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Effect of Polypropylene Fiber on Properties of Bagasse Ash-Cement Stabilized Clay Soil

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ABSTRACT: Soil strength improvement is one of the interesting and challenging tasks in Geo-Technical Engineering. This research work presents a hybrid approach of sugarcane bagasse ash and ordinary Portland cement to stabilize the clayey soil. The waste polypropylene fibers have been further used to reinforce the amalgamation of these materials. Several tests (unconfined compression) were performed on soil specimens. During experimentation, the rate of baggage ash and cement was varied as 3%, 6%, 9% and 12%. Likewise, the rate of polypropylene fiber was varied as 0.1%, 0.25%, 0.5%, 0.75% and 1% by weight of soil. The experimental results proved that the use of this hybrid approach has effectively enhanced the shear strength of clayey soil. Moreover, the durability of the soil was also improved. For better results, the ratio of the parameters i.e. sugarcane bagasse ash, cement, and polypropylene fiber should be set as 6%, 6%, and 0.75% respectively.

Keywords: cement, waste polypropylene fiber; soil stabilization; sugarcane bagasse ash

I. INTRODUCTION

One of the major problems for contractors as well as designers is the construction of the embankments on weak soils. So it is imperative to take out the weak soil and replace it with decent additive or improvising the properties of soft soil by soil reinforcement or soil stabilization or combination of both. The problems like lack of suitable construction sites, inadequate mechanical properties of soil, collapsible soils, etc. force engineers and researchers to become more innovative and to utilize new products for improving the soil properties. The ground improvement techniques such as soil stabilization [4], [5], [6], [10], [16], [17] and soil reinforcement are proved to be economical and effective methods. The ground can be improved by several other methods like compaction, stone column method [3], reinforcement, and admixture or grouting. All these methods are used as per site requirement by considering the economy and feasibility of the method. Soil reinforcing technique is also gaining acceptance widely as a viable alternative to other ground improvement techniques. Economical and simple construction process are major advantages of reinforcement technique. Use of metallic bars, sheets, etc. are old techniques. At present, the agricultural and industrial wastes are of a major threat to environment and humanity due to their improper disposal and that as well if happens without legitimate consideration makes a terrible effect on ecological wellbeing. The present paper examines the use of pozzolanic material sugarcane bagasse ash in stabilizing the clayey soil and reinforcing it with randomly distributed waste polypropylene fibers. The residue produced after the bagasse is burnt in factories producing sugar is called bagasse ash. Punjab is running a huge number of sugar plants which confronts a disposal problem of a substantial amount of bagasse ash. The effective utilization of this waste product through economic and environmental impact is a demanding task for the researchers. It contains amorphous silica indicating that it has pozzolanic properties which help in developing a good bond between soil grains in case of clayey soil.

Many investigations are executed on a clayey soil to stabilize it with the help of bagasse ash. Much research has presented that SCBA (sugarcane bagasse ash) is an effective material to improve the cement or lime stabilized soils [11], [13], [14], [15]. The brittleness behavior of stabilized soil can be reduced by using plastic fibers as a reinforcing material in it [1], [2], [7], [8], [9], [12], [18]. For strength improvement of soil, randomly distribution of fibers is not a new technique. It has been used from very old time but the potential use of fiber-reinforced soil was not frequent because of a lack of understanding of the reinforcing mechanism of fibers in soil fiber reinforcement. Utilization of PPF (Polypropylene Fiber) as reinforcement is similar to the randomly distributed fiber. We are looking at two major problems for any civil engineer and environment here, first is a geotechnical problem i.e., the construction of any structure on weak soil and second is an environmental problem i.e., disposal of industrial waste. The use of PPF as soil reinforcing material represents the solution for these two problems. The wastes we used to solve the problems are waste Polypropylene fibers from plastic chairs. By doing this we can also maintain the concept of sustainable development. Experimental verification reported by various researchers [19], [20], [21], [22], [23], [24], [25], [26] have demonstrated that the fiber-reinforced soils can be favorably utilized in enhancing the strength of stabilized and virgin soils. Previous researches have shown that the most controlling strength parameter is fiber content and not fiber length. Also from the previous researches, it is found that the effect of PPF on properties of bagasse ash-cement stabilized clay is not studied yet. In the present study, the effect of PPF on unconfined compressive strength and durability of clayey soil stabilized with bagasse ash-cement mix and reinforced with PPF is studied. A series of unconfined compression tests were conducted on bagasse ash stabilized soil, ordinary Portland cement stabilized soil, bagasse ash-cement mix stabilized soil and soil specimens stabilized with bagasse ash-cement mix reinforced with PPF. SEM (Scanning Electron Microscope) tests were conducted to study the effect of stabilizers on soil structure and soil fiber interface.

II. EXPERIMENTAL METHODS

A. Materials description

The clayey soil used in the present study was collected from a construction site near Dugri, located in district Rupnagar, Punjab. Bigger size lumps of soil were broken down with pickaxes and rammers and then it was oven-dried. The physical properties of soil used are reported in Table 1. The Bagasse ash used in this study was collected from the Doaba Cooperative Sugar Mills Limited, Nawanshahr, Punjab. The bagasse ash collected was oven dried for 3 consecutive days before it could be sent for X-Ray Fluorescence test and for further use. The specific gravity of bagasse ash used in this study was 1.92. The chemical properties of bagasse ash obtained by X-Ray Fluorescence test is given in Table 2.

Table 1: Physical properties of soil used.

Parameters	Values
Specific Gravity, G_s	2.61
Natural Moisture Content, W	13.06 %
Liquid Limit (LL)	39.10 %
Plastic Limit (PL)	16.08 %
Plasticity Index (PI)	23.02 %
MDD (kN/m^3)	16.5
OMC	19.54 %
UCS, q_u(kPa)	90.86
Unified soil classification system	CI

Table 2: Chemical composition of sugarcane bagasse ash.

