Stabilization of Contaminated Soil by Mixing of Corn Husk Fibers

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Abstract: Soil contamination has always been a major cause for land degradation and deterioration of soil properties in various ways. Numerous activities involving the use of petrochemicals on a daily basis, accidents leading to oil spilling, and pipeline or reservoir leakage lead to the contamination of soil. In addition to this contamination is also leading to groundwater pollution, altering the geotechnical properties of soil. The uses of natural fibers incorporated soil as a construction material since ancient times, led to the understanding of the variations in soil properties and also the need to improve these properties to achieve desired construction proficiency. Thus with this view this research work deals with the improvement of compaction and strength characteristics of synthetic oil contaminated soil by random mixing of corn husk fibers at different percentages of 1%, 2%, 3% and 4% by weight of soil. The experimental study was conducted on soil samples which were prepared artificially by mixing synthetic oil at 5%, 10% and 15% by weight of soil. Index properties of soil were tested, then proctor compaction test and CBR tests were conducted in order to observe the changing pattern with the addition of corn husk fiber. Results showed marked improvement in compaction and strength characteristics of soil. The pH value of soil was also determined and results showed a remarkable change in soil characteristics from acidic in nature towards neutralization with addition of corn husk fiber.

Keywords: Stabilization; Contaminated soil; Corn husk fiber, pH value; CBR improvement.

1. Introduction

Contamination can lead to an accumulation of contaminants in soils. It may frequently cause damage to buildings, dams and highways etc. situated in those sites as well as can make the site unsuitable for developmental activities. The major chemicals implementing concern are petroleum hydrocarbons, polynuclear aromatic hydrocarbons (such as naphthalene and benzo(a) pyrene), solvents, pesticides, lead, and other heavy metals. Contamination is directly proportional to the degree of industrialization and severity of chemical substance. The emphasis over soil contamination stems primarily due to health risks either from direct contact with the contaminated soil, or vapors from the contaminants, also the water bodies and supplies within and underlying the soil can get contaminated.

Air, water, and land are being contaminated for short-term benefits by industrial, petrochemical, construction, and sanitary activities. Considering land contaminations, environmentalists are concerned about subsurface water aquifer contaminations, plant growth in contaminated soil, and environmental and health hazards. Nevertheless, geotechnical experts are continuously studying and experimenting the effects of soil contamination on the geotechnical properties of the soil. The soil-bearing capacity, foundation settlement, shear resistance, compressibility, and plasticity are the factors that must be taken into consideration.

Synthetic oil is a lubricant composed of chemical compounds which are artificially made. The exact process of synthesizing and composition of different additives is generally a commercial trade secret and vary among producers.

Synthetic oil is used as a replacement for petroleum-refined oils when operating in high temperatures. Hydrocarbons present in synthetic oil reduce permeability and in turn reduces the strength and compaction characteristics of natural soil.

Since ancient ages, many natural materials were recognized for use as reinforcement, in soft soils. There are evidences of the use of woven mats made of reeds in temples of Babylonia, the use of tree twigs with leaves (as tensile elements) in construction of Great Wall of China, uses of straw and hay to reinforce mud blocks and bamboo thatch in mud walls in India. In Kerala, there is an age old practice of spreading coconut leaves over sub-grades. Also stolons of trees were laid on soft marshy soils to facilitate walking in some developing countries.

However intensive research started in early 1950s to find means of utilizing the accumulating end products during fractional distillation of crude oil refineries for gainful use and eliminating disposal problem for such end wastes. In the process polymeric materials like poly amide, polyeyhelene, etc. were developed for making synthetic fibers. Worldwide research started to develop methods of using such material for improving soil properties to desired levels. Thus the concept of geosynthetics originated. The success of man-made geosynthetics was completely based on vigorous research, studies and trials and its growth has been remarkable over the last five decades. The concept of reinforcing soil with inclusion was given by French architect-engineer Henri Vidal in 1963 and was employed in construction of retaining walls which were reinforced by inclusion of linear strips placed horizontally. Later this concept was verified in 1969 by Vidal and Schlosser in LCPC cohesion theory, also Hausmann (1976) proposed Sigma model and Tau model, dealing with bond and tensile failure of soil with reinforcement. Since then the concept of reinforced earth has been well established and present conventional reinforcement methods consist of inclusion of fibers, strips, grids into the soil mass for improving the bearing capacity, filter and drainage control in soils etc. Recently, methods of random mixing of various types of fibers have attracted increasing attention in many geotechnical applications like airfield construction. In fact use of geosynthetics in civil engineering heralded a new revolution in civil engineering.

