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Strength behavior of clayey soil stabilized with saw dust ash

Wajid Ali Butt[1*], Karan Gupta[2] and J. N. Jha[2]

*Correspondence: Wajid2643@gmail.com; Wajid2643@yahoo.com
[1] College of Engineering and Technology, BGSB University, Rajouri 185234, Jammu and Kashmir, India
Full list of author information is available at the end of the article

Abstract

Huge quantity of saw dust is being generated worldwide due to the rapid urbanization. The disposal of saw dust in open areas or landfills is not an environment friendly solution. Utilization of saw dust as ash in geotechnical applications is likely provides a better solution. Keeping this in view, an extensive experimental study was carried out to demonstrate the soil improvement prospective of saw dust ash (SDA) by performing California bearing ratio (CBR) and unconfined compression strength tests. The experimental study has revealed that the addition of SDA results a significant increase in CBR and unconfined compressive strength. Furthermore the values of CBR obtained are within the limits recommended by the Asphalt Institute for Highway sub-base and sub-grade. Thus from the present study it is concluded that SDA, an industrial waste, is a cheap satisfactory stabilizing agent for sub-base and base course in clayey fills; although its performance can be improved by combining it with other bonding materials such as lime, and becomes an alternatives use of industrial waste to reduce the construction cost of road particularly in the rural areas of the country.

Keywords: Saw dust ash, California bearing ratio, Compaction, Unconfined compressive strength, Clayey soil, Stabilization

Background

Upholding and replacement of existing pavements consumes a huge amount of budgets of transportation departments in every country of the world. Methods for reducing the cost of construction and lengthening pavement life can help in better maintain the road network on limited budgets. Modern roads are expected to provide a high level of safety and comfort to the users. Soil can be enhanced either by adjustment or stabilization, or both. The alteration of soil is done by the addition of different type of admixtures like (cement, lime, etc.) to a soil in order to change soil's index properties, though the stabilization of soil is its treatment to improve its strength and durability such that to make it suitable for building a proposed structure [1, 2]. Soil stabilization is modifications or adjustments of the soils properties in order to fulfill the specified engineering requirements. The ways to stabilize the soil are compaction and usage of admixtures. Commonly used stabilizers for altering the properties of soils are Lime and Cement. Recent studies indicates the use of solid waste materials like fly ash and rice husk ash for soil stabilization by means of or devoid of lime or cement [3]. Saw dust is one of the by-product from timber industries and wood cutting factories. Saw dust by itself has little cementitious value but in presence of moisture it reacts chemically and form cementitious compounds and attribute to the improvement of strength and compressibility properties of soils. Silica is the main constituent of saw dust ash (SDA), which oversees the reactivity of the ash. The compounds of silicon account for the maximum amount as eight seven of earth's-crust, and silica is that the major component of soil [4]. The technology of construction is subjected to modifications to overcome the ever changing transport pattern, materials for the building and sub-grade environments. Mostly pavement failures may be attributed to existence of pure sub-grade conditions and costly sub-grade is one such challenging state [5]. A number of researchers have studied the physical and chemical properties of SDA. Elinwa et al. [6, 7] found that SDA can be used in combination with metalkaolin as a ternary blend to act as an admixture in concrete. Mageswari and Vidivelli [8] study the use of SDA as fine aggregate replacement in concrete by replacing sand with 5–30 % of SDA and found similar results as obtained with sand. The studies of Elinwa and Abdulkadir [9] confirmed SDA as posolinic material and reducing porosity as well as being effective in reducing corrosion of reinforcement. Recent studies by Ettu et al. [10] have confirmed the suitability of Nigerian SDA as pozzolanic material for producing concrete, sandcrete or soilcrete. Otoko and Honest [11] carried research on stabilization of Nigerian deltaic laterites with SDA. Okunada carried the research on the effect of wood ash and sawdust ash admixtures on the engineering properties of burent lateritic–clay bricks. The high percentage of siliceous material present in the SDA indicates that it has pozzolanic properties. The normal method of conversion of Saw Dust to ash is by incineration. The characteristics of SDA depends on whether the saw dust have gone complete combustion or have been partially burnt.