Constituents	%age
Silica (SiO_2)	75.20
Magnesium Oxide (MgO)	3.15
Iron oxide (Fe_2O_3)	1.68
Sodium Oxide (Na_2O)	0.35
Potassium Oxide (K_2O)	5.62
Calcium Oxide (CaO)	4.86
Alumina (Al_2O_3)	2.18
Sulphur Trioxide (SO_3)	1.45
Phosphorus Pentoxide (P_2O_5)	4.14
Other Oxides	1.37

The OPC (Ordinary Portland Cement) used in this investigation was OPC-53 grade cement bought from the market. The chemical properties of cement obtained from the supplier are presented in Table 3. The polypropylene plastic (PP) waste used as the fiber reinforcement was collected from Chair manufacturing industry “Nilkamal Plastics Limited, Mani Majra, Chandigarh”. The physical and chemical properties of Polypropylene Plastic fibers (PPF) used in this investigation are presented in Table 4. Fig. 1 shows the PPF (Polypropylene Fiber) which appeared brown in color and was chopped down manually with the help of scale and scissor to a length of 25mm and width of a single fiber approximately equals to 2.5 mm.

Fig. 1. Photograph of PPF used in this study.

Table 3: Chemical composition of OPC-53 used.

Constituents	%age
Silica (SiO_2)	19.35
Calcium Oxide (Cao)	68.64
Magnesium Oxide (MgO)	1.39
Iron oxide (Fe_2O_3)	1.21
Sodium Oxide (Na_2O)	0.47
Alumina (Al_2O_3)	4.57
Sulphur Trioxide (SO_3)	3.14
Other Oxides	1.23

Table 4: Physical and chemical properties of PPF.

Parameters	Values
Specific weight	0.94 g/cm^3
Length	25 mm
Width	2.5 mm
Tensile strength	390 MPa
Elastic Modulus	3900 MPa
Melting point	171ºC
Burning point	580ºC
Acid and alkali resistance	Very good

B. Experiments overview

A series (i.e. U, S, and SR) of unconfined compression tests were conducted in this study. The experiments were performed on unstabilized/unreinforced (U), bagasse ash stabilized (S), ordinary Portland cement stabilized (S), bagasse ash-cement mix stabilized (S) and bagasse ash-cement mix stabilized soil reinforced with polypropylene fibers (SR). The amount of bagasse ash and cement was varied from 3% to 12% in steps of 3% by dry weight of soil. Several mix designs of bagasse ash-cement mix were prepared to find the optimum value of bagasse ash-cement for soil reinforcement with PPF. There was a total of 24 mixtures (S1-S24) prepared and tested to find the optimum value of bagasse ash-cement in clayey soil. The details of the design mix and type of experiments conducted are presented in Table 5. All specimens were tested for unconfined compression test after a curing period of 14 days to find the optimum blend of bagasse ash (SCBA) and Cement. Further, for performing unconfined compression tests and durability tests on SCBA-Cement stabilized soil with PPF, the fibers content was varied as 0.1%, 0.25%, 0.5%, 0.75%, and 1%. The UCS tests were performed on these specimens after 7, 14 and 28 days of curing periods. Durability tests were also performed on these mixtures after 28 days of curing period.

Table 5: Design mix and type of experiments conducted in this study.

Mix No.	Mix Design				Tests performed				
	Soil (%)	Bagasse Ash (%)	OPC (%)	Fiber (%)	MDD and OMC	UCS 7 days	UCS 14 days	UCS 28 days	DUR 28 days
U1	100	0	0	0	√	×	√	×	×
S1	97	3	0	0	√	×	√	×	×
S2	94	6	0	0	√	×	√	×	×
S3	91	9	0	0	√	×	√	×	×
S4	88	12	0	0	√	×	√	×	×
S5	97	0	3	0	√	×	√	×	×
S6	94	0	6	0	√	×	√	×	×
S7	91	0	9	0	√	×	√	×	×
S8	88	0	12	0	√	×	√	×	×
S9	94	3	3	0	√	×	√	×	×
S10	91	3	6	0	√	×	√	×	×
S11	88	3	9	0	√	×	√	×	×
S12	85	3	12	0	√	×	√	×	×
S13	91	6	3	0	√	×	√	×	×
S14	88	6	6	0	√	×	√	×	×
S15	85	6	9	0	√	×	√	×	×
S16	82	6	12	0	√	×	√	×	×
S17	88	9	3	0	√	×	√	×	×
S18	85	9	6	0	√	×	√	×	×
S19	82	9	9	0	√	×	√	×	×
S20	79	9	12	0	√	×	√	×	×
S21	85	12	3	0	√	×	√	×	×
S22	82	12	6	0	√	×	√	×	×
S23	79	12	9	0	√	×	√	×	×
S24	76	12	12	0	√	×	√	×	×
SR1	87.9	6	6	0.1	√	√	√	√	√
SR2	87.75	6	6	0.25	√	√	√	√	√
SR3	87.5	6	6	0.5	√	√	√	√	√
SR4	87.25	6	6	0.75	√	√	√	√	√
SR5	87	6	6	1	√	√	√	√	√

C. Preparation of samples

The amount of bagasse ash, cement and polypropylene fibers required were calculated by the formulas given below:

$$\rho_b = W_b / W \quad (1)$$

$$\rho_c = W_c / W \quad (2)$$

$$\rho_f = W_f / W \quad (3)$$

Here, W_b is the weight of SCBA (Sugarcane bagasse ash), W_c is the weight of ordinary Portland cement, W_f is the weight of fiber and W is the weight of sample. In the present study, the value of ρ_b varies as 0.03, 0.06, 0.09 and 0.12, value of ρ_c varies as 0.03, 0.06, 0.09 and 0.12 and values of ρ_f varies as 0.001, 0.0025, 0.005, 0.0075 and 0.01. From the known values of ρ_b, ρ_c, ρ_f and W, the required amount of bagasse ash, ordinary Portland cement and PPF was calculated from equations (1), (2) and (3) respectively.

D. Mixing procedures

Following mixing procedure was adopted for making soil specimens for unconfined compression test:

For virgin/unstabilized soil: At the point when neither bagasse ash and cement nor PPF was utilized, then the soil was blended with a measure of water as per OMC of virgin soil.

