types of soil treated with different techniques and amount of stabilizing agents have been investigated by many researchers over the years. Soil stabilization can be achieved by any of the methods explained in Figure 1.

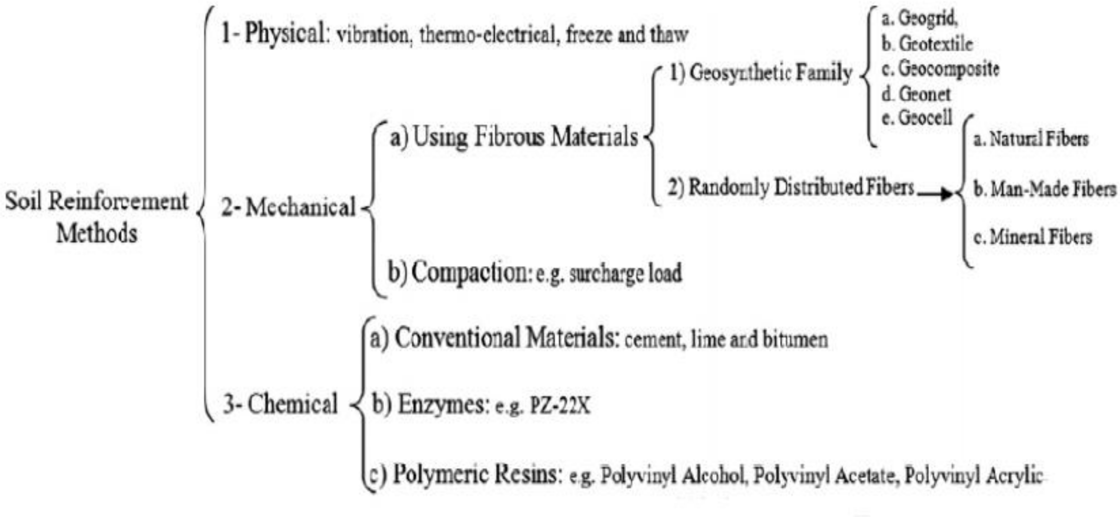

Figure 1: Methods for achieving soil stabilization

Literature Review

Literature survey helps in conceptualises the problems and gaps in the concerned area of study. It contains the information of problems being studies and gives idea for the future scope of study. The review describes and summarise the literature. The literature review has been described and summarised in the table form.

Krishna and Sayida [1] (2009) used black cotton soil mixed with fibres cut to different lengths (1.5cm, 2.0cm, 2.5cm and 3.0cm) and in varying percentages (0.25%, 0.50%, 0.75% and 1.00%) by dry weight of soil and compacted to MDD at OMC indicated a reduction in the MDD and the OMC of soil due to the addition of sisal fibre. It also indicated an improvement in the CBR value and UCS of soil due to the addition of sisal fibre. The optimum CBR value and UCC value were obtained for 2.5cm length of fibre with 0.50% fibre content.

Nwaiwu et. al. [2] (2012) experimented the effect of quarry dust on improving the properties of black cotton soil. Quarry dust (10%, 20%, 30%, 40% and 50%) was mixed with soil and tested for MDD, CBR, Swell potential and Atterberg limits. It was found that with the increase in quarry dust percentage swell potential and swelling pressure decreases. Plasticity index also decreases with increase in dust percentage. MDD and CBR values increased with the increase in quarry dust percentage which provided a clear idea of soil stabilizing properties of quarry dust.

Manjunath and Venugopal [3] (2013) investigated the effect of sisal fibre on the strength and compaction characteristics of lime treated black cotton soil. The fibre length 10 mm randomly mixed with soil in varying percentages (0.25%, 0.5%, 0.75% and 1%) with 3% lime by dry weight of soil. The varying percentages of sisal fibre reinforced with 3% lime treated soil increased the MDD and OMC value. Addition of various percentages of lime to black cotton soil gave increase in the CBR value upto 3% and further addition of sisal fibre gave increase in CBR for 0.75% sisal fibre content. Hence, the combination of 3% lime and 0.75% sisal fibre gave more increased value than addition of lime and sisal fibre individually. Thus, 3% of lime content and 0.75% of sisal fibre were considered as optimum percentages for black cotton soil to increase the UCS and CBR value.

