

EVALUATION OF ENGINEERING PROPERTIES OF EXPANSIVE SOIL ON ADDITION OF RICE HUSK ASH WITH JEO JUTE FIBER

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ABSTRACT

Black Cotton (B.C) soil is highly plastic clayey soil. In dry state, it is very stiff that clods may not be effortlessly pulverized to be treated for its use in road construction. This poses severe troubles when considered in respect to subsequent performance of road. In addition, the softened subgrade has a tendency to upheave into the upper layers of pavement, mainly when sub-base consists of stone soling with lot of voids. Regular intrusion of soaked B.C soil perpetually leads to road failure. Roads resting on B.C soil base develop undulation on pavement top because of strength loss of subgrade through softening at time of monsoons.

In the current study, Specific Gravity Test, Consistency Indices (Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI)), Modified Proctor's Test, and California Bearing Ratio (CBR) Tests will be executed on B.C Soil (Highly Clayey Soil) first by mixing with altered percentage of Rice Husk Ash (10% , 20% ,30% ,40%) to stabilize soil and then percent of Rice Husk Ash at which maximum CBR is gained is chosen for further experimental work. . The optimal proportion (percentage) of Rice Husk Ash at which maximum CBR is achieved will be selected and gets reinforced with varying proportion (percentage) of Geosynthetic fibre. Along with these altered percentages of reinforcement, the optimal quantity of fibre required to obtain maximum strength is well-known.

Keywords: Black Cotton soil, California Bearing Ratio, Consistency Indices, standard Proctor's Test, Geosynthetic fibre.

1. INTRODUCTION

Black Cotton (B.C) soil is highly plastic clayey soil. In dry state, it is very stiff that clods may not be effortlessly pulverized to be treated for its use in road construction. This poses severe troubles when considered in respect to subsequent performance of road. In addition, the softened subgrade has a tendency to upheave into the upper layers of pavement, mainly when sub-base consists of stone soling with lot of voids. Regular intrusion of soaked B.C soil perpetually leads to road failure. Roads resting on B.C soil base develop undulation on pavement top because of strength loss of subgrade through softening at time of monsoons. Soaked laboratory CBR standards of B.C soil are usually found in range of 2 to 4%. Due to very small CBR values on subgrade B.C soil, enormous pavement stratum is vital to design flexible pavement. Research & Development (R&D) efforts were made for a long time to advance strength characteristics of B.C soil with new technologies.

It's a recognized piece of information that water is worst enemy for road pavements, mostly in condition of expansive soil region. Penetration of water into road pavements from 3 sides (top surface, side beams and from subgrade due to capillary action). Thus, for expansive soil areas, road specifications must consider these factors into consideration. Road surfacing should be impervious, side beams paved and subgrade well-handled to check capillary actions. An observation says, that while handling a varied collection of road investigation assignments to assess cause of road breakdowns that water has effortless ingress into pavement. It saturates sub-grade soil and hence lessens its bearing capacity, as a conclusion effecting intense depression and settlement. In base course layer, consisting of Water Bound Macadam (WBM), water lubricates binding material and makes mechanical interlock less stable. At top bituminous surfacing, ravelling, stripping and cracking develops due to stagnation of water and its seepage into these layers.



Fig. 1. Failure of highway constructed on B.C soil

Randomly distributed discrete fiber reinforced soil, called “ply-soil”, and is comparable to admixture stabilization in its preparation. Discrete fibers are supplemented and blended randomly to soil, in the similar way as cement, lime, RHA and supplementary additives. One very chief benefit of randomly distributed fiber is strength isotropy maintenance and nonexistence of potential planes of weakness that may be build up parallel to orientation of reinforcement (Gray and Maher 1989; Maher 1988). Randomly oriented fibers incorporated into granular soil enhances its load deformation performance by interaction with soil element mechanically through surface friction (bond) and by interlocking and not creating any internal forces at molecular levels. The function of bonder interlock is to transfer stress from soil to tensile inclusions, and to activate their tensile strength and impart this resisting force to the soil, thus reducing strains induced in reinforced soil that leads to enhancement in load carrying capacity of soil. Thus, fiber reinforced soil may be utilized as soil reinforcement method for embankment, subgrade, sub-base, and other related problems.

