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Effect of Plastic Strips and Bottom ash on Engineering Properties of Sandy soil

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Abstract Scarcity of land with favorable conditions have raised due to the rapid development of urban areas and the increase in construction activities. This has necessitated the use of locally available weak soils for construction activities through stabilization techniques. In the present study, bottom ash (BA) is used as a stabilizing agent, and the suitability of plastic strips as reinforcement is demonstrated through detailed experimental investigations. Soils poor in engineering properties in terms of bearing capacity, shear strength, compressibility and permeability need some proper treatment so that they can be useful in construction purposes. Such soils need to be either replaced or treated well with some materials. This paper deals with the valorization of sandy soil with the use of bottom ash in various percentages of 10, 20, 30 and 50% along with plastic strips of 0.5, 0.75, 1 and 1.25%. The laboratory research indicated that the mechanical properties of the soil are improved with the addition of bottom ash and plastic strips. Test method includes finding unit weight, specific gravity, unconfined compressive strength, peak strength, cohesion and angle of internal friction.

Keywords: Stabilization, Compressive Strength, Bottom Ash, Plastic strips, Reinforced earth

1 Introduction

Engineering properties of the different types of soil differ from place to place and some may also be deficient of some important properties because of which there is need for costly remedial process to improve their engineering properties and make them stable. Whenever the soil lacks proper strength, they are either replaced or treated well to enhance their properties. Soil stabilization is the method that changes the soil structure for the improvement of its properties with the addition of chemicals such as cement, fly ash, lime, GGBS, kiln dust and bottom ash. Using cement and lime is not favored nowadays as they result in environmental problems [1]. Effective dose of chemicals needed for stabilization of fine-grained soils has been done by few researchers. Factorial experimental analysis, effective size estimation all together helped in finding the effective dosage rates of bottom ash to improve the properties of bottom ash. Up to 30% bottom ash addition to the soil gave better results[2].

Pozzolanic activity of industrial waste materials such as fly ash, bottom ash, sludge ash along with soil particles is good and also, their usage benefits the environment from the point of recycling and achieving sustainability [3]. Clays are also stabilized using calcium carbide residue and biomass ash[4] Also, the possibility of mixing bottom ash with different proportions of fly ash was evaluated [5]. It was seen that with increasing percentages of fly ash the maximum dry density decreased and optimum moisture content increased.

Due to improper disposal of plastic wastes the landfills are getting covered and has clogged the sewerage system, disrupted the ecological cycle and has resulted into not so pleasing environment. Inclusion of fibers within soil comes in the category of reinforced earth concept where it can be reused or recycled whenever needed to improve engineering properties such as bearing capacity, permeability, compressibility and shear strength. This soil reinforcing method can be done in two ways. One is by randomly mixing fibers into soil matrix and another is by placement of geosynthetics such as geocell, geogrid, geonet within soil. Fiber type, content, length and binder type are important parameters affecting strength of soil. They may be man-made, natural or mineral. Soil has less tensile strength but its compressive strength is high so they don't resist the applied shearing stresses. If some soil reinforcement in form of fibers is used the shear stresses are absorbed and hence less load acts on soil which otherwise would have failed in shear or excessive deformation.

2 Literature Review

The uniform sand was reinforced with PET fibers obtained from recycling waste plastic bottles showed engineering properties improved as the peak and ultimate strength of cemented and uncemented specimens improved [6]. Waste plastic bottle strip reinforced silty clay with varying percentages of plastic strips and their changing aspect ratios showed 0.4% plastic content as the optimum value [7]. By product of corn known as corn silk was used in proportions 0.5, 1, 1.5 and 2% and of length10, 30 and 50mm to reinforce the soil showed the mechanical properties of the mix improved by conducting compaction test, unconfined compression test, splitting tension test [8]. Sisal fibers in proportion 0.25, 0.5, 0.75 and 1% was used to stabilize soil. It was seen that for fiber content above 0.75% the shear strength decreases with increase in fiber content [9]. Reed fibers and glass synthetic fibers and fabrics were used to reinforce the soil. Results showed the improvement in strength is directly proportional to the percentage of reinforcement [10]. Influence of fiber type and sand properties was studied where model was prepared to compare the triaxial results that showed with increase in the size of particles the fiber contribution to strength reduces [11]. Strips of High-density Polyethylene (HDP) was mixed with sand and California Bearing Ratio (CBR) values and secant modulus was evaluated that showed that the reinforced sand enhances the resistance to deformation and its strength [12]. Waste plastic was used to improve the bearing capacity of the granular trench [13].