In order to achieve the need of improvement in the geotechnical properties of clayey soil and make use of industrial wastes, the present experimental study has been carried out. Also the purpose of this study is to determine the effect of SDA stabilizer on geotechnical properties of clayey soils. This will encourage the use of SDA as stabilizer in road construction.

Methods

Soil

The soil used in the present investigation was obtained about 1.25 m deep underground in site. The soil was clayey in nature and brought from local area of Rajouri J&K India. All the indispensable physical and mechanical properties were determined as per the relevant standard tests (IS: 2720). The physical properties are given in Table 1.

Saw dust ash (SDA)

The Saw dust was collected from local Saw mill in Industrial area, Kheora Rajouri @ Rs 2 per kg. The saw dust collected was obtained from sawing of deodar and kail wood. Saw dust is actually by-products of sawmills generated by sawing timber. It is the loose particles or wood chippings obtained by sawing wood into useable sizes. After collection, clean saw dust not having much bark and so not much organic content was air dried and burnt at the room temperature. The SDA was then sieved through 600 micron sieves to remove the lumps, gravels, unburnt particles and other materials which are deleterious to soil. The SDA passing through 600 microns sieve was used for

Table 1 Properties of soil used

Soil property	Value
Clay content %	58
Silt content %	23
Sand content %	19
Specific gravity	2.78
Liquid limit (LL) %	33.8
Plastic limit (PL) %	24.4
Plasticity index (PI) %	9.4
Classification from plasticity chart	CL
Compression index (C_c)	0.166
Maximum bulk density (gm/cc)	1.99
Maximum dry density (gm/cc)	1.81
Optimum moisture content %	11
Shear strength (S) of soil at optimum moisture content KN/m^2	124
CBR values at OMC %	6.75

the laboratory work. Figure 1 shows saw dust, Fig. 2 shows burning of saw dust and Fig. 3 shows SDA used in the present study. The main chemical components of saw dust are carbon 60.8 %, hydrogen 5.19 %, oxygen 33.83 % and nitrogen 0.90 %. The specific gravity of SDA is 2.03 and loss in ignition is 4.27 %. The chemical composition of saw dust is SiO_2 is 86 %, Al_2 O_3 is 2.6 %, CaO is 3.6 %, Fe_2O_3 is 1.8 %, MgO is 0.27 %, MnO is 0.07 %, K_2O is 0.11 %, SO_2 is 0.45 % and P_2O_5 is 0.43 %. The physical properties are tabulated in Table 2.

Laboratory studies

The laboratory studies were carried out on the samples of clayey soil and soil with different percentages of SDA Table 3.

i. *Liquid limit and plastic limit* Liquid limit and plastic limit tests were conducted on soil samples mixed with different percentages of SDA as 0, 4, 8, 12 % as per the procedures laid down in IS: 2720, Part V, 1985 reaffirmed 1995 [12].

Fig. 1 Saw dust

Fig. 2 Burning of saw dust

Fig. 3 Saw dust ash

Table 2 Properties of saw dust ash used

Colour	Greyish black
Specific gravity	2.03
Fineness	600 µm
Water absorption (%)	64
Fineness modulus	1.81
Rate of burning	3 h per kg
Unsoaked CBR (%)	7.85
Soaked CBR (%)	7.15

Table 3 Unconfined compressive strength and shear strength of stabilized clayey soil

Saw dust ash percentage	Unconfined compressive strength (q_u) KN/m^2	Undrained shear strength KN/m^2
0	248.00	124.00
4	313.14	156.57
8	184.43	92.21
12	182.00	91.00

ii. *Compaction proctor test* The mould of capacity 1000 ml with an internal diameter of 100 mm and height 127.3 mm was used. Compaction Proctor tests were conducted on soil samples mixed with different percentages of SDA as 0, 4, 8, 12 % as per IS: 2720 Part VII (Light Compaction), 1980, reaffirmed 1997 [13].

iii. *Unconfined compression test* Cylindrical test specimens of diameter 38 mm with height of 76 mm prepared using remoulded samples were used for the test. The curing period for the samples was 7 days, and three specimens were tested for each case. The tests were conducted as per IS: 2720 Part 10, 1991 [14]. All the samples were prepared by static compaction using split mould at optimum moisture content (OMC) and at maximum dry density (MDD).

iv. *California bearing ratio test* California bearing ratio (CBR) tests were carried out as per IS: 2720, Part 16, 1987 reaffirmed 1997 [15]. The tests were conducted at optimum moisture content and samples were tested in unsoaked conditions. The mould for placing the CBR sample has inner diameter of 150 mm and height 175 mm, and were kept for curing in moist sand for 7 days before testing.