Rice milling industry generates a lot of rice husk during milling of paddy which comes from the fields. During milling of paddy about 22% of the weight of paddy is received as husk. This rice husk is mostly used as a fuel in the boilers for processing of paddy. This husk contains about 75% organic volatile matter and the remaining 25% of the weight of this husk is converted into ash during the firing process, known as Rice Husk Ash (RHA).

This RHA in turn contains around 85% - 90% amorphous silica. So for every 1000 kg of paddy milled, about 220 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25%) of RHA is generated. It is estimated that about 20 million tonnes of RHA is produced annually.



Fig. 2. Rice mills dumping rice husk ash

Utilization of RHA will not only minimize discarding problems but will also help in utilizing precious land in a better method. Road construction using RHA, involves encapsulation of RHA in earthen core. Since rain water does not seep into RHA core, leaching of heavy metals is also countered. When RHA is mixed to concrete, it chemically starts to react with cement and reduces its effect due to leaching. Even after being utilized for stabilization work, alike chemical reaction takes place which joins RHA particles. Hence probability of pollution, due to utilization of RHA in road works is negligible.

Sisal Fiber is one of the most widely used natural fiber and is very easily cultivated. It is obtain from sisal plant. The plant, known formally as *Agave sisalana*. These plants produce rosettes of sword-shaped leaves which start out toothed, and gradually lose their teeth with maturity.

Sisal fiber is fully biodegradable, green composites were fabricated with soy protein resin modified with gelatin. Sisal fiber, modified soy protein resins, and composites were characterized for their mechanical and thermal properties. It is highly renewable resource of energy. Sisal fiber is exceptionally durable and a low maintenance with minimal wear and tear. Its fiber is too tough for textiles and fabrics. It is not suitable for a smooth wall finish and also not recommended for wet areas. The sisal plant has a 7–10 years lifespan and typically produces 200–250 commercially usable leaves. Each leaf contains an average of around 1000 fibers. It is extracted by a process known as decortications.

Sisal is much more advantageous in different applications for control of erosion, reinforcement and soil stabilization and is preferred when compared to any other natural fibres. (Singh and Mittal, 2014). Due to high lignin content, Sisal degradation slows down as correlated to other natural fibres. Hence, fibres are durable & long-lasting, with infield service life of 4–10 years. The water absorption is about 130–180% and diameter about 0.1–0.6 mm. Sisal maintains its tensile strength, when it is saturated. It has low tenacity but the elongation is much higher. The deterioration of coir depends upon medium of embedment, the climatic conditions and it is found to maintain 80% of its tensile strength even after 6 months of embedment in clay. Mainly, coir fibre shows better resilient response against artificial fibres by higher coefficient of friction. The percentage of water absorption boosts with rise in percentage of coir. Tensile strength of coir reinforced soil (oven dry samples) boosts with a rise in coir percentage. (Hejazi et al, 2012).



Fig. 3. Sisal fibre

Following are the objectives of this work-

- To study variation of Liquid Limit, Plastic Limit, Plasticity Index, Dry density, OMC, CBR (Soaked) of clayey soil with and without RHA with different fiber concentration and aspect ratio.
- To determine optimal percentage quantity of RHA and optimal value of fiber aspect ratio and fiber content.
- To determine effect of optimal sisal fiber and RHA on varying depth of subgrade.

2. LITERATURE REVIEW

Yohanna et.al (2022), An experimental study was carried out on the natural and the modified properties of the soil which include Atterberg limits, compaction, Unconfined compressive strength UCS (i.e., for varying Moulding Water Content (MWC) relative to Optimum Moisture Content (OMC); OMC-2, OMC, OMC+2, OMC+4) and Volumetric Shrinkage Strain (VSS) at MWC relative to OMC; (OMC-2, OMC, OMC+2, OMC+4) were determined, for different percentages inclusion of sisal fibre (0, 0.5, 1, 1.5 and 2% SF). Results obtained show that the liquid limit and plasticity index of the natural soil are 44.47% and 18.65% which increased with an increase in the sisal fibre content. OMC increased from a value of 19% for the natural soil to a peak value of 24.5% at 1.5% of sisal fibre and thereafter decreased. The natural soil has a Maximum Dry Density (MDD) of 1.55 Mg/m³ which decreased to 1.5 Mg/m³ at 1.5% additive. The VSS of the modified soil significantly decrease compared to the natural soil and it continually decreased as the percentage of sisal fibre increased. The lowest VSS values were observed at 2% SF, having values of 2.85, 3.5, 4.75, and 5.5% for OMC-2, OMC, OMC+2, and OMC+4, respectively. The UCS initially increased and thereafter decreased. Based on the results, soil optimally treated with a maximum of 0.5% sisal fibre and compacted with OMC-2 significantly improved the soil and is recommended for use in waste containment applications.