For soil mix with bagasse ash-ordinary Portland cement mix: When both bagasse ash and OPC were to be mixed, then 50% of the water required to take the corresponding bagasse ash-OPC-soil mix to the OMC level was added first to the soil alone. Then cement and bagasse ash were mixed in a separate pan and after that bagasse ash-cement mix was added to the soil water mixture with the remaining 50% water.

For soil mix with bagasse ash-ordinary Portland cement mix and polypropylene fibers: The mixing of soil-bagasse ash-cement and polypropylene fibers was done in three stages. Initially, the required amount of cement and bagasse ash was mixed in a different pan and then in the second stage, cement-bagasse ash mix was added to the soil with 50% of the water required to take the corresponding soil-bagasse ash-cement-fibers mix of their OMC level. In the third stage, the required amount of polypropylene fibers were distributed randomly to the mix in three equal amounts and remaining 50% water was added to the mix. As the fibers used to make lumps together, huge care and time were taken to separate the fibers and to evenly distribute them in a mix.

After the process of mixing, compaction and completion of required specimens, they were covered with plastic membranes for different curing periods and stored at room temperature to avoid any moisture loss.

E. Testing

Unconfined compression test: It is a quick method to find out the approximate compressive strength of the soil. Several unconfined compression tests were done as per IS 2720 part 10 on unstabilized, bagasse ash stabilized, bagasse ash-cement mix stabilized and bagasse ash-cement mix stabilized soil reinforced with PPF specimens. All samples were shaped in a mould with a length of 76 mm and an inner diameter of 38 mm at MDD and OMC of the corresponding mix. For uniform compaction, the mix was compacted in 3 equal layers. Three identical specimens were prepared for each type of mixture. The total number of 40 samples for unconfined compression tests was used.

Durability test: This test is important for all soil stabilization and soil reinforcement techniques. In this study, the durability of soil specimens was checked by the method of Wetting and Drying test as per IS 4332 Part 4. For this, samples of optimum bagasse ash-cement mix stabilized soil reinforced with varying percentages of PPF were prepared and cured for 28 days. All samples were prepared in the same way as in the case of an unconfined compression test. In this process, 12 cycles of wetting and drying were completed and outcomes were jotted down after every cycle. In each cycle, the sample was immersed in potable water for 5 hours and after that oven drying of the sample was done for 42 hours at 70 degree Celsius. Then the sample was given 18-20 strokes in a vertical direction with the help of wire-scratch brush and 4 strokes at each end of a specimen which corresponds to a force of 1.4 kgf approximately. After the completion of twelve cycles, samples were tested for unconfined compressive strength test and results hence obtained were compared with a corresponding actual unconfined compressive strength test.

Scanning electron microscope test: In this investigation, SEM (Scanning Electron Microscope) test was conducted to study the effect of stabilizers and fibers on soil structure and soil fiber interface. Three Soil samples of optimum mix (i.e. Soil, Soil: bagasse ash: cement = 88:6:6 and Soil: bagasse ash: cement: PPF = 87.5:6:6:0.5) with a size of approximately 1cm x 1cm x 1cm were taken from the samples undergone unconfined compression test. The soil samples were coated with gold coating before the SEM test. Finally, the necessary SEM images were obtained from the image tool in the computer attached with SEM instrument.

III. RESULTS AND DISCUSSION

A. Effect of bagasse ash content on MDD and OMC

In this, maximum dry density shows a trend of decrease with an increase in the percentage of bagasse ash. This decrease is due to the fact that stabilizer (bagasse ash) with low density is replacing the soil having higher density i.e. our clayey soil sample having specific gravity 2.61 is replaced with varying percentages of lighter additive bagasse ash (SCBA) having specific gravity 1.92. Fig. 2 depicts that the MDD of the soil decreases from 1.65 g/cc to 1.43 g/cc as bagasse ash content increases from 0% to 12% in steps of 3% increment.

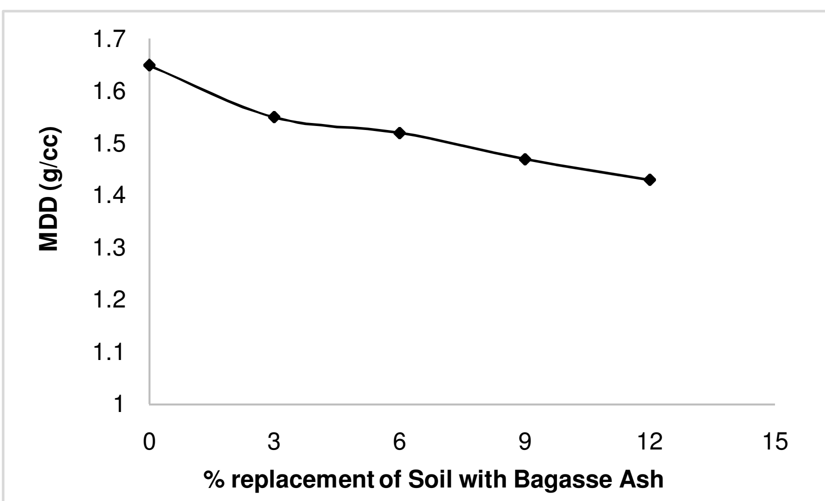

Fig. 2. Variation in MDD with % replacement of soil with Bagasse Ash.

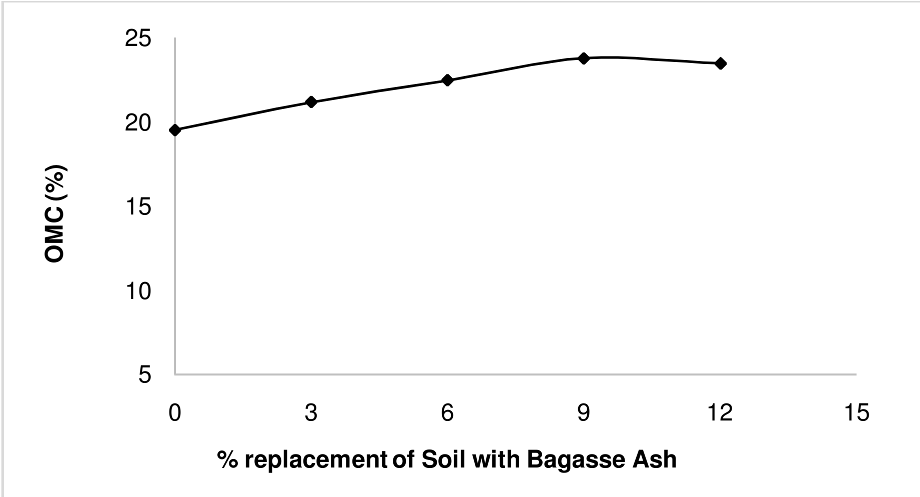

Fig. 3. Variation in OMC with % replacement of soil with Bagasse Ash.