However presently, the market is dominated by synthetic geotextiles, but it has certain disadvantages compared to natural geotextiles. They are:

i. Synthetic geotextiles are not eco-friendly, particularly where they are laid open to sunshine/ atmosphere.
ii. The products are not renewable

iii. Increasing price of polymeric raw materials, due to the diminishing amount of available crude in earth, leads to increase in the overall cost of geotextiles.

Thus the need of an eco-friendly, renewable, abundantly available and economically viable alternative became important in environ conscious and economically backward countries. As a result, search for suitable natural geotextiles have been important. In the last two decades reports on soil used with different natural geotextiles made from natural fibers are in evidence. Many natural fibers have been identified and experimented for possible use in construction.

Mainly geotextiles made from jute, coir, sisal are commonly been tested and used. Some of the basic advantages of such geotextiles are:

i. High moisture absorbing capacity
ii. High initial tensile strength
iii. Low extension at break
iv. Bio degradable, soil nourisher
v. Renewable resource , easily available
vi. Economic and eco- friendly

Researches and experiments have been conducted by using the method of random mixing of natural fibers in order to improve the properties of contaminated soil. Though no extensive work have been reported using corn husk fibers in synthetic oil contaminated soil.

2. Literature review

Extensive research work has been reported for improving the properties of contaminated soil by different stabilization methods. They are as follows:

i. Al-Sanad et al. (1995)[1] and Al-Sanad and Ismael (1997)[2] conducted laboratory testing programs to evaluate the influence of oil contamination and aging effects on the geotechnical properties and behavior of Kuwaiti sand.
ii. Aiban (1998) [3] studied the effect of temperature on the strength, permeability, and compressibility of oil-contaminated sand obtained from eastern Saudi Arabia. He found that the compressibility and permanent deformation of the oil-contaminated sand increased as the temperature increased above room temperature and that the shear strength parameters were not sensitive to the testing temperature.
iii. Evgin and Das (1992) [4] conducted triaxial tests on clean and oil-contaminated quartz sand. They found that full saturation with motor oil caused a significant reduction in the friction angle of both loose and dense sands and a drastic increase of the volumetric strain. They also showed through a finite-element analysis that the settlement of footing increased due to oil contamination.
iv. A laboratory testing program was performed to determine the effects of crude oil contamination on some of the geotechnical properties of clayey and sandy soils from the coastal soils from Persian Gulf beaches by Khamehchiyan et al. (2007)[5]. Their testing program examined basic properties, Atterberg limits, compaction, direct shear, uniaxial compression, and permeability on clean and contaminated soil samples that had the same density.

v. Ur-Rehman et al. (2007) [6] conducted another laboratory testing program to compare the engineering properties of uncontaminated and contaminated clay. They reported that the contaminated clay behaved more like cohesion less materials due to the formation of agglomerates. This contamination has been shown to affect the plasticity and the cation exchange capacity (CEC) of the investigated clay.

vi. Shroff (1997) [7] mentioned that physical, chemical, biological and thermal methods can be used for improvement of the strength of crude oil contaminated soil. The author reported that for best results to stabilize crude oil contaminated soil, the mixing of 10% lime, 10% cement and 5% attaptilgite clay may be used.

Some work has also showed the effective use of corn husk as a reinforcement material in soil. They are as follows:

i. The study by S.A Akinloye (2004), G.M Bankole (2004), and A. Medubi (2004) [8], assessed the effect of corn husk ash on the engineering properties of lateritic soil. The lateritic soil, which was modified with corn husk and lime as stabilizing agents, was obtained from Kuedenda along Kaduna- Abuja expressway, Kaduna. The optimum moisture content and maximum dry density of the laterite soil without stabilizing were 15.24% and 1.73 g/cm ^{3} respectively. The compressive strength was observed to be increased with curing age. Thus it was deduced that lateritic soil strength can be improved at 10% each for lime and corn husk.

ii. A study was conducted by Peter Paa Kofi Yalley (2014) [9] to investigate the potential of corn husk as an enhancer for the production of soil blocks for low cost housing. Five different levels of stabilization (0%, 5%, 10%, 15%, and 20%) using corn husk ash were adopted for this study. Fifteen blocks were moulded for each stabilization level. In all a total of 75 blocks were moulded and subjected to the compressive strength, abrasion resistance and water absorption by capillarity tests after curing 28 days and compared with the relevant standards of compressive earth blocks. In general, there was a significant improvement in the compressive strength characteristics of the stabilized soil blocks. Soil blocks mixed with 20 % corn husk ash had the highest compressive strength of 5.311 MPa followed by blocks with 15% corn husk ash with compressive strength of 4.917 MPa.