Bottom ash can be used in replacement of Portland cement because of pozzolanic reactions after grounding [14]. To control low strength applications, bottom ash can be used as an aggregate to replace fine and coarse aggregate [15]– [18]. Advantages offered by lightweight cement-based composites include weight reduction, improved strength, durability, low expansibility, good thermal and sound insulation, and ease of use in construction. Moreover, the final product is inexpensive. Bottom ash being fine in nature will help in cement hardening [19]. Biomass bottom ash has been used as a filler material for embankment construction [20]. Compressive strength of concrete produced by partial or full replacement of aggregate by bottom ash showed better resistance to sulphuric acid [21]. Bottom ash was used for producing sound absorbent materials for highway. It was seen that it showed better results than porous concrete when used as noise barrier [22].

In the present study, an attempt has been made to explore the possibility of using plastic strips and bottom ash in stabilizing the soil. Experimental investigations have been carried out to study the variations of dry unit weight, unconfined compressive strength, specific gravity, angle of internal friction and poisons ratio with change in proportions of plastic strips and bottom ash.

3 Materials and Method

Sand, bottom ash and plastic strips were used to prepare the geomaterial. Various tests were conducted on them to analyze their geotechnical properties as per IS code.

3.1 Sand

The sand was collected from a local dealer. It was air-dehydrated and was made to pass through 4.75mm sieve. The grain-size distribution of the soil was found by carrying out dry sieve analysis per IS 2720 [23]. The particle-size distribution of the soil sample is shown in Fig. 1, which indicates that it is of a sandy nature. The soil consists of 0% gravel, 98.48% sand, and 1.52% clay. Physical properties of the soil are given in Table 1.

Fig. 1. Sand

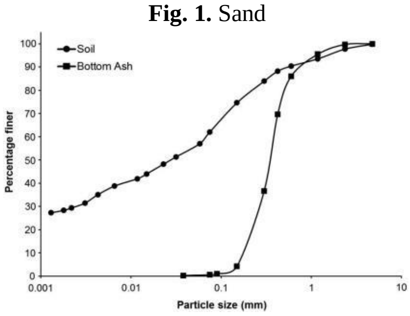


Fig. 2. Particle size distribution of soil and bottom ash

Table 1. Physical properties of the soil

Sr no	Property	Value
1	Specific Gravity	2.67
2	Gravel>4.75 mm	0
3	Sand (0.75-4.75mm)	98.48%
4	Coarse sand (2mm-4.75mm)	1.18%
5	Medium sand (.425-2mm)	16.1%
6	Fine sand (0.075-.425mm)	81.2%
7	Coefficient of Uniformity	1.68
8	Coefficient of Curvature	0.024
9	Classification	SP

3.2 Bottom ash

The bottom ash samples used in this study were extracted from DIRK India Pvt Ltd. Bottom ash is the by-product released from thermal power plant, because of its similar particle size distribution it can be used as replacement to cement binder, sand or aggregates as construction material. The specific gravity was determined to be 2.36 as per IS 2720, Part 3[24].Fig. 2 shows the grain-size distribution of the BA, which consists mainly of uniformly graded sand.

Table 2. Physical properties of bottom ash

Sr no	Property	Value
1	Specific gravity	2.36
2	Water content	3.55%
3	Classification	SP
4	Coefficient of uniformity	3.19
5	Coefficient of curvature	1.17
6	D_{10}	0.94 mm
7	D_{30}	1.82 mm
8	D_{60}	3 mm

3.3 Plastic strips

Plastic strips were obtained from KDM Chemicals and Research Pvt. Ltd. It was made from glass yarn having whitish in color. The physical properties of fibers are listed in Table 3.