Raneesh. K.Y, Mathew [4] (2013) studied bagasse ash and waste glass powder which were randomly mixed with soil in varying percentages (3.5%,7%, 10.5% and 14%) and (7%, 14%, 21% and 28%) respectively.

The fibres were cut into pieces of 15mm to 20mm length and were randomly mixed with soil in varying percentages (0.3%, 0.6%, 0.9% and 1.2%) by dry weight of soil. The results indicated that with addition of sisal fibre, bagasse ash and glass powder waste the dry density increases and optimum moisture content decreases. The unconfined compressive strength and California bearing ratio values increased with addition of optimum percentage of sisal fibre, bagasse ash and glass powder waste to the mixture of black cotton soil. The best result was obtained for mixture of black cotton soil and optimum dosage of 0.3% of sisal fibre, 7% bagasse ash and 14% glass powder waste. At 0.3% replacement of SF, the UCS value increased from 113.114 kPa to 142.021 kPa, at 7% replacement of bagasse ash, the UCS value increased from 113.114 kPa to 122.935 kPa and for 14% replacement of glass powder waste, the UCS value increased from 113.114 kPa to 154.439 kPa. The CBR value at 0.3% sisal fibre was found to be 2.43 times of the CBR value of virgin soil. The CBR ratio at 7% bagasse ash was found to be 1.86 times of CBR value of virgin soil and the CBR ratio at 14% glass powder waste was found to be 3.36 times of CBR value of virgin soil.

Wu et al. [5] (2014) investigated the mechanical properties of randomly distributed sisal fibre reinforced soil at sisal fibre percentages of 0.5%, 1% and 1.5% having 5 mm, 10 mm and 15mm length. Soil sample was prepared by varying percentages of sisal fibre and varying lengths and tested in triaxial test apparatus. From the test data, it was inferred that stress – strain curve performed as strain hardening. It was reported that the peak of the principal stress difference of the sisal fibre reinforced soil was related to the fibre length, fibre content and confining pressure. There was considerable improvement in the shear strength of reinforced soil of 10mm long fibre as compare with reinforced soil of 5 mm and 15 mm long fibre. Bearing capacity of reinforced soil was improved upto a sisal fibre content of 1%. The work suggested the optimum percentage (1% and 10 mm length) usage of sisal fibre for enhancing the properties of weak soil.

Jayapal et. al. [6] (2014) conducted a comparative study on the use of different admixtures for weak soil stabilization. The various admixtures taken were Fly ash (10%, 20% and 30%), Lime (2%, 5% and 8%) and Quarry dust (10%, 20% and 30%). Modified proctor test, CBR test, Differential free swell tests were conducted on different percentages of various admixtures. It was resulted that the improved values of various parameter comes at 30% of quarry dust proportion, 30% of fly ash content and 8% lime content when each admixture was tested individually in varying percentages.

Jiesheng et al. [7] (2014) performed a comprehensive study on the effect of adding sisal fibre on the properties of clay. The varying percentages of sisal fibre taken were 0.2%, 0.4%, 0.6% and 0.8% by dry weight of soil and were of 10mm length. From the shear strength and UCS point of view 0.6% of sisal fibre content gave the maximum values of these parameters. Sisal fibre works as reinforcement which redistributes the stress distribution more evenly and increased the deformation resistance of clay. In SEM test, result showed that the sisal fibre was damaged partially when the sample was tested. Optimum fibre content was reported as 0.6% by dry weight of soil.

Abhijith and Aruna [8] (2015) conducted the experimental study to find the effect of ground granulated blast furnace slag (GGBS),(10%, 20%, 30%, 40%) and Sisal fibre (0.25%, 0.5%, 0.75%, 1%, 1.25%,1.5%) on mechanical properties of black cotton soil. Initially the basic properties of black cotton soil and sisal fibre were found out. The first phase of the work stressed upon the effect of GGBS on compaction characteristics of black cotton soil. The next phase focused on the unconfined compressive strength and CBR values of mixture of black cotton soil and optimum dosage of GGBS randomly mixed with varying percentage of sisal

fibres. The work also focused on change in unconfined compressive strength and CBR value with curing period. The results indicated that with addition of GGBS to black cotton soil the maximum dry density increased and optimum moisture content decreased. Up on addition of GGBS to BC soil the density of BC soil increased from 13.15KN/m3 to dry unit weight was maximum corresponding to 20% GGBS when compared with other percentages of GGBS. UCS strength of BC soil found to be 134.593 KN/m3 which was increased to 530.712kn/m3 upon addition of 20% GGBS and 0.75% SF, UCS strength has increased 4 times that of BC soil alone. From the whole study it was concluded that 0.75% SF and 20% GGBS was optimum dosage for BC soil used in present study.