3. Scope of work

Studies made in literature review regarding the effect of natural fiber on contaminated soil, indicate that there are possibilities for improvement in the compaction, strength and pH characteristics of oil contaminated soil. Therefore, with the aim of getting more comprehensive results, corn husk fibers have been selected in this research work as inclusion in week cohesive soil for improving its compaction, strength and pH characteristics.

For this project work, local soil was collected from Dakhshin Gobindapur area (South 24 Parganas, West Bengal) and the sample was artificially contaminated by mixing synthetic oil (mobil) at different percentages i.e. 5%, 10% and 15% respectively by weight of dry soil sample. The samples were then put in plastic bags and were placed in desiccator for 24 hours. Since the soil was being artificially contaminated, therefore in order to optimize the experimental results, the soil was mixed with three different percentages of synthetic oil.

The corn husks were collected from Baruipur area (South 24 Parganas, West Bengal) and used as an inclusive and mixing material for studying its effects on compaction, strength and pH characteristics of the contaminated soil sample.

For vigorous study, the prepared soil samples were subjected to different routine testing in order to determine the index properties, compaction characteristics, California bearing ratio (CBR) value at optimum moisture content (OMC), as well as pH characteristics of the soil sample.

The experimental work was conducted by randomly mixing the corn husk leaves in the contaminated soil sample. The corn husk, were to be cut in three different sizes namely 1 cm x1 cm, 2 cm x 1 cm, 3 cm x 1cm & 4 cm x 1 cm. For each of these sizes, the fibers were to be mixed with dry soil in different percentages of 1%, 2%, 3% and 4% by weight of dry soil. OMC, MDD were to be evaluated and un-soaked as well as soaked CBR value at OMC value was to be found for each of these cases. The result of all these tests were to be utilized to see the effect of mixing corn husk fibers of a particular size, at a particular percentage by weight of contaminated soil, on compaction characteristics and un-soaked CBR values at OMC. For pH determination the corn husk fibers were grinded into a particle size similar to the soil particles and were mixed with the contaminated soil at different percentages of 2%, 4% and 6%.

4. Materials Used For Experiment

4.1 Soil Sample

The locally available soil was collected from Dakshin Gobindapur, South 24 Parganas, West Bengal. In order to artificially contaminate the soil, for further studies, the collected soil samples were mixed with different percentages of synthetic oil. The index properties of the prepared soil samples were conducted and the results are reported in table 1.

Table 1. Properties of the three contaminated soil sample

Soil properties	**Soil Contaminated with different percentages of Synthetic oil**		
	5% synthetic oil	**10% synthetic oil**	**15% synthetic oil**
Liquid limit	47%	40	32
Plastic limit	33%	29	19
Specific gravity	2.42	2.42	2.42
Sand	3.9%	3.9%	3.9%
Silt	68.5%	68.5%	68.5%
Clay	27.6%	27.6%	27.6%
Classification of Soil	Inorganic clay of low plasticity (CL)	Inorganic clay of low plasticity (CL)	Inorganic clay of low plasticity (CL)
OMC	17%	15%	11%
MDD	1.77g/cc	1.79	1.72
CBR (un-soaked)	4.5	4.4	4.0
CBR (soaked)	4.2	4.1	3.8

4.2 Corn Husk Fibers

The corn husks were collected from Baruipur area (South 24 Parganas, West Bengal) and used as an inclusive material for studying its effects on compaction and strength characteristics of contaminated soil sample. The physical properties of corn husk fibers are given in table 4.

Table 2. Physical properties of corn husk fibers

Properties	Values
Width	6 cm
Thickness	0.39 mm
Mass per unit area	3.1X10[illegible]n/mm²
Unit weight	5.1X10[illegible]/mm

5. Experimental results and discussion

The experimental work involves the random mixing of corn husk fibers of different sizes of 1cm, 2cm, 3cm and 4cm at varying percentages of 1%, 2%, 3% and 4% by weight of dry soil. For appropriate experimental results three different samples of contaminated soil was prepared. Sample 1 (S1), Sample 2 (S2) and Sample 3 (S3) were prepared by mixing dry soil with 5%, 10% and 15% of synthetic oil respectively. For each case of contamination, the soil sample was mixed with corn husk fibers of 1cm length were added at four different percentages i.e. 1%, 2%, 3% and 4% by weight of dry soil and standard proctor test was conducted to determine the optimum moisture content and maximum dry density for each case of percentage variation. Both un-soaked and soaked CBR was then conducted by conventional ways at the predetermined OMC by randomly mixing the date palm leaves at different percentages. Also, the prepared soil samples were mixed with grinded corn husk fibers at different percentages of 2%, 4% and 6% and their pH value were determined with a pH meter following the conventional test methods. The experimental results showing the OMC & MDD, CBR (both un-soaked and soaked) and pH values of the three soil samples are provided in Table 3, Table 4, and Table 5 respectively.

