

Use of Lime and Saw Dust Ash in Soil Stablization

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ABSTRACT: Stabilization is process of fundamentally changing the chemical properties of soft soils by adding stabilizers or binders, either in wet or dry conditions to increase the strength and stiffness of the originally weak soils. The main objective of the paper was to study about stabilization of clayey soil using Saw Dust Ash and Lime. Index properties of parent soil, Atterberg Limits, compaction characteristics and UCC of both parent soil and soil treated with saw dust ash and lime were found out. All the tests were conducted by following the Indian standards guidelines. It was found that the utilization of the industrial wastes like saw dust ash is an alternative to stabilize the soil for various construction purposes however this study clearly shows that when an activator like lime is added to the sawdust ash the results are very encouraging. One can easily realize after the results that with small percentage of activator, SDA an industrial waste can be efficiently used in soil stabilization. This can reduce construction cost of the roads particularly in the rural areas of developing countries like India.

KEYWORDS: Clayey soil, Stabilization, Saw Dust Ash, Lime, Dry density, UCC, OMC, Liquid Limit, Plastic limit

I. INTRODUCTION

Soils containing large quantities of clay and silt are the most burdensome to the engineer. These materials exhibit marked changes in physical properties with changes in water content, a hard, dry clay, for example, may be suitable as a foundation for heavy loads so long as it remains dry, but it may become unstable when wet whereas many of the fine soils shrink on drying and expand on wetting, which may adversely affect structures founded upon them or constructed of them. Even when the water content does not change, the properties of fine soils may vary significantly between their natural condition in the ground and their state after being disturbed. The clay often is weak and has not enough stability in heavy loading. In this regard, it is necessary to reinforce or stabilize the soil. Stabilization in a broad sense assimilates the various methods employed for modifying the properties of a soil to improve its engineering performance. Stabilization is being used for a variety of engineering works, the most common application being in the construction of road and airfield pavements, where the main objective is to increase the stability or strength of soil and to reduce the construction cost by making best use of locally available materials. Stabilization is process of fundamentally changing the chemical properties of soft soils by adding stabilizers or binders, either in wet or dry conditions to increase the strength and stiffness of the originally weak soils. The geotechnical engineers design foundations and other structures on the soil after investigation of the type of soil, its characteristics and its extent. If the soil is good at shallow depth below the ground surface, shallow foundation such as footing and rafts are generally most economical. However if the soil just below the ground surface is not good but a strong stratum exist at a great depth, then deep foundation such as piles, wells and caissons are required. Deep foundations are quite expensive and are cost effective only where the structure to be supported is quite heavy and huge. Sometimes the soil conditions are very poor even at greater depth and it is not practical to construct even deep foundation. In such cases various methods of soil improvement (stabilization) techniques are adopted. The objective is to improve the characteristics at site and make soil capable of carrying load and to increase the shear strength, decrease the compressibility of the soil, so that the bearing

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capacity of the soil is increased and the settlement of the structures built on it are reduced. Sometimes, the aim is to decrease the permeability of the soil.

Scientists, engineers and technologists are continuously on the lookout for materials which can be used as substitute for conventional materials or which possess such properties which would enable their use for new designs and innovation. Lately, a large amount of laboratory experimental studies have been carried out, wherein soil is mixed with artificial and natural fibers. Besides soil, concrete has also been extensively reinforced with different waste fibers like lathe scrap (Qureshi et.al, 2016). Soils have been mixed with fibers like hair, bamboo Coconut (coir), fiber Sisal, Palm fiber, Jute, Flax, and Pine etc. Soil Stabilization can also be done by adding lime, cement, calcium chloride, sodium chloride etc. Sometimes combination of both fibers and chemicals has been used. (Chen and Wang 2006) studied; different types of additional admixtures were used with cement to stabilize a soft soil with a high natural content. (Punthutaecha et.al 2006) uses class F fly ash, bottom ash, polypropylene fibers, and nylon fibers to know and increase volume alteration chattels of sulfate affluent expansive soils. Ash stabilizers provided enhancement in plummeting swelling, shrinkage, and plasticity characteristics by 20–80% whereas fibers treatments resulted in varied improvements. In together, class F fly ash mixed with nylon fibers was the most effective treatment on both Dallas and Arlington soils, which also led to improvement in strength of soils. (Okunade 2008) carried research on the effects of wood ash and sawdust admixtures on the engineering properties of a burnt laterite-clay bricks. The admixtures were added in various combinations of proportions by volume (from 0 to 10%). It was discovered that the major contribution of the saw dust admixture is the reduction in dry density of finished burnt brick product. (Henry & Ogunribido 2009) carried research on geotechnical properties of saw dust ash stabilized south-western Nigeria lateritic soils. This research was carried out to evaluate the effects of saw dust ash on the geotechnical properties of soil. The results show that saw dust ash has improved geotechnical properties of soil samples. (Tiwari and Mahiyar 2014) tried 48 samples test samples to study the physical properties of soil such as hygroscopic water content grain size allotment, specific gravity, Atterberg's limits, Direct shear test, Swelling pressure, MDD-OMC, CBR, Permeability test values in first phase. In second phase, a variety of test exploration were done on black cotton soil using different percentages of Fly Ash (FA), Coconut Coir Fiber (CCF) and Crushed Glass (CG). It was found that there was significant increase in strength of