The optimum moisture content shows a general trend of increase with an increase in bagasse ash content. This increase in OMC could be as a result of the presence of CaO and SiO_2 in bagasse ash which will increase demand of water to undergo hydration reaction. The OMC of soil mix increases from 19.54% for virgin soil to 23.5% as the bagasse ash content increases from 0% to 12%. Fig. 3 shows the variation of OMC with an increase in percentage replacement of soil with cement.

B. Effect of bagasse ash content on unconfined compressive strength

Fig. 4 presents the effect of bagasse ash on unconfined compressive strength after 14 days of curing period of various soil-bagasse ash mixes. The peak UCS value for standard proctor compaction effort is 192.58 kPa at 6% bagasse ash content treatment. The graphs show a trend of increase in UCS value with increase in the percentage of bagasse ash up to 6% and then decreases up to 12% bagasse ash. The increasing trend is due to the strength gain action of pozzolans present in bagasse ash. The decrease in UCS value above 6% bagasse ash content can be attributed to availability of inadequate amount of water than required for pozzolanic reactions at higher bagasse ash content.

C. Effect of cement content on MDD and OMC

In this, maximum dry density shows a trend of increase with an increase in the percentage of bagasse ash. This increase is due to the fact that stabilizer (cement) with high density is replacing the soil having comparatively lower density i.e. our clayey soil sample having specific gravity 2.61 is replaced with varying percentages of additive bagasse ash (SCBA) having specific gravity 3.15. Figure 5 shows that the maximum dry density of soil-cement mix initially increased from 1.65 g/cc to 1.71 g/cc up to 6% cement and then decreased up to 1.68 g/cc at 12% cement content.

The optimum moisture content shows a trend of increase with an increase in bagasse ash content. This increase in OMC is a result of the presence of Cao and SiO_2 in cement which will increase demand of water to undergo hydration reaction.

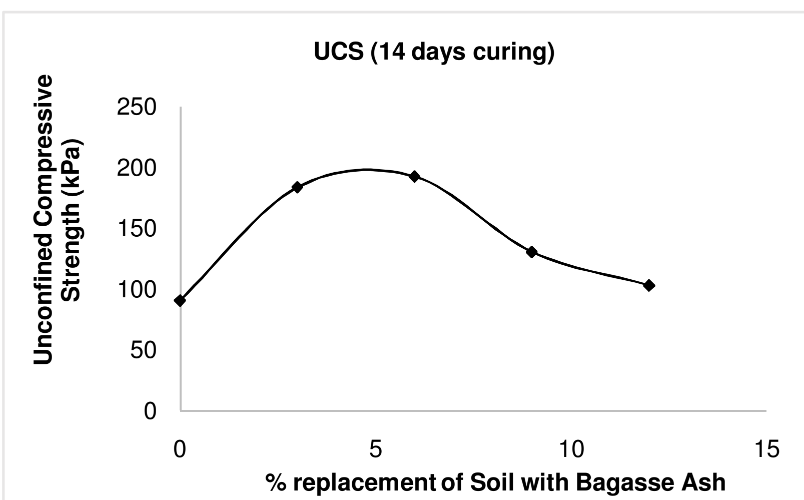

Fig. 4. Variation in UCS with % replacement of soil with Bagasse Ash.

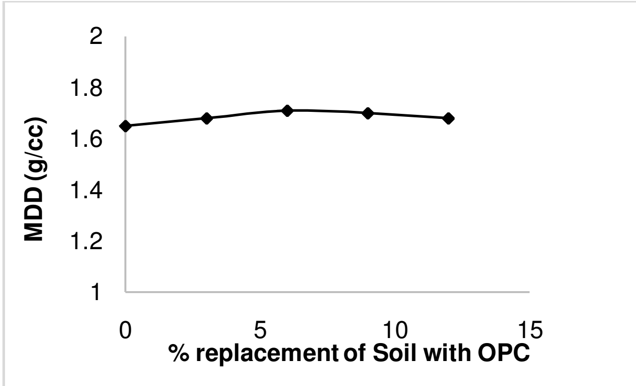

Fig. 5 Variation in MDD with % replacement of soil with OPC.

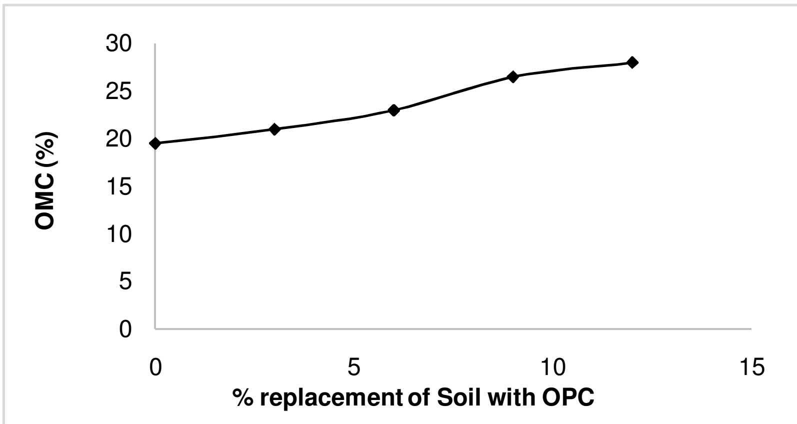

Fig. 6. Variation in OMC with % replacement of soil with OPC.