Fig 3. Bottom ash

Fig. 4. Plastic strips

Table 3. Physical properties of plastic strips

Sr no	Property	Value
1	Color	Whitish
2	Length	12mm
3	Diameter	0.014mm
4	Average aspect ratio	857
5	Limiting oxygen index	1%
6	Moisture	0.9%
7	Tensile strength	1700 MPa

4 Sample preparation

The sandy soil was mixed with different proportions of bottom ash as 10,20,30 and 50%. For reinforcing the soil, the plastic strips were added in different proportions as 0.5,0.75,1 and 1.25% to the same geomaterial formed. Table 4 shows various mix proportions. To obtain geomaterial of any proportion the quantity of each material was worked out as per the weight to be obtained and it was dry mix properly in a tank as shown in Fig.5. After proper mixing, 10% water was added to obtain uniform mix as shown in Fig.6. The geomaterial so formed was used to find the various geotechnical properties.

Fig. 5. Dry mix

Fig. 6. Wet mix

Table 4. Various mix proportions

Sand	Bottom ash	Plastic strips
100 %	-	-
89.5 %	10%	0.5%
		0.75%
		1%
		1.25%
79.5 %	20%	0.5%
		0.75%
		1%
		1.25%
69.5 %	30%	0.5%
		0.75%
		1%
		1.25%
59.5 %	50%	0.5%
		0.75%
		1%
		1.25%

5 Experimental program and Results

In this study, in order to examine the physical properties of both native and stabilised soils, different laboratory tests were performed including compressive strength tests, pycnometer method to find the specific gravity, sand replacement method in order to find the dry density of soil, direct shear box test to find the shear strength parameters for stabilised and unstabilised soils. All the tests were performed according to IS code.

5.1 Unit weight

As per IS code 2720, Part 28 [25] the dry density of the soil can be found out. In order to access the degree of compaction, it is necessary to use the dry unit weight, which is an indicator of compactness of solid soil particle in each volume. As per the various mix proportions the soil was tested for the unit weight and it was found that with the increase in proportion of bottom ash and plastic strips the dry unit weight of the soil increases i.e., the soil gets compacted well and there are less voids that results in soil having good strength which is shown in Fig. 7.

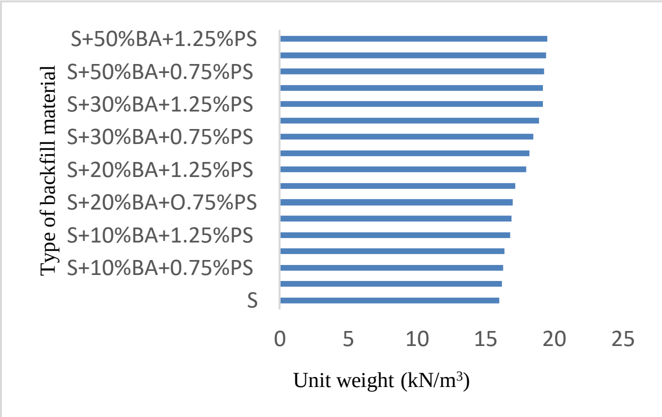


Fig.7. Variation of unit weight with the various percentages of bottom ash and plastic strips

5.2 Specific gravity

For different mixes the specific gravity was found out as per IS 2720, Part 3 Determination of Specific Gravity by pycnometer method[26]. It is an indicator how porous the soil is i.e., how many voids it has and the measurement of how much saturated the soil is with water.

With the addition of bottom ash and plastic strips in varying proportions it was seen that the specific gravity value decreased as shown in Fig. 8.