The results indicate that there is a continuous increase in optimum moisture content with increase in percentage of fiber content for each particular length of corn husk fiber. Similarly the maximum dry density goes on decreasing with the increase in percentage of corn husk fiber from 1% to 4% for each particular length of fiber. This pattern of increasing OMC and decreasing MDD has been noticed for all three samples of contaminated soil. As the water content increases, the pores gets filled with water, which hinders the close packing of the grains of soil and thus the dry density reduces. Also it is seen that with the increase in length of date palm leaves, when the percentage of fiber is increasing, the maximum dry density decreases. This is due to the fact that the leaves are occupying more space in the soil and is preventing proper compaction in soil.

Table 3. Values of Optimum Moisture Content and Maximum Dry Density with different length of corn husk fibers mixed at different percentages

Contaminated soil sample	% of corn husk fiber added	OMC value without corn husk fibers (%)	OMC value with corn husk fibers of different length (%)				MDD value without corn husk fibers (g/cc)	MDD value with corn husk fibers of different length (g/cc)			
			1	2	3	4		1	2	3	4
S1	1%	17	21	23	26	28	1.77	1.74	1.72	1.69	1.66
	2%		25	27	29	31		1.72	1.7	1.66	1.63
	3%		29	30	32	35		1.7	1.68	1.64	1.59
	4%		32	34	36	38		1.68	1.66	1.62	1.56
S2	1%	15	18	20	22	25	1.79	1.71	1.69	1.66	1.64
	2%		21	24	26	28		1.69	1.65	1.61	1.59
	3%		24	27	29	32		1.65	1.6	1.58	1.56
	4%		27	30	33	35		1.62	1.58	1.56	1.54
S3	1%	11	14	16	18	19	1.72	1.69	1.67	1.65	1.63
	2%		18	19	21	23		1.66	1.63	1.6	1.58
	3%		21	22	24	26		1.63	1.6	1.58	1.55
	4%		25	25	27	29		1.6	1.58	1.55	1.53

Table 4. Values of Un-soaked and Soaked with different length of corn husk fibers mixed at different percentages

Contaminated soil sample	% of corn husk fiber added	Un-soaked CBR value without corn husk fibers	Un-soaked CBR value with corn husk fibers of different length (g/cc)				Soaked CBR value without corn husk fibers	Soaked CBR value with corn husk fibers of different length (g/cc)			
			1	2	3	4		1	2	3	4
S1	1%	4.5	5.2	5.7	6.0	6.3	4.2	4.9	5.2	5.6	6
	2%		5.9	6.2	6.6	7.0		5.5	5.8	6.0	6.4
	3%		6.5	6.7	7.8	6.6		6.1	6.3	7.3	6.1
	4%		7.3	7.6	7.4	6.0		6.5	7.1	6.8	5.7
S2	1%	4.4	4.8	5.0	5.3	5.7	4.1	4.6	4.7	4.9	5.3
	2%		5.6	5.4	5.7	6.6		5.1	5	5.2	6
	3%		6.2	6.1	6.9	5.9		5.7	5.6	6.3	5.6
	4%		7.0	6.7	6.5	5.4		6.4	6.2	5.9	5
S3	1%	4.0	4.4	4.8	5.2	5.5	3.8	4.1	4.3	4.7	5
	2%		4.9	5.3	5.5	6.1		4.5	4.9	5.2	5.7
	3%		5.3	5.9	6.1	5.7		4.9	5.3	5.7	5.4

The CBR values however showed an interesting orientation. The maximum CBR values (both un-soaked and soaked) was observed at a mixing percentage of 4% for 1cm and 2 cm of fiber length, indicating the increase of CBR value with increase in percentage fiber. But in case of 3 cm fiber length the maximum CBR value was observed at a mixing percentage of 3% after which it decreased with increase in fiber content. Similarly in case of 4cm fiber length the maximum CBR value was obtained at a mixing percentage of 2% thereafter decreased with increased percentage of corn husk fiber. These results showed a similar trend for all three samples of contaminated soil.

Table 5. pH values mixed at different percentages of grounded corn husk fiber in contaminated soil

Contaminated Soil Sample	% of corn husk fiber added in grounded form	pH value without corn husk fibers (g/cc)	pH value when soil is mixed with grounded corn husk fiber
	2%		5.1
S1	**4%**	4.5	5.9
	6%		6.8
	2%		4.6
S2	**4%**	3.8	5.3
	6%		6.2
	2%		4
S3	**4%**	3.3	5.2
	6%		6

The results for pH value of each soil sample showed improvement in pH value with increase in percentage of grounded corn husk fiber into the soil sample from 2% to 6%. The contaminated soil samples generally showed low pH value, indicating the sample to be acidic in nature. The addition of grounded corn husk fiber into the soil showed improvement in pH value of the soil thus indicating the neutralization of the soil sample.