The OMC of soil mix increases from 19.54% for virgin soil to 28% as the cement content increases from 0% to 12%. Fig. 6 shows the variation of OMC with an increase in percentage replacement of soil with cement.

D. Effect of Cement Content on Unconfined Compressive Strength

Figure 7 presents the effect of ordinary Portland cement on unconfined compressive strength after 14 days of curing period of various soil-cement mixes. The peak UCS value for standard proctor compaction effort is 422.82 kPa at 12 % cement content treatment. This graph shows a trend of increase in UCS value with increase in the percentage of cement content. The increasing trend is due to the strength gain action of CaO and SiO_2 present in ordinary Portland cement which increases with increase in the percentage of cement in various soil-cement specimens.

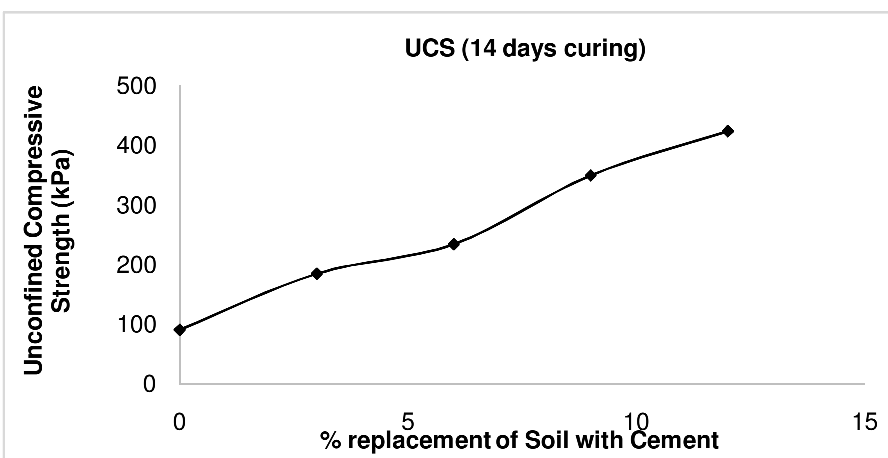

Fig. 7. Variation in UCS with % replacement of soil with OPC.

E. Effect of Bagasse Ash-Cement Mix on MDD, OMC, and Unconfined Compressive Strength

In this, maximum dry density shows a trend of increase with an increase in the percentage of cement in a soil-bagasse ash mix due to a heavier specific gravity of cement in comparison to bagasse ash and soil as discussed earlier. The variation of MDD with % replacement of soil with bagasse ash and cement is shown in Figure 8. The optimum moisture content shows a trend of increase with an increase in cement and bagasse ash content and then decreases as shown in Figure 9. This increase in OMC is a result of the presence of Cao and SiO_2 in cement which will increase demand of water to undergo hydration reaction. The decrease might be due to cation exchange reactions which causes the flocculation of soil particles. Figure 10 shows the variation in UCS values with cement content for soil-cement-bagasse ash mixtures.

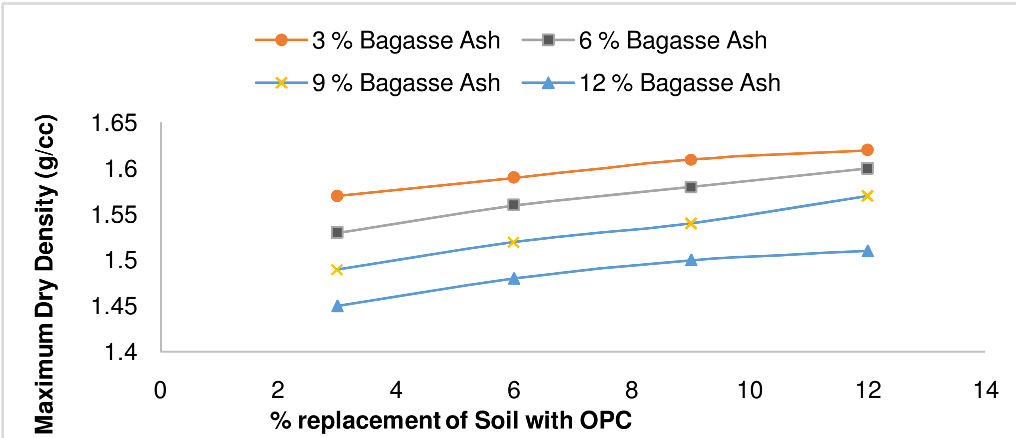

Fig. 8. Variation in MDD with cement content for soil-cement-bagasse ash mixtures.

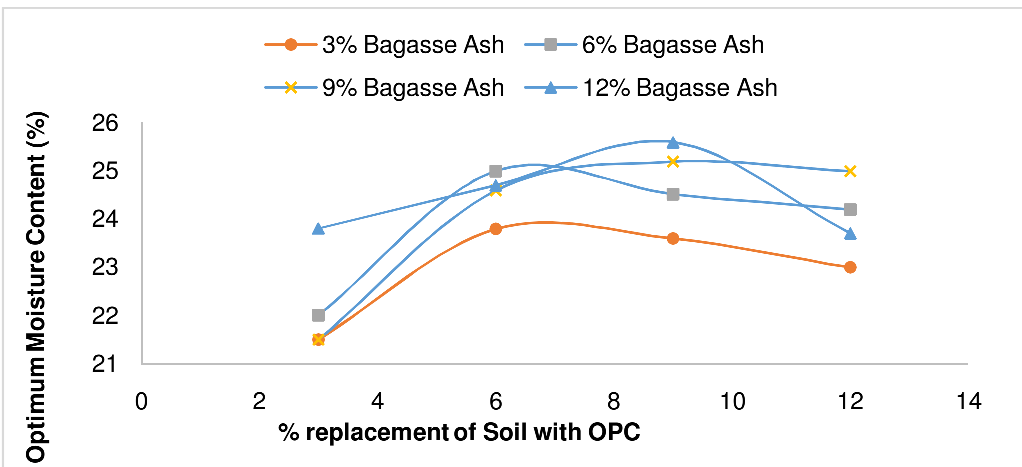

Fig. 9. Variation in OMC with cement content for soil-cement-bagasse ash mixtures.