Biswas et.al (2021) This study has been aimed to get dual benefit, first to stabilize expansive soil by addition of RHA and second to effectively utilize RHA, the agricultural waste. The effect of incorporating RHA in soil as a soil stabilizer was studied by using various proportions with soil (6%, 12%, 18%, 24% by weight of soil mass) at constant cement content (5%). The specimens were completely blended by employing a mechanical mixer and tested further with standard compaction in agreement with IS: 2720(Part 7). Atterberg's limit (liquid limit) and CBR (California Bearing Ratio) were analyzed in agreement with IS: 2720 (Part-5)-1985 and IS: 2720(Part16) respectively. The 12% addition of RHA to the expansive soil was found to provide the maximum CBR value indicating the optimized content that can be used for stabilization of the soil under study.

Daryati and M A Ramadhan (2020) This study aims to stabilize expansive soil with RHA by 0%, 3%, 6% and 9%. The index properties test with existing soil included lean clay (CL). The existing soil was repaired by adding stabilizing material in the form of RHA as an added material. Based on the specific gravity test, it can be concluded that the addition of RHA reduced the value of specific gravity, made the plastic limit (PL), liquid limit (LL) and plasticity index (IP) decrease, which means that it could improve the properties of the existing physical soil. Standard Proctor Compaction Test (SPCT) with unsoaked method was conducted by giving 3 different number of blows, i.e. 10, 25, and 56 blows in 3 layers. From the research that was carried out, it can be concluded: The original soil is classified as CL, which is clay with low plasticity. The addition of RHA tends to reduce the value of specific gravity. RHA slightly increases OMC and MDD from the soil. Increasing the use of RHA will reduce the soil plasticity index. The addition of RHA can increase the CBR value to 130%, i.e. the composition to 6%. From various additional variations of RHA, it obtains an increase in the value of soil cohesion.

Yuyi et. Al (2019) this paper presents a cementitious material combined with rice husk ash (RHA) obtained from biomass power plants and lime to stabilize expansive soil. Based on compressive and flexural strength of RHA-lime mortars, blending ratio of RHA/lime was adopted as 4 :1 by weight for soil stabilization. When mix proportion of RHA-lime mixture varied from 0% to 20%, specific surface area of stabilized expansive soil decreased dramatically and medium particle size increased. /e deformation and strength properties of stabilized expansive soil were investigated through swelling test, consolidation test, unconfined compression test, direct shear test, and so on. With increase in RHA-lime content and curing time, deformation properties including swelling potential, swelling pressure, compression index, crack quantity, and fineness of expansive soil lowered remarkably; meanwhile, strength properties involving unconfined compressive strength, cohesion, and internal friction angle improved significantly. Considering engineering performance and cost, mix proportion of 15% and initial water content of 1.2 times optimum moisture content were recommended for stabilizing expansive soil. In addition, effectiveness of RHA-lime to stabilize expansive soil was achieved by replacement efficiency, coagulation reaction, and ion exchange.

Prof Mayura Yeole and Dr. J.R. Patil (2013) executed a laboratory CBR test on granular soil in presence and in absence of geotextile which was located in 1 or 2 layer in the mould. Single layer of geotextile was placed at depth of (25, 50, 100 mm) from top of mould, the maximum CBR obtained was at 25mm and when the geotextile was located in 2 layers at {(25 &75 mm),(50 &75 mm), (50 &100 mm)} CBR was increased and it was maximum at 25 & 75mm geotextile layer by 38.21% when correlated to CBR with absence of geotextile.

1. Material Used

The following materials are used during the research work-

- Raw soil or B.C soil only
- Rice Husk Ash (RHA)
- Sisal Fiber
- Water

The soil used for this investigation is an expansive clay ,one type of most problematic soil for subgrade constructions is used for current research work which is locally available Black Cotton Soil collected from Raisen road near Bhopal (Madhya Pradesh) from depth of 2.5 m from ground level. It contains deleterious substances and of various sizes. The soil was air dried and pulverized manually. This natural soil is grey and black in colour.