Comparing the experimental values for OMC, MDD, CBR (un-soaked and soaked) and pH of Sample 1 (soil mixed with 5% synthetic oil) with that of Sample 2 (soil mixed with 10% synthetic oil) and Sample 3 (soil mixed with 15% synthetic oil), it has been clearly observed that with the increase in synthetic oil content the overall results showed a decreasing trend.

The graphical representation of the results of OMC, MDD Un-soaked CBR and Soaked CBR for soil Sample 1 is given in Fig 1, Fig 2, Fig 3 and Fig 4 respectively.

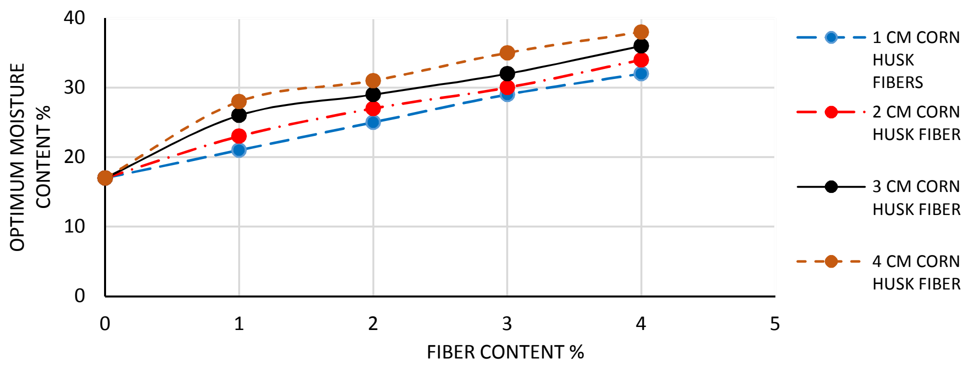

Fig. 1. OMC vs Fiber content graph for Sample 1

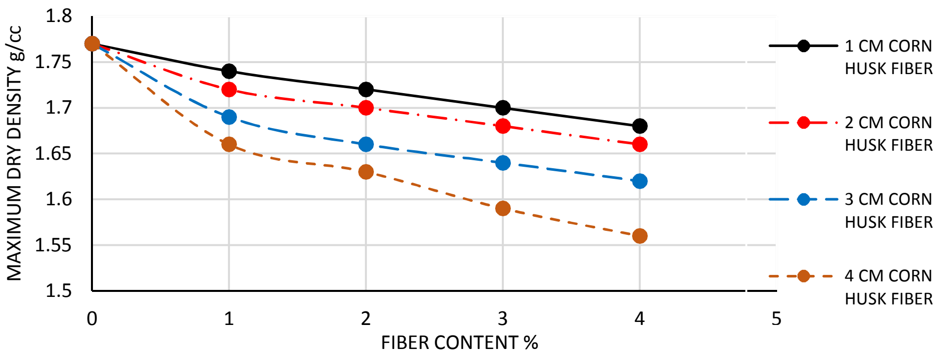

Fig. 2. MDD vs Fiber content graph for Sample 1

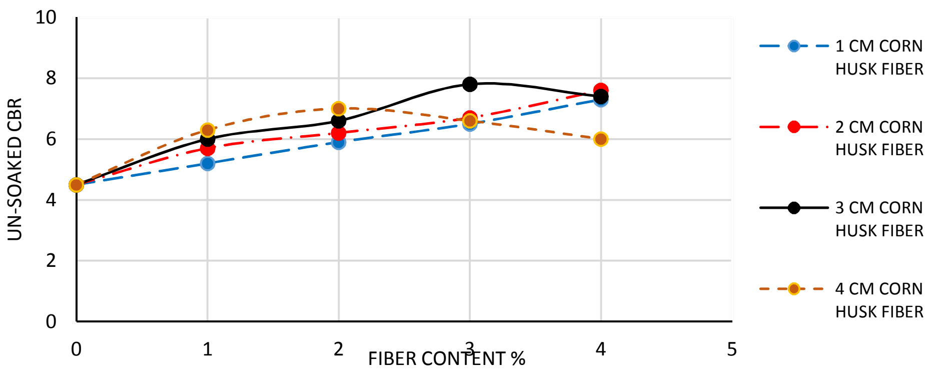

Fig. 3. Un-soaked CBR vs Fiber content for Sample 1

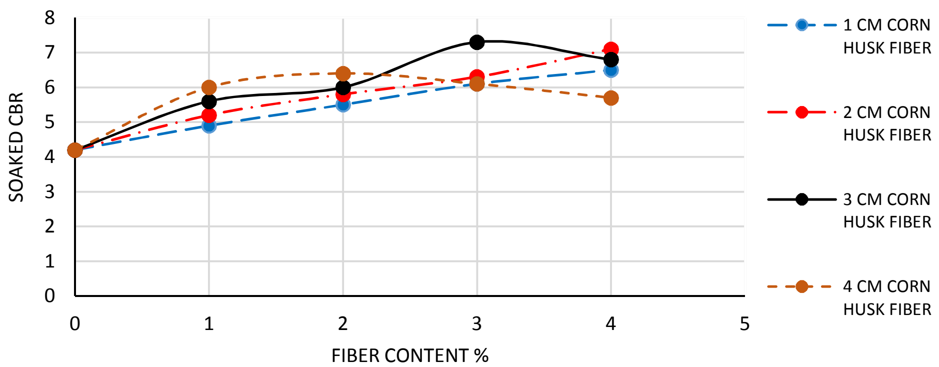

Fig. 4. Soaked CBR vs Fiber content for Sample 1

The graphical representations of the results of OMC, MDD Un-soaked CBR and Soaked CBR for soil Sample 2 are given in Fig 5, Fig 6, Fig 7 and Fig 8 respectively.