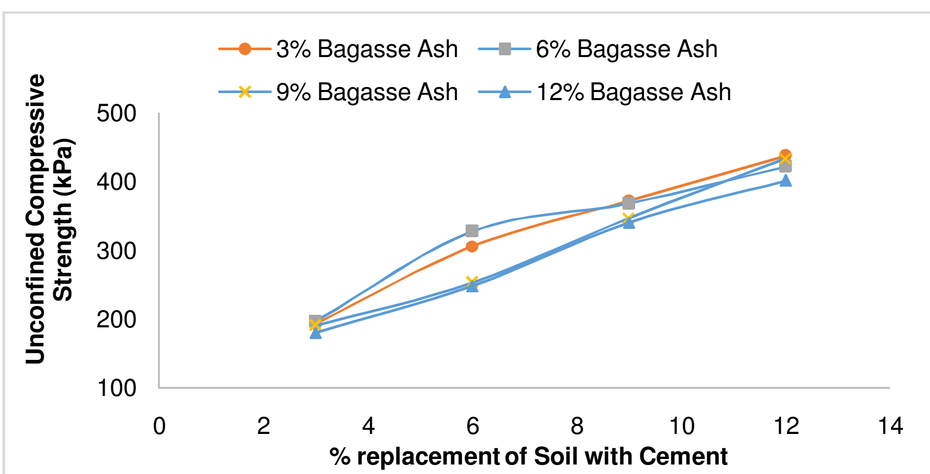

Fig. 10. Variation in UCS (14 days) with cement content for soil-cement-bagasse ash mixtures.

From all the UCS test results performed until this section, we chose an optimum value of Bagasse Ash-Cement mix on the basis of the following factors:

- The % Change in Unconfined Compressive Strength values of the soil-bagasse ash-cement mix.
- Maximum consumption of Sugarcane Bagasse Ash (SCBA).
- Minimum consumption of Cement for economic considerations.

On the basis of these factors, its Optimum value comes out to be: Soil: Bagasse ash: Cement: 88:6:6. This mix was used further in studying the effect of Polypropylene Fibers reinforcement on the strength and durability of clayey soil stabilized with Bagasse Ash-Cement mix.

F. Effect of bagasse ash-cement mix soil with PPF on MDD and OMC

In this, maximum dry density shows a decreasing trend with an increase in the percentage of stabilizers and fibers. This decrease is due to the fact that PPF with lower density is replacing the soil having higher density i.e. our clayey soil sample having specific gravity 2.61 is replaced with varying percentages of PPF having specific gravity 0.92. The MDD of soil mix decreases from 1.56 g/cc for OPC: SCBA optimum blend (6:6) to 1.52 g/cc as the fiber content increases from 0% to 1% as shown in Figure 11. Also, an increase in the percentage of fiber content slightly decreases the OMC as shown in Fig. 12.

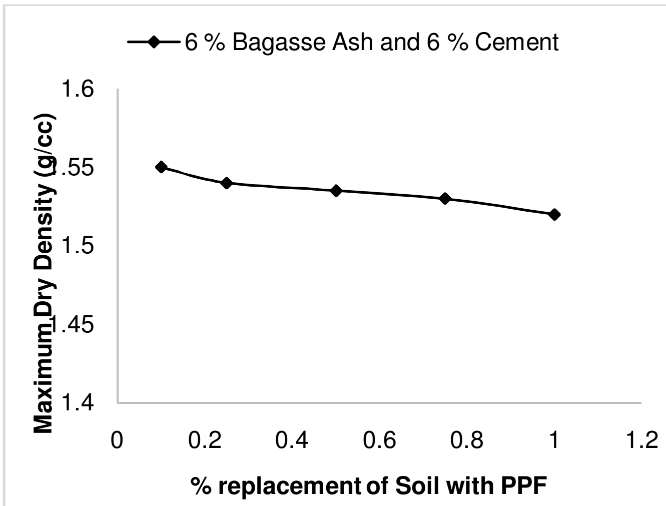

Fig. 11. Variation in MDD with PPF content in optimum soil-cement-bagasse ash mix.

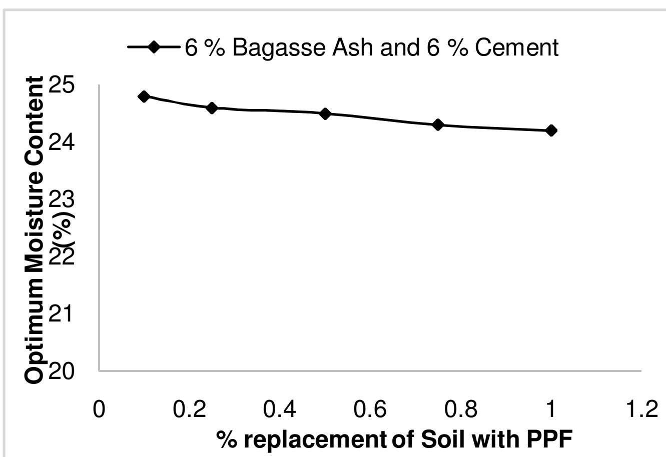

Fig. 12. Variation in OMC with PPF content in optimum soil-cement-bagasse ash mix.

G. Effect of bagasse ash-cement mix with ppf on unconfined compressive strength

Table 6 presents the effect of SCBA/OPC/PPF on unconfined compressive strength of various soil/SCBA/OPC/PPF mixes after different curing periods. Figure 13 shows that UCS value enhances with an increase in the curing period of the fiber-reinforced SCBA/Cement/Soil mixtures. The peak UCS values of 436.1 kPa, 724.6 kPa, and 1018.3 kPa were obtained at Mixture no. SR 4 (Soil: SCBA: OPC: PPF = 87.25: 6: 6: 0.75) after 7, 14 and 28 days of curing periods respectively. UCS values show an increasing trend up to 0.75% PPF content and further addition of fibers decrease the unconfined compressive strength but it is still higher than the stabilized (S6 and S14) and unstabilized/ virgin soils (U1). The increase in UCS value might be due to an increase in the contact area between the soil mixture particles and PPF with an increase in the percentage of PPF which increases the friction between soil particles. The friction between fibers and soil at the interface makes it difficult for soil particles to change their position from one point to another which enhances the bonding force between soil particles. However if the amount of fibers added to the soil is much more than required like in this case more than 0.75%, the fibers adhere with each other to form lumps and also causes slippage forming improper contact of fiber-soil particles. This leads to a decrease in cohesion and unconfined compressive strength.