Fig. 4. Black cotton Soil Sample

Table 1. Physical properties of Soil

S. No.	Properties	Values
1	Specific Gravity	2.58
2	Liquid Limit (%)	72
3	Plastic Limit (%)	29
4	Plasticity Index (%)	43
5	CBR (%)	1.67%

In this research work, natural soil was stabilized using the Rice husk ash is obtained from Sawstik krishi farm in Mandideep (Near the Bhopal). Rice husk ash is air dried and pulverized. Rice husk ash is waste by product of Thermal power plant. Rice husk ash by itself has little cementatious value but in the presence of moisture it reacts chemically and forms cementatious compounds and attributes to the improvement of strength and compressibility characteristics of soils.

Table 2. Properties of Rice husk ash

S. No.	Properties	Values
1	Specific Gravity	1.10
2	Appearance	powder
3	PH	11
4	Size	Less than 150 micron
5	Flammability	Inflammable

Coconut Fiber Material used is derived from coco fiber obtained by taking the residual yield (waste) of coconut use. Percentage of coconut coir fiber are taken by weight of soil mixture. The fibers were extracted manually and separated into strands.

Table 3. Physical Properties of Sisal fiber

S. No.	Properties	Value
1	Appearance	Thin like threads
2	Specific gravity	0.65
3	diameter	0.40 mm

3. METHODOLOGY

Following procedure has been adopted for the work:

Table 4. Cases considered for study

	Material prepared	Test conducted
Phase 1	Raw soil or B.C soil only	- Specific Gravity - Consistency Indices Modified Proctor’s Test (Heavy Compaction) - CBR Test (Soaked)
Phase 2	Black Cotton Soil with Rice husk ash (RHA)	
	Black Cotton Soil with 10 %RHA	- Specific Gravity - Consistency Indices Modified Proctor’s Test (Heavy Compaction) - CBR Test (Soaked)
	Black Cotton Soil with 20 %RHA	
	Black Cotton Soil with 30 %RHA	
	Black Cotton Soil with 40 %RHA	
From results of above performed tests, Optimal RHA percentage having maximum CBR value is chosen to carry out next step of experiment.		
Phase 2	Black Cotton Soil with Optimal Quantity of RHA and Randomly Distributed Sisal Fiber percentage with Aspect ratio (L/D) of 40	
	B.C Soil with Optimal Quantity of RHA and 0.25 percent Sisal Fiber	Modified Proctor’s Test (Heavy Compaction) CBR Test (Soaked)
	B.C Soil with Optimal Quantity of RHA and 0.50 percent Sisal Fiber	
	B.C Soil with Optimal Quantity of RHA and 0.75 percent Sisal Fiber	
	B.C Soil with Optimal Quantity of RHA and 1.0	

	percent Sisal Fiber	
	B.C Soil with Optimal Quantity of RHA and 0.25 percent Sisal Fiber	
	B.C Soil with Optimal Quantity of RHA and 1.50 percent Sisal Fiber	

4. RESULTS

4.1 RESULTS FOR B.C SOIL WITH ALTERED PERCENTAGE OF RHA

Table 5 Specific gravity of B.C Soil and Soil with altered RBI grade 81 percentages

RHA used	0%	10%	20%	30%	40%
Specific Gravity	2.58	2.53	2.46	2.37	2.23

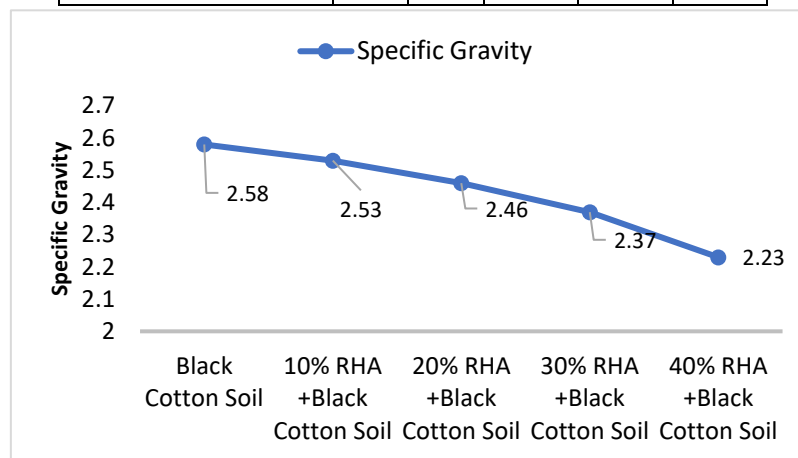


Fig. 8. Specific gravity of Soil with altered RHA percentages.