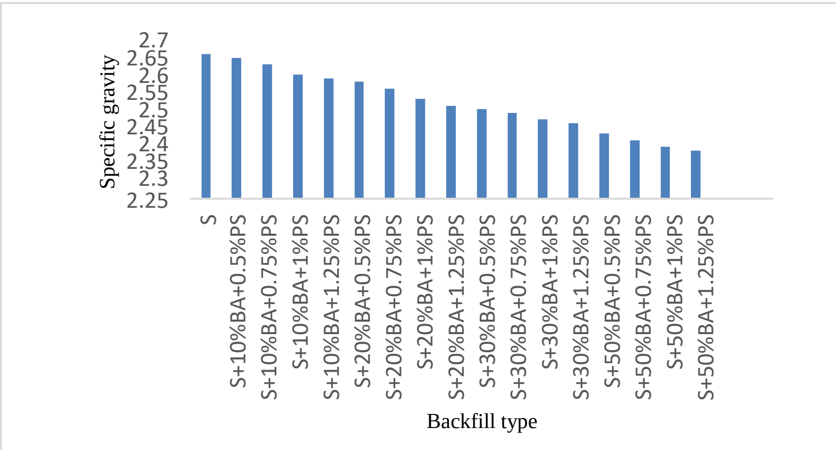


Fig.8. Variation of specific gravity with various mix proportions

5.3 Unconfined compressive strength

The Unconfined compressive strength of the cured sample kept for 21 days was found out as per IS 2720, Part 10 Determination of Unconfined compressive strength[27]. With the addition of plastic strips and bottom ash the strength of stabilized soil increased as compared to the native soil which was only 92 kPa. The increase in UCS depends mainly on the percentage of the plastic strips. The main findings show that there is a tendency for UCS values to increase due to the increase in fiber content. The soil reinforced with a fiber content of 1% showed an expressive increase in between 46%- 152% based on the varying percentages of bottom ash and plastic strips in the UCS value when compared to unreinforced soil. Because of the bridging effect of fiber, there are no development of failure planes and no deformation of soils takes place. On addition of fibers into soil, fiber tries to transfer the applied load to the frictional interface between soil particles and fibers. Because of high tensile strength of fibers, when incorporated with soil its load taking capacity increases and hence the UCS value. It is clear from Fig. 9 that the UCS value once increases with the increase in bottom ash and plastic strips percentages but for 1.25% PS for all the other proportions of bottom ash the value gets decreased, it is because with increase in fiber content above certain percentage will result in slippage of fiber over each other because of which soil particles separate and decreases the strength of soil. Table 5 shows the UCS test results.

The study revealed that the choice of percentages of bottom ash and plastic strips must be made carefully in order to get higher strength with optimized percentages of fiber and bottom ash.

Table 5. Unconfined compressive strength of various proportions of geomaterial

Sand	Plastic strips	Bottom ash	UCS value (kPa)	% Increase w.r.t virgin soil
100%	0%	0%	92	-
89.5%	0.5%	10%	110	19.56
89.25%	0.75%	10%	118	28.26
89%	1%	10%	135	46.74
88.75%	1.25%	10%	124	34.78
79.5%	0.5%	20%	133	44.56
79.25%	0.75%	20%	150	63.04
79%	1%	20%	171	85.86
78.75%	1.25%	20%	153	66.3
69.5%	0.5%	30%	185	101.08
69.25%	0.75%	30%	210	128.26
69%	1%	30%	225	144.56
68.75%	1.25%	30%	207	125
49.5%	0.5%	50%	210	128.26
49.25%	0.75%	50%	215	133.69
49%	1%	50%	232	152.17
48.75%	1.25%	50%	215	133.69

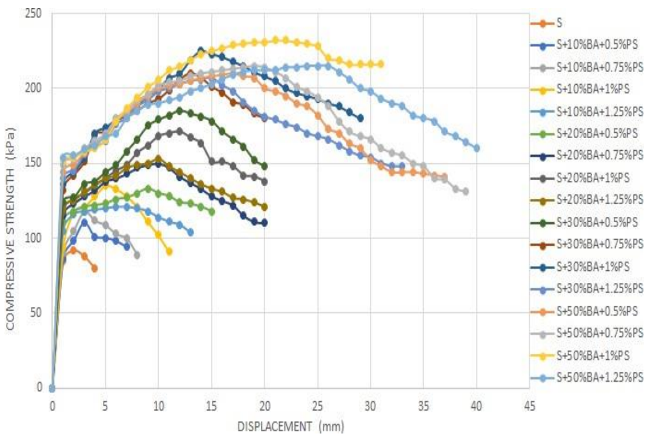
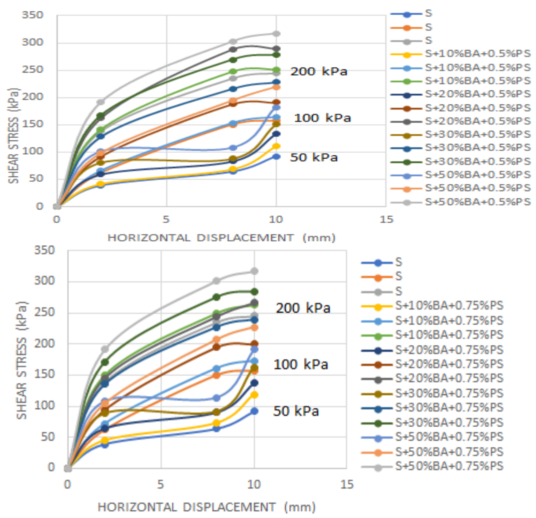