Table 6: Variation in UCS with curing periods for bagasse ash-cement mix with PPF sample.

Mix Proportion by %age replacement					Curing Period (in days)	UCS (kN/m^2)
Mixture No.	**Soil**	**Bagasse Ash**	**Cement**	**Fiber**		
SR1	87.9	6	6	0.1	7	345.2
					14	563.7
					28	728.3
SR2	87.75	6	6	0.25	7	356.9
					14	632.8
					28	815.6
SR3	87.5	6	6	0.5	7	378.7
					14	602.3
					28	902.8
SR4	87.25	6	6	0.75	7	436.1
					14	724.6
					28	1018.3
SR5	87	6	6	1.0	7	413.5
					14	625.5
					28	914.6

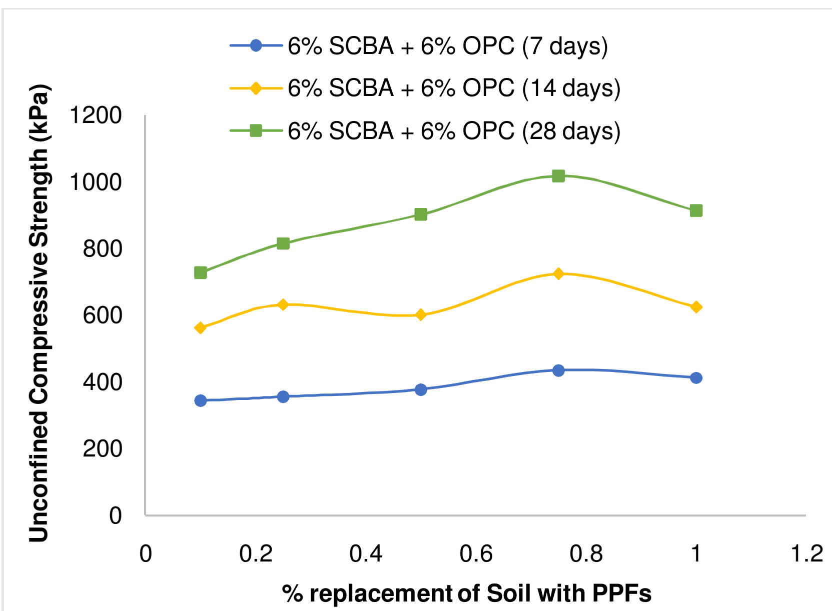

Fig. 13. Variation in UCS with a curing period of Soil/Cement/Bagasse ash/PPF mix.

Durability test. In this test, the durability of soil specimens was checked by the method of Wetting and Drying test [IS 4332 Part 4] to study the consequences of Wetting and Drying on the unconfined compressive strength of mixes. Table 7 shows the unconfined compressive strength before and after the wetting and drying cycles of various selected samples. The compressive strength alters after the wetting and drying cycles. This change in unconfined compressive strength is considered as residual strength index (R_s). The R_s is the ratio of unconfined compressive strength of soil mix after wetting and drying cycles ($q_{u\ (wet/dry)}$) (Muntohar *et al.*, 2013) to the compressive strength prior to a cycle ($q_{u\ (0)}$).

$$R_s = \frac{\text{qu (wet/dry)}}{\text{qu (0)}}$$

Table 7: Unconfined compressive strength after the durability test.

Mix Proportion by %age replacement					$q_{u\,(0)}$ 28 days	$q_{u\,(wet/dry)}$ 28 days	$R_s = \frac{qu\,(wet/dry)}{qu\,(0)}$
Mixture No.	**Soil**	**Bagasse Ash**	**Cement**	**Fiber**			
SR1	87.9	6	6	0.1	728.3	305.8	0.42
SR2	87.75	6	6	0.25	815.6	464.89	0.57
SR3	87.5	6	6	0.5	902.8	577.79	0.64
SR4	87.25	6	6	0.75	1018.3	743.35	0.73
SR5	87	6	6	1.0	914.6	621.9	0.68

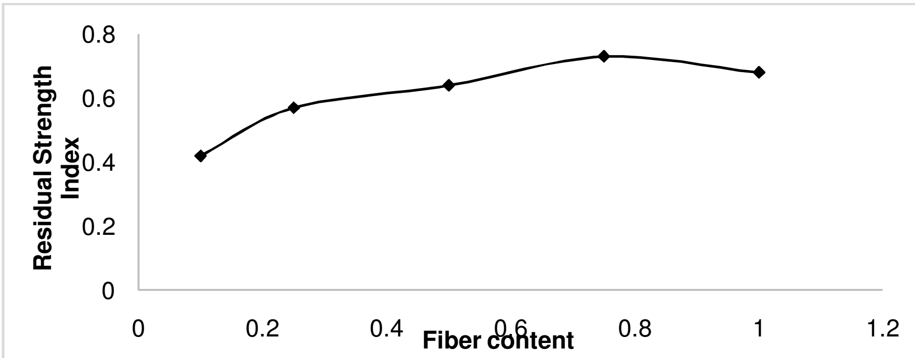

Fig. 14. Variation in Residual Strength Index with PPF content in Soil/SCBA/OPC mix.

The variation of R_s with PPF content in soil/SCBA/OPC mix is shown in Figure 14. From the R_s values obtained after the wetting/drying cycles, it can be seen that mixture no. SR4 with 0.75% fiber content shows the maximum value of residual strength index (R_s = 0.73) which means SR4 is most durable to the effect of wetting/drying.

Scanning electron microscope (SEM) test. In this study, the SEM (Scanning Electron Microscope) test was conducted to study the effect of stabilizers on soil structure and soil fiber interface with the help of SEM machine. Figure 15, 16 and 17 show the various SEM images that were taken with the SEM test.