Naman Aggarwal [9] (2015) mixed stone dust in soil collected from G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand in a varying percentages of 10%,20%.,30%,40% and 50% by dry weight of soil. The maximum dry density was found to increase and optimum moisture content was found to decrease with the increase in the percentage of stone dust. The value of specific gravity increases in a nearly linear fashion upto 30% stone dust addition and then gradually decreases. Adding about 30% stone dust resulted in increase in the CBR value of about 50% beyond which CBR falls down. Thus about 30 % stone dust could be effectively used to enhance the geotechnical properties of soil.

Venkateswarlu et al. [10] (2015) studied the strength parameters of expansive soil using quarry dust (5%, 10% and 15%). With the addition of quarry dust, differential free swell index decreases. Shear strength parameter such as cohesion decreased from 16 kn/m2 to 4 kn/m2 and angle of internal friction increased from 19º to 29º with the addition of 10% quarry dust. The soaked CBR increased from 1.2 to 6.7 at 10% quarry dust. From the cyclic load test it was observed that load carrying capacity increased upto 10% quarry dust addition. This experimental work suggested 10% quarry dust as optimum percentage for enhancing the properties of weak soil.

Venkateswarlu et al. [11] (2015) presented the variation of index and engineering properties of expansive soil, compaction characteristics, CBR and shear strength when it was mixed with different percentages (0%, 5%, 10% and 15%) of quarry dust by dry weight of soil. From the test results it was observed that liquid limit and plastic limit value decreases with the increase in percentage of addition of quarry dust. Dry density attained its maximum value at 10% quarry dust and OMC goes on decreasing with increase in percentage of quarry dust. It was found that cohesion and unsoaked CBR goes on decreasing and increasing respectively with increase in percentage of quarry dust which concluded that quarry dust upto 10% could be utilized for strengthening the expansive soil with a substantial save in cost of construction.

Dixit and Patil [12] (2016) collected two different soil samples and stone dust samples each from two different locations of Maharashtra state. Samples were prepared using soil- stone dust ratios of 100:0 to 40:60 at an interval of 10%. With the successive increase in the percentage of stone dust, plasticity index decreased. From the compaction study it was concluded that the maximum dry density increased and optimum moisture content decreased with increase in the stone dust percentage. The CBR value of soil- stone dust sample of 40:60 was found to increase about 170% of the CBR value of virgin soil. Hence, stone dust was effectively used for improving the properties of expansive soil.

Shrithi S Badami [13] (2017) evaluated the index properties and strength behavior of Black cotton soil when stabilized with sisal fibre by varying the percentage of sisal fibre from 0.2 % to 0.8% by dry weight of the soil at the interval of 0.2% and also varying the length from 2.2 to 2.8 cm at the interval of 0.2 cm. It was resulted that for a particular length of sisal fibre the value of maximum dry density increased and optimum moisture content decreased with the varying percentages of sisal fibre upto 0.6 % giving the max value of MDD at 0.6 % sisal fibre of length 2.6 cm. In respect of strength parameter the UCS value also increased in the same pattern as of MDD and OMC giving maximum UCS value of 256 kN/m2 at 0.6 % sisal fibre of length 2.6 cm. Also, the swell index was minimum for 0.6 % sisal fibre of length 2.6 cm. Hence, it was concluded that the optimum dosage was 0.6% sisal fibre having length 2.6 cm gave best strength results.