Results and discussion

Consistency limits

The variation in consistency limits with SDA content (%) is shown in Fig. 4. As seen from the figure both liquid limit and plastic limit increases with increase in SDA content. This may be considered to be a result of addition of SDA, which has higher water absorption affinity.

Compaction characteristics

The variation in maximum dry density and optimum moisture content with SDA content (%) is shown in Figs. 5 and 6 respectively. The maximum dry density decreases with increase in SDA content. However, the optimum moisture content increases with increase in SDA content up to 8 % and the decreases. A decrease in the dry unit weight may be due to the lower specific gravity of the SDA, while an increase in the optimum moisture content may be as a result of water needed to be hydrated.

California bearing ratio

The CBR method has been found most reliable practical means of finding the strength of the sub-grade (bearing capacity of soil) and evaluating the required thickness of pavement to satisfy a given loading. CBR is a measure of resistance to direct penetration

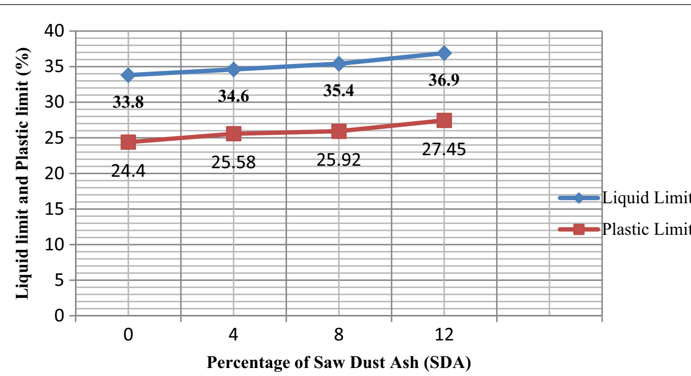

Fig. 4 Variation in consistency limits with saw dust ash content (%)

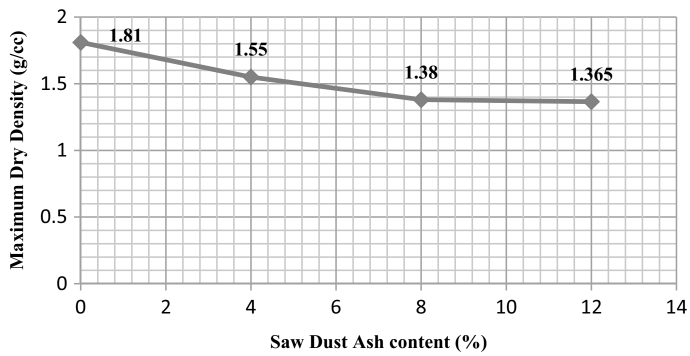

Fig. 5 Variation in maximum dry density with saw dust ash content (%)

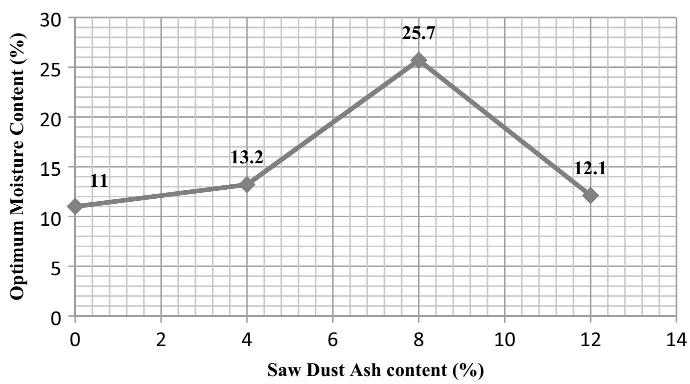

Fig. 6 Variation in optimum moisture content with saw dust ash content (%)