Table 6 Consistency indices of B.C Soil with altered percentage of RHA

Consistency Indices	Liquid Limit(LL) %	Plastic Limit(PL) %	Plasticity Index(PI) %
Black Cotton Soil	72	29	43
10 % RHA +Black Cotton Soil	58	25	33
20 % RHA +Black Cotton Soil	52.50	23.50	29
30 % RHA +Black Cotton Soil	48.60	21.70	26.90
40 % RHA +Black Cotton Soil	45.0	20.10	24.90

Table 7 Results for Clayey Soil treated with altered percentages of RHA

Material	MDD(gm/cc)	OMC(%)
Black Cotton Soil	1.56	18.60
10 % RHA +Black Cotton Soil	1.81	16.74
20 % RHA +Black Cotton Soil	1.88	17.00
30 % RHA +Black Cotton Soil	1.84	18.00
40 % RHA +Black Cotton Soil	1.80	18.00

Table 8 CBR Test Results for Clayey Soil treated with varied percentage of RHA

Material	CBR (%)	Percentage Increase
Black Cotton Soil	1.67	
10 % RHA +Black Cotton Soil	4.63.	177.20
20 % RHA +Black Cotton Soil	4.87	191.60
30 % RHA +Black Cotton Soil	3.56	113.20
40 % RHA +Black Cotton Soil	3.33	99.40

4.2 Results for B.C soil with 20% RHA grade 81 and altered fiber content

Table 9 Modified Proctor's Test Results for Soil- RHA mix with different fiber concentration

Material	MDD(gm/cc)	OMC (%)
0.25 % Fiber + 20 % RHA + B.C Soil	1.93	12.2
0.50 % Fiber + 20 % RHA + B.C Soil	1.95	16.83
0.75 % Fiber + 20 % RHA + B.C Soil	1.98	16.71
1.00 % Fiber + 20 % RHA + B.C Soil	1.94	16.89
1.25 % Fiber + 20 % RHA + B.C Soil	1.93	16.45
1.50% Fiber + 20 % RHA + B.C Soil	1.87	16.87

Table 10 CBR Test Results for Soil- RHA mix with different fiber concentration

Material	CBR %
0.25 % Fiber + 20 % RHA + B.C Soil	6.67
0.50 % Fiber + 20 % RHA + B.C Soil	6.92
0.75 % Fiber + 20 % RHA + B.C Soil	7.22
1.00 % Fiber + 20 % RHA + B.C Soil	6.44
1.25 % Fiber + 20 % RHA + B.C Soil	6.33
1.50% Fiber + 20 % RHA + B.C Soil	6.22

5. CONCLUSION

From the results we can conclude that

- The consistency indices value of B.C soil reduces with mixing of RHA. Initially LL, PL and PI values of untreated soil are 72%, 29% and 43% respectively which on mixing RHA in ranges from 10 % to 40 % gradually decreased. With 40% addition of RHA to soil, LL, PL and PI values are obtained as 45.00%, 20.10%, and 24.90 % respectively. The outcome was that soil plasticity is decreased on mixing of RHA and soil became less problematic.
- Also the mixing of RHA has pronounced effect on compaction characteristics. The MDD of untreated soil is founded as 1.56 gram/cc at OMC of 18.60%. It increased to 1.88 gram/cc at OMC of 17.32% on 20% adding of RHA. On addition of RHA causes reduction in MDD.
- Soaked CBR value of untreated soil is 1.67 and after mixing of RHA in soil, there is notable transformation in CBR value. On addition of 20% RHA increased CBR value from 1.67 to 4.87, but further addition of RHA caused decrease in CBR value. Thus, optimal quantity of RHA i.e., after which CBR value starts decreasing, is 20 %.
- At aspect ratio of 40 with 0.75% fiber content in 20% RHA mixed soil, the maximum value of CBR is acquired which is 7.22 which is 4.32 times superior than CBR value of untreated soil

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