Sandyarani and Patil [14] (2018) stabilized the black cotton soil using varying percentages of lime (2%, 5% 9% and 12%) and sisal fibre of varying percentages of 0.2%, 0.5%, 0.9% and 1.2% with fibre length varying from 3cm, 3.2cm and 3.4 cm. In the first phase compaction test, CBR test and UCS tests at 1, 3 and 7 days curing period were conducted on varying percentages of lime only and it was resulted that soil attained maximum dry density, CBR and UCS values at 9% lime content. Taking 9% lime content further tests were conducted with 3.4 cm sisal fibre length (3.4cm length was selected based on highest aspect (l/d) ratio) and varying percentages of sisal fibre. With 9% lime and 0.5% sisal fibre of length 3.4cm, MDD, CBR and UCS parameter attained their maximum values out of the varying percentages of sisal fibre. Thus, it was concluded that 9% lime with 0.5% sisal fibre of length 3.4cm stabilized the black cotton soil effectively.

Mathada et al. [15] (2018) stabilized the black cotton soil with sisal fibre taking in varying percentages of 0.2, 0.5, 0.9 and 1.2 and varying lengths of 3cm, 3.2cm and 3.4cm. For a particular fibre length MDD maximized at 0.5% sisal content and maximum MDD comes for 3.4cm length. Other parameters like CBR & UCS values attained their maximum values at 0.5% sisal of 3.4 cm length which optimized the use of 0.5% sisal fibre of 3.4cm length for 99stabilization purpose.

Almajed et al. [16] (2018) worked on the enzyme induced carbonate precipitated (EICP) treated soil with the inclusion of two different lengths (10 mm and 20 mm) of sisal fibre at fibre ratios of 0.2%, 0.3%, 0.4%, 0.75% and 0.85%. EICP precipitates changed the mechanical properties of treated soil through binding particles together, roughening particle surfaces and filling pores. UCS samples were prepared of EICP treated soil with varying percentage and length of sisal fibre. At optimized fibre content of 0.3% and 10 mm length, strength increased by 4 times the strength of treated soil without reinforcement.

Dixit and Patil [17] (2016) collected two different soil samples and stone dust samples each from two different locations of Maharashtra state. Samples were prepared using soil- stone dust ratios of 100:0 to 40:60 at an interval of 10%. With the successive increase in the percentage of stone dust, plasticity index decreased. From the compaction study it was concluded that the maximum dry density increased and optimum moisture content decreased with increase in the stone dust percentage. The CBR value of soil- stone dust sample of 40:60 was found to increase about 170% of the CBR value of virgin soil. Hence, stone dust was effectively used for improving the properties of expansive soil.

The summary of all literature in nutshell is presented in Table 1. The table critically categorized whole literature in different parts indicating author name, year of publication, techniques and methods adopted by different researchers on sisal fibre and quarry dust to stabilize soil and their remarks. This table will further help other researchers to understand various literature in easy way.

Table 1: Summary of Literature Review

Author name and year	**Materials used**	**Test/ Technique or Method used**	**Remarks**
Krishna and Sayida [1] (2009)	Black cotton soil, sisal fibres.	Proctor test, UCS and CBR	Different lengths and varying percentages of sisal fibres are tested with soil and optimum UCS and CBR values were obtained with 2.5 cm length with 0.50% fibre content.
Nwaiwu *et. al.* [2] (2012)	Black cotton soil, quarry dust.	Proctor test, CBR and swell potential.	With the increase in quarry dust percentages swell potential and swell pressure decreased, plasticity index decreased and MDD and CBR values increased.
Manjunath and Venugopal [3] (2013)	Lime treated black cotton soil, sisal fibre	Proctor test, UCS and CBR.	With increase in the content of lime and sisal fibre individually MDD, UCS and CBR values gets increased. Best results were given by 3% lime content and 0.75% sisal fibre content of 10 mm length.
Raneesh. K.Y, Mathew [4] (2013)	Expansive soil, bagasse ash, waste glass powder, sisal fibre	Proctor test, UCS and CBR.	With addition of sisal fibre, bagasse ash and glass powder waste MDD increased and OMC decreased. Best results were obtained with 0.3% of sisal fibre, 7% bagasse ash and 14% glass powder waste. CBR value at 0.3% sisal fibre content increased 2.43 times the CBR value of original soil.
Wu et al. [5] (2014)	Expansive soil, sisal fibre	Triaxial test	Peak of the principal stress difference of fibre reinforced soil was related to the fibre length, fibre content and confining pressure. The work suggested the optimum percentage (1% and 10 mm length) usage of sisal fibre for enhancing the properties of weak soil.