(load carrying capacity) of any soil which is expressed as a percentage of the load carrying capacity of the standard crushed rock specimens (which is taken as 100 % value) determined by penetration test. In the present investigation, an attempt was made to conduct CBR tests on soil stabilized with different proportions of SDA. Figure 7 shows the results of the CBR tests for the stabilized soil. As seen, CBR values of stabilized soil was improved significantly which is beneficial for the construction of the road pavements. The Asphalt Institute [16] recommended a CBR value of 7–20 % for Highway sub-base and 0–7 % for the sub-grade materials. Based on this the soil stabilized with SDA can be used as a sub-base material for the construction of Highway pavements. The Fig. 8 shows the variation of CBR with SDA content. The increase in the CBR may be due to the pozzolanic effect of SDA, and decrease after optimum value is attributed to the low strength exhibited by the SDA.

Unconfined compressive strength

Unconfined compression strength test is the most common, popular and adoptable method of evaluating the strength of cohesive and stabilized soils. This test may be considered as a special case of triaxial compression test when the lateral confining pressure is equal to zero. It is the main test recommended for the determination of the required amount of additive to be used in stabilization of the soils. As a general rule,

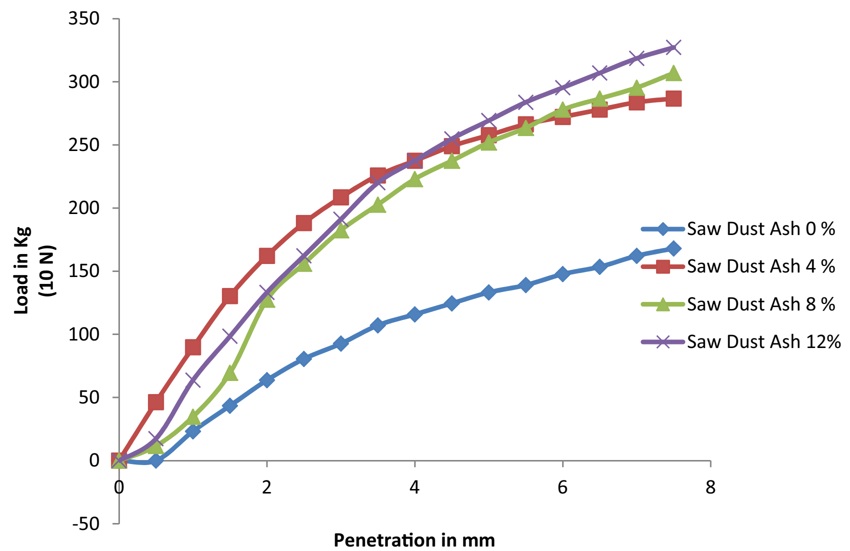

Fig. 7 Penetration curves for CBR tests for clayey soils stabilized with saw dust ash (SDA)