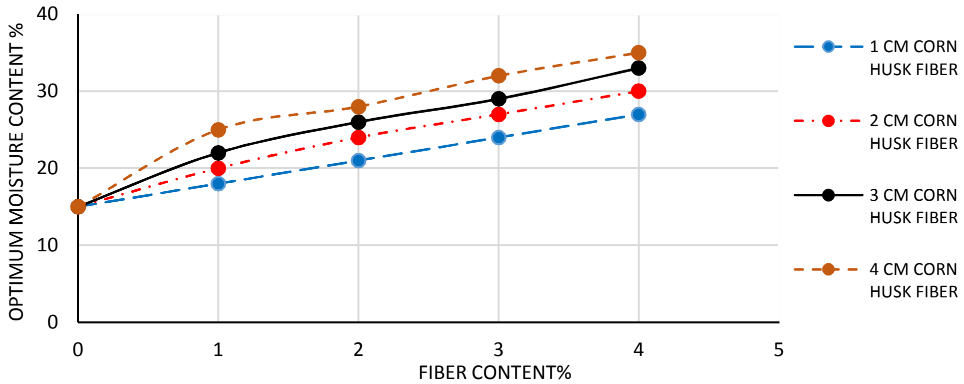

Fig. 5. OMC vs Fiber content graph for Sample 2

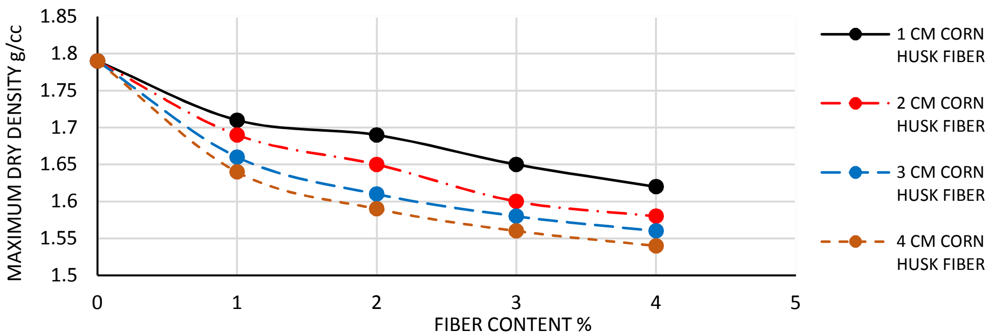

Fig. 6. MDD vs Fiber content graph for Sample 2

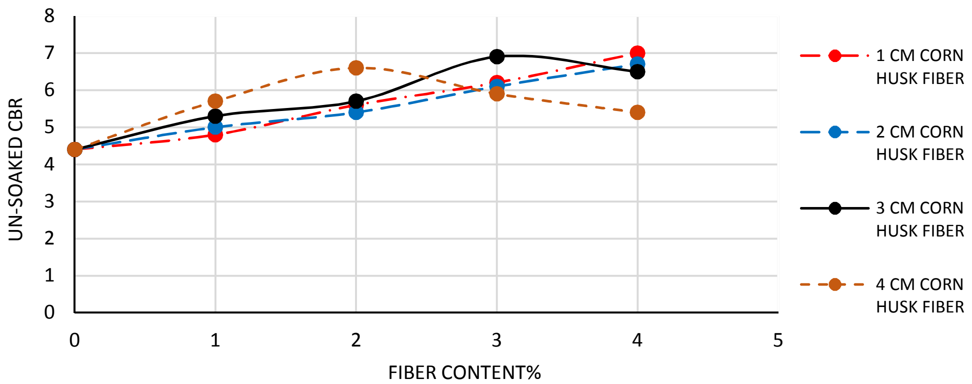

Fig. 7. Un-soaked CBR vs Fiber content for Sample 2

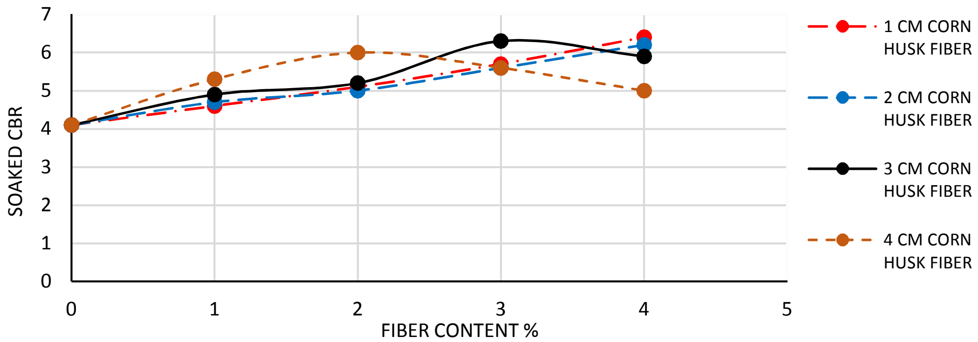

Fig. 8. Soaked CBR vs Fiber content for Sample 2

The graphical representations of the results of OMC, MDD Un-soaked CBR and Soaked CBR for soil Sample 3 are given in Fig 9, Fig 10, Fig 11 and Fig 12 respectively.