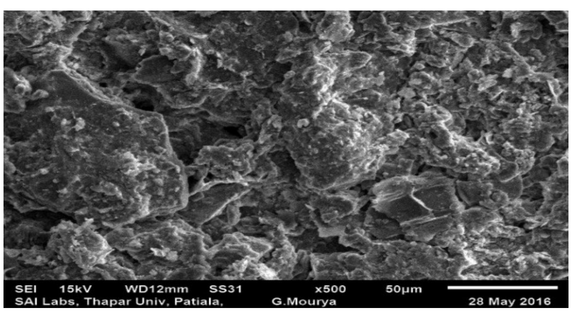

Fig. 15. SEM image of clayey soil.

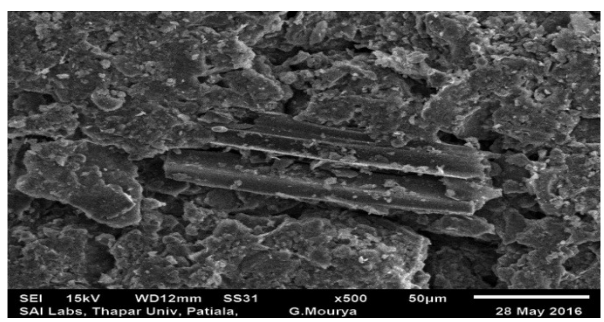

Fig. 16. SEM image of Soil/SCBA/OPC(88:6:6).

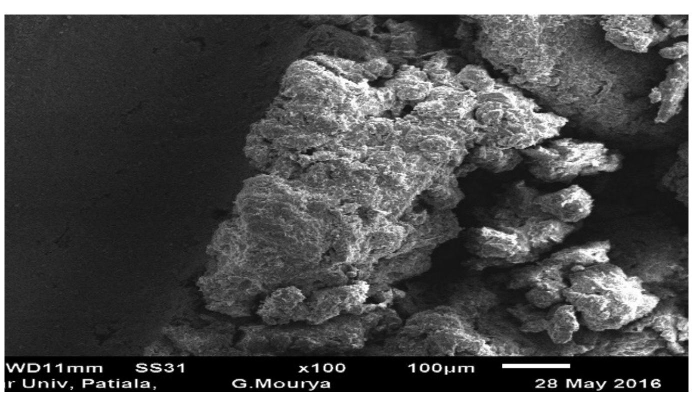

Fig. 17. SEM images of fiber-reinforced bagasse ash-cement mix stabilized soil (6% Bagasse ash, 6% Cement and 0.75% fibers).

From the SEM images, it can be clearly seen that soil-bagasse ash-cement mix particles are attached to the fiber surface which increases the bond strength of the mix and also the friction between soil particles. This phenomenon restricts the movement of soil mixture particles to move from one position to another (Tang *et al.,* 2007) [7] as shown in Fig. 17. Therefore, the fiber reinforced-cement-bagasse ash-soil mix enhances the efficiency of load transfer from soil mix to the fibers. This increases the strength of the soil matrix.

CONCLUSIONS

In the present study, unconfined compressive strength and durability of bagasse ash-cement mix stabilized soil reinforced with polypropylene fibers have been studied. Based on the results obtained, the following major conclusions can be made-

1. The maximum dry density of soil-bagasse ash mix decreased from 1.65 g/cc for virgin soil to 1.43 g/cc and optimum moisture content increased from 19.54 % to 23.5 % with an increase in SCBA content.
2. The maximum dry density of soil-cement mix initially increased from 1.65 g/cc to 1.71 g/cc up to 6% cement and then decreased up to 1.68 g/cc at 12% cement content and optimum moisture content increased from 19.54 % to 28 % with an increase in OPC content.
3. Based on the results obtained from U.C.S. after 14 days curing period of different mixes of bagasse ash, cement and bagasse ash-cement mix, an optimum blend of SCBA/OPC is 6% bagasse ash and 6% cement.
4. The plasticity index of soil/SCBA/OPC optimum blend (88:6:6) decreased from 23.02% for virgin soil to 19.78 %.
5. On inclusion of PPF into SCBA/OPC optimum blend, maximum dry density of soil/SCBA/OPC/PPF decreased from 1.55 g/cc to 1.52 g/cc and optimum moisture content slightly decreases from 24.8 % to 24.2 % with increase PPF content.
6. The UCS of soil mix increased on adding PPF to the SCBA/OPC optimum blend till 0.75 % fiber content and afterward it decreased. The UCS value increased by 39.8 % from 728.3 kPa with 0.1% fiber content to 1018.3 kPa with 0.75% fiber content. This increase might be due to the increase in cohesion between fiber and soil matrix and UCS value further decreased due to the formation of kinks and lumps at the higher fiber content.
7. The UCS of Soil/SCBA/OPC/PPF matrix increased with increase in the curing period. The peak UCS values of 436.1 kPa, 724.6 kPa and 1018.3 kPa were obtained after 7, 14, and 28 days of curing period respectively for mixture no. SR4 with 0.75 % fiber content.
8. The residual strength of stabilized soil increases upon inclusion of plastic waste fibers. The soil mix with 0.75% fiber content is more durable to wetting/drying cycles with resistance to a loss in strength equals to 73%.
9. The optimum fiber content is 0.75% by dry weight of soil in soil/SCBA/OPC/PPF matrix.
10. Thus an optimal mixture of 87.5% Soil / 6% SCBA / 6% OPC / 0.75% PPF is recommended for successful use in soil stabilisation.

FUTURE SCOPE

1. Here the effect of bagasse ash-cement mix and PPF reinforced soil on unconfined compressive strength and durability of the mix was studied, so their effect on California bearing ratio (CBR), Split tensile strength and shear strength (consolidation characteristics) can also be tested.
2. In my investigation, fibers content up to 1% was taken, so the effect of fibers content up to 2% or 5% can be studied.
3. In this study, clayey soil of intermediate plasticity was used, so the effect of bagasse ash-cement mix and PPF reinforced soil can be studied in other types of soil too.

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