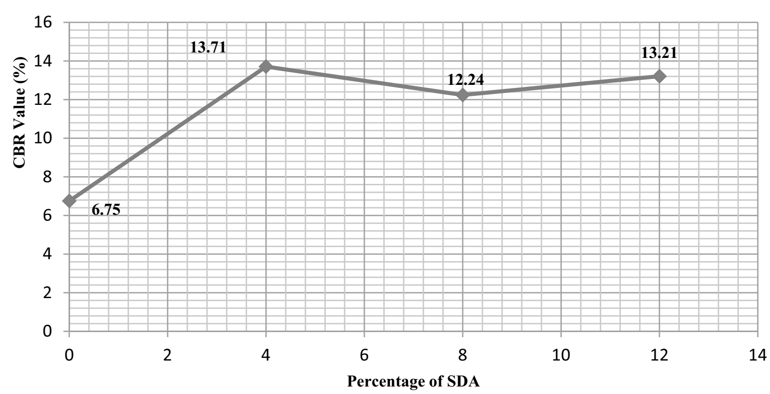

Fig. 8 Variation of CBR with addition of different percentages of saw dust ash

for a given type of stabilization, higher the compressive strength, the better is the quality of the stabilized material. The stress–strain curve for all the samples is shown in the Fig. 9 The variation in unconfined compressive strength with SDA content is shown in Fig. 10. Unconfined compressive strength increases from 248 to 313.14 KN/m^2 on addition of 4 % SDA which is taken as optimum. The increase in strength may be due to the pozzolanic reactions of SDA to form the cementious products between the CaOH present in the soil and the Pozzolana present in SDA. Whereas, the strength decreases to 184.428 and 182 KN/m^2 on addition of 8 and 12 % SDA respectively. This is due to the low strength of the SDA which consequently occupies within the sample. When excess SDA is introduced to the soil it forms weak bonds between the soil and the cementious compounds formed. According to Das [17], consistency of a clayey soil can be determined as follows: 0–25 KN/m^2 indicates very soft, 25–50 KN/m^2 is soft, 50–100 KN/m^2 is medium soft, 100–200 KN/m^2 is stiff, 200–400 KN/m^2 is very stiff and greater than 400 KN/m^2 indicates hard clay. From the study area: consistency of plain clayey soil and

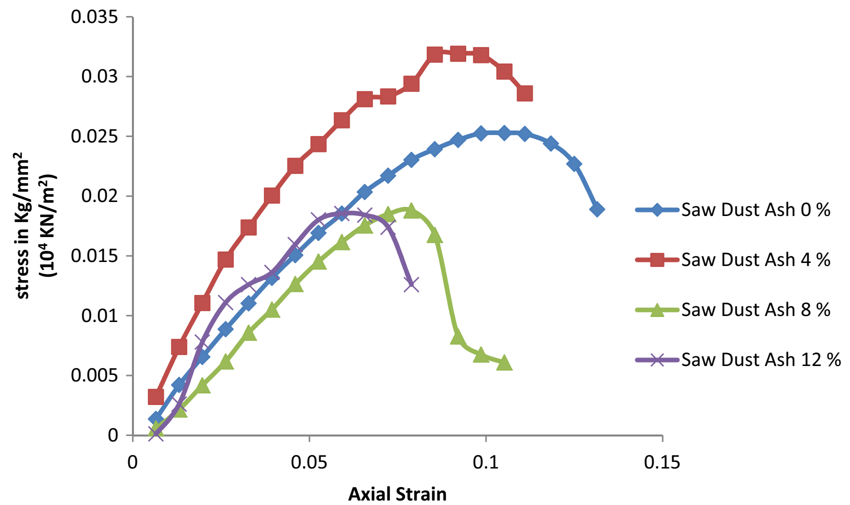

Fig. 9 Stress–strain curves for clayey soil stabilized with different percentages of SDA

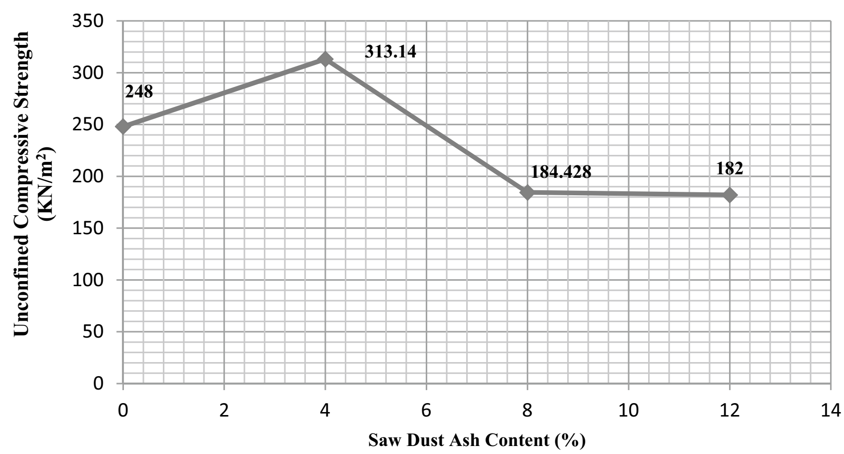

Fig. 10 Variation of UCS with addition of different percentages of saw dust ash

clayey soil with 4 % SDA content is very stiff whereas clayey soil with 8 and 12 % SDA is stiff. If target soil changes the properties and strength may change as per the composition of soil.