Fig. 9. Unconfined compressive strength-displacement response for reinforced and unreinforced samples

5.4 Shear strength

Soil specimens with and without fibers were tested inside a shear box of 60 mm×60 mm in plane and 25 mm in depth as per IS 2720 Part 11[28].

A typical shear stress-horizontal displacement curve with the increasing percentages of the bottom ash and with same percentage of plastic strips under normal stress of 50, 100, 200 KPa is showed in Fig 10. It was seen that the improvement is more if we increase the percentages of the bottom ash keeping percentage of plastic strips constant. As the normal stresses increased the shear stress for a horizontal displacement is more. Similar trend was obtained for other combinations as well.



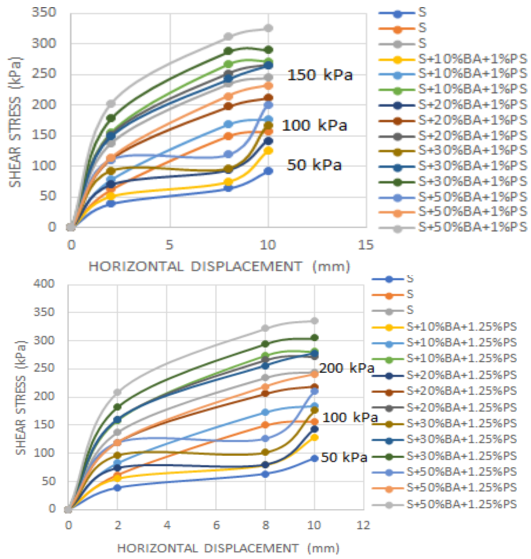
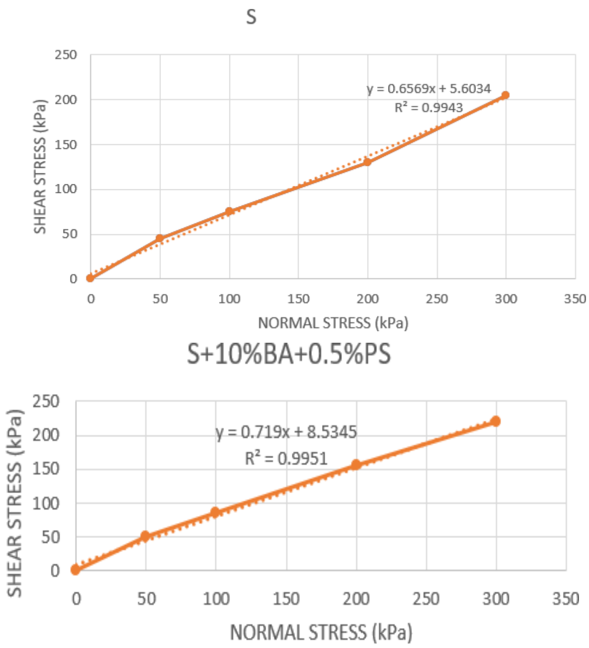


Fig. 10. Shear stress-horizontal displacement response for reinforced and unreinforced specimens with same PS percentage and varying BA percentages

With the inclusion of fibers, the shear strength increased. Based on results of direct shear tests shown in Fig. 11, it can be concluded that an increase in the fiber content increases the internal friction angle and cohesion values of the reinforced soil specimens. Direct shear tests revealed that as the normal stress increases the shear strength of sample increases for all mixtures. As the fine content increased bottom ash increased the cohesion gets larger and it contributes to the shear strength significantly.