Jayapal *et. al.* [6] (2014)	Fly ash, lime, quarry dust	Modified proctor test, CBR test and differential free swell tests.	Improved values of various parameters comes at 30% of quarry dust proportion, 30% of fly ash content and 8% lime content when each admixture was tested individually in varying percentages.
Jiesheng *et al.* [7] (2014)	Clayey soil, sisal fibre	Proctor test, UCS and SEM test.	From the shear strength and UCS point of view 0.6% of sisal fibre content gave the maximum values of these parameters. In SEM test, result showed that the sisal fibre was damaged partially when the sample was tested. Optimum fibre content was reported as 0.6% by dry weight of soil.
Abhijith and Aruna [8] (2015)	Ground granulated blast furnace slag, sisal fibre and black cotton soil.	Proctor test, UCS and CBR.	With the addition of GGBFS, MDD increased and OMC decreased. With the addition of GGBFS in the increment of 10%, maximum MDD value corresponds to 20% content. 20% GGBFS and 0.75% sisal fibre gave optimum results in terms of UCS and CBR values.
Naman Aggarwal [9] (2015)	Stone dust and expansive soil.	Proctor test and CBR.	MDD was found to increase and OMC was found to decrease with the increase in the percentage of stone dust. Adding about 30% stone dust resulted in increase in the CBR value of about 50% beyond which CBR falls down
Venkateswarlu *et al.* [10] (2015)	Expansive soil and quarry dust.	Free swell test, cyclic load test and CBR.	With the addition of quarry dust, differential free swell index decreases; cohesion value decreased and internal friction value increased. Soaked CBR value also increased at 10% quarry dust content.
Venkateswarlu *et al.* [11] (2015)	Quarry dust and expansive soil.	Compaction test, CBR and shear strength tests.	Liquid limit and plastic limit value decreased with the increase in the value of quarry dust. MDD attained at 10% content of quarry dust. Unsoaked CBR also maximized at 10% quarry dust.
Dixit and Patil [12] (2016)	Stone dust and expansive soil	Compaction test and CBR.	It was concluded that soil- stone dust ratio of 40:60 gave the maximum value of MDD and CBR.
Shrithi S Badami [13] (2017)	Black cotton soil, sisal fibre	Compaction test and UCS.	When soil was mixed with varying length and percentages of sisal fibre, it was found that at 0.6% of sisal of length 2.6 cm gave maximum values of MDD and UCS.

Sandyarani and Patil [14] (2018)	Black cotton soil, sisal fibre and lime.	Compaction test, CBR and UCS.	Soil was tested with varying % and lengths of sisal fibre and it was concluded that at 9% lime and 0.5% sisal fibre of length 3.4 cm gave the maximum values of MDD, CBR and UCS.
Mathada *et al.* [15] (2018)	Black cotton soil, sisal fibre.	Compaction test, CBR and UCS.	For varying % and length of sisal fibre; CBR, UCS attained their maximum values at 0.5% sisal of 3.4 cm length.
Almajed *et al.* [16] (2018)	Enzyme included carbonate precipitated treated soil and sisal fibre.	UCS	UCS samples were prepared of EICP treated soil with varying percentage and length of sisal fibre. At optimized fibre content of 0.3% and 10 mm length, strength increased by 4 times the strength of treated soil without reinforcement.

Conclusion:-

After going through the exclusive literature survey regarding the use of various waste materials for enhancing the engineering properties of soil following conclusions were made:-

1. The use of various waste materials like fly ash, quarry dust, sisal fibre etc can be effectively used for the improvement of expansive soil.
2. Various tested were conducted firstly for the optimization of quarry dust and then sisal fibre was added which further increase the engineering properties of soil, thus providing an optimum values of the materials for practical uses.
3. It is clearly understood that various waste materials have the ability to enhance the soil properties to make it useful for engineering purposes.
4. As far as environmental pollution is considered, eliminating waste from environment and using with soil serve the two fold purposes i.e. enhancing soil properties and proper utilization of waste materials.
5. Various studies showed that sisal fibre when mixed with varying percentages and lengths have ability to enhance the soil properties when used individually and along with other waste materials making it useful for engineering purposes.

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