Conclusions

1. Liquid limit, plastic limit, plasticity index, specific gravity, un-soaked CBR and unconfined compressive strength of the stabilized soils were optimally improved by adding SDA.
2. With increase in SDA content a general reduction in maximum dry unit weight was observed. The optimum moisture content (OMC) shows increase with increase in SDA content.
3. The CBR value increases by 103.11 % and unconfined compressive strength increases by 26.35 at 4 % SDA content which is taken as optimum.

4. This investigation has discovered that SDA acceptably acts as a cheap stabilizing material for sub-grade and sub-base purposes in clayey soils.

Thus it is concluded that SDA is a satisfactory stabilizing agent for clayey soils. The utilization of the industrial wastes like SDA is an alternative to reduce construction cost of the roads particularly in the rural areas of developing countries like India.

Authors' contributions
WAB and KG performed the experiment. JNJ provided the guidance. All authors read and approved the final manuscript.

Author details
[1] College of Engineering and Technology, BGSB University, Rajouri 185234, Jammu and Kashmir, India. [2] Guru Nanak Dev Engineering College, Ludhiana, Punjab, India.

Competing interests
The authors declare that they have no competing interests.

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References

1. Ramaji AE (2012) A review on the soil stabilization using low-cost methods. J Appl Sci Res 8(4):2193–2196
2. Alhassan M (2008) Potentials of rice husk ash for soil stabilization. Assumpt Univ J Technol 11(4):246–250
3. Dahale PP, Nagarnaik PB, Gajbhiye AR (2012) Utilization of solid waste for soil stabilization: a review. Electron J Geotech Eng 17:2443–2461
4. Thenabadu MW (1977) Silica content of rice husk as determined by soil properties and varietal differences. Trop Agric 133:71–80
5. Koteswara RD, Anusha M, Pranav PRT (2012) Effect of ferric chloride and rice husk ash in the stabilization of expansive soil for the pavement subgrades. Int J Eng Sci Adv Technol 2(2):146–153
6. Elinwa AU, Ejeh SP, Mamuda MA (2008) Assessing of fresh concrete properties of self compacting concrete containing sawdust ash. Constr Build J 22:1178–1182
7. Elinwa AU, Ejeh SP, Akpabio IO (2005) Using metakaoline to improve sawdust-ash concrete. Concr Int 27(11):49–52
8. Mageswari M, Vidivelli B (2009) The use of saw dust ash as fine aggregate replacement in concrete. J Environ Res Dev 3(3):720–726
9. Elinwa AU, Abdulkadir S (2011) Characterizing sawdust ash for use as an inhibitor for reinforcement corrosion. New Clues Sci 1:1–10
10. Ettu LO, Ibearugbulem OM, Anya UC, Awodiji CT, Njoku FC (2013) Strength of binary blended cement composites containing sawdust ash. Int J Eng Sci 2(4):51–56
11. Otoko GR, Honest BK (2014) Stabilization of Nigerian deltaic laterites with saw dust ash. Int J Sci Res Manag 2:1287–1292
12. Bureau of Indian Standards (1985) Indian standard method of test for soils, IS: 2720 Part-5 Determination of liquid limit and plastic limit (Second Revision)-1985. (Reaffirmed 1995)
13. Bureau of Indian Standards (1980) Indian standard method of test for soils, IS: 2720 Part-7 Determination of water content- dry density relation using light compaction (Second Revision)-1980. (Reaffirmed 1997)
14. Bureau of Indian Standards (1991) Indian standard method of test for soils, IS: 2720 Part-10, Determination of unconfined compressive strength, (Second Revision)-1991. (Reaffirmed 1995)
15. Bureau of Indian Standards (1980) Indian standard method of test for soils, IS: 2720 Part-16, Laboratory determination of CBR-1980. (Reaffirmed 1997)
16. Asphalt Institute (1962) The Asphalt handbook. Maryland, p 176
17. Das BM (2000) Fundamentals of geotechnical engineering. In: Frias M (ed) Thomson learning USA and cement and concrete research, 4th edn