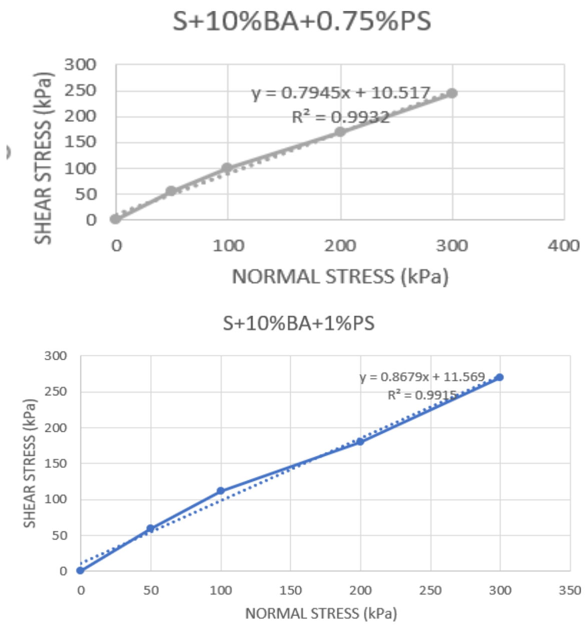


Fig. 12. Mohr-Coulomb failure envelopes for virgin and stabilized soil

Based on the direct shear test, it was seen that with the increasing percentages of the bottom ash and plastic strips the values of angle of internal friction and cohesion also increased as shown in Fig. 12 and Fig. 13

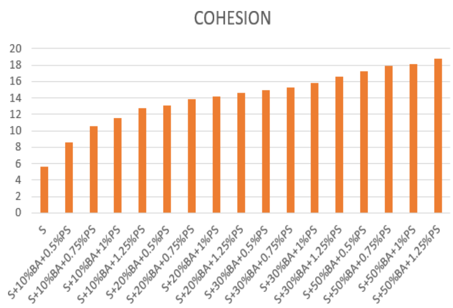


Fig. 12. Variation of cohesion

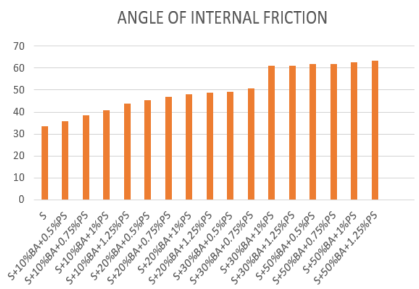


Fig. 13. Variation of angle of internal friction

6 Conclusions

This study was conducted to investigate the effect of fiber content and bottom ash on the geotechnical properties of stabilized soil. A series of laboratory test including pycnometer test, sand replacement test, unconfined compression, direct shear tests were performed. The following conclusions can be drawn from the study:

For various mix proportions, with increase in proportion of bottom ash and plastic strips the dry unit weight of the soil increases. With increase in percentages of plastic strips and bottom ash the UCS value increased till 1% PS with varying percentages of bottom ash, but for 1.25%PS with varying percentages of bottom ash the value decreased because the increase in fiber content above a specific value led to slippage of fiber panels over each other and causes soil to separate, thus it decreases strength of the soil. By pycnometer method, it was found that with addition of bottom ash and plastic strips the specific gravity value decreased. Performing the direct shear test, a typical shear stress-horizontal displacement curve with fiber content of 0.5,0.75, 1 and 1.25% with 10% bottom ash at normal stress of 50, 100 and 200 kPa, it was seen that with increase in the inclusion of plastic strips the shear strength increases but the improvement is not much. Also, as the normal stress increases the shear strength for horizontal displacement is more. A typical shear stress-horizontal displacement curve with increasing percentages of bottom ash and with same percentages of plastic strips under normal stress of 50, 100 and 200 kPa the improvement was more. Based on the results of direct shear test, by plotting Mohr circle it was found that with increase in fiber content and bottom ash the internal friction and cohesion values increased.

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