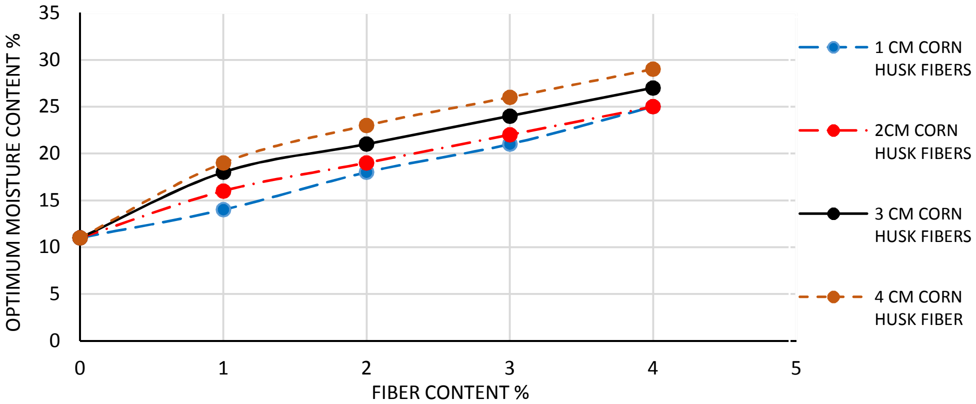

Fig. 9. OMC vs Fiber content graph for Sample 3

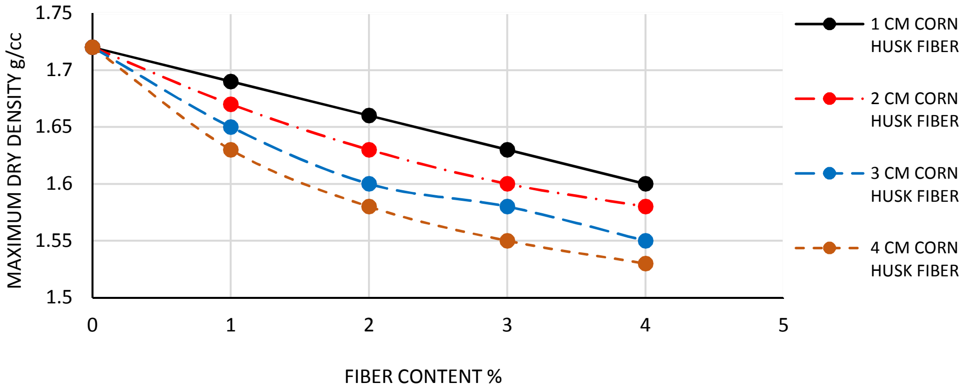

Fig. 10. MDD vs Fiber content graph for Sample 3

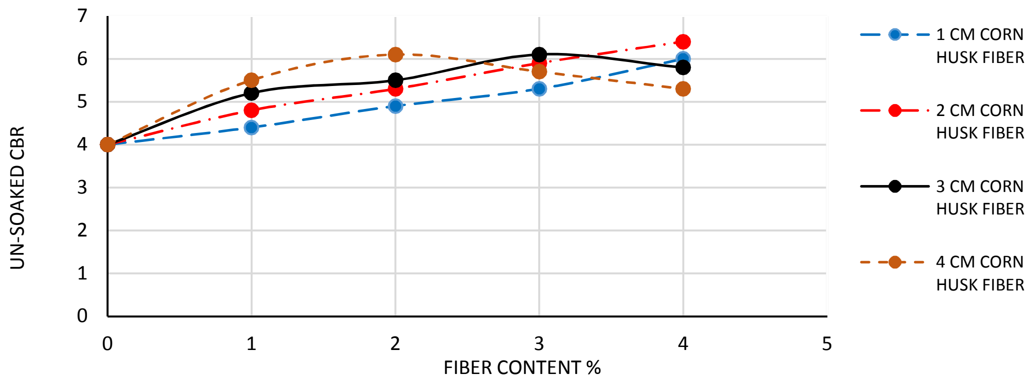

Fig. 11. Un-soaked CBR vs Fiber content for Sample 3

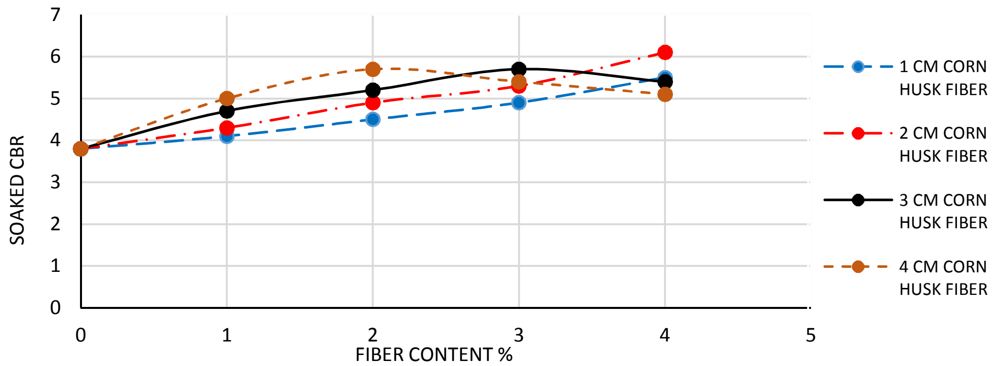

Fig. 12. Soaked CBR vs Fiber content for Sample 3

6. Conclusion

On the basis of extensive study on the effect of corn husk fibers in random mixing in contaminated soil, following conclusions are drawn. These conclusions are presented sequentially initially on compacted contaminated soil randomly mixed with corn husk fibers.

i. For all three samples of contaminated soil there is an increase in optimum moisture content, pH value and California bearing ratio (Soaked and un-soaked) value as well as a decrease in maximum dry density when corn husk fibers are randomly mixed within the soil sample.

ii. For Sample 1 the maximum CBR improvement was 73% with corn husk fiber length of 3 cm mixed at a percentage of 3%.

iii. For Sample 2 the maximum CBR improvement was 59% with corn husk fiber length of 1 cm mixed at a percentage of 4%.

iv. For Sample 1 the maximum CBR improvement was 60% with corn husk fiber length of 2 cm mixed at a percentage of 4%.

v. Therefore Sample 1 showed better CBR improvement compare to the other two Samples.
vi. For Sample 1 pH value was increased as 51% for a corn husk fiber mixing percentage of 6%.
vii. The pH value for Sample 2 was increased by 63% when mixed with 6% of corn husk fibers.
viii. The pH value improvement for Sample 3 was 81% at a mixing percentage of 6%. Therefore it can be concluded that addition of more corn husk fiber will provide better improvement in pH value of the contaminated soil.
ix. The results indicate that with the increase in fiber size there is a decrease in maximum dry density and also in CBR value; therefore for optimum results smaller fiber sizes are appropriate for application. The results may be utilized for strengthening contaminated soil by reinforcing with corn husk fibers, which in general have less strength due to contamination by soil.
x. Improvement in pH value reduces the acidity in soil which occurred due to contamination. As a result the soil will improve in terms of strength and fertility, thus improving the overall index properties of the soil sample.
xi. Thus with the improvement in strength of contaminated soil, the soil could be used as a subgrade material which in turn will reduce the other materials used in base, and surface layers can be reduced, thus reducing the thickness of the roads as well as will reduce the cost of road construction. Also the fertility of the effected soil can be improved which will also be beneficial for irrigational purposes. Therefore the experimental values can be used beneficially for practical road construction purposes and mainly as a remedial solution for contaminated soil to be used as a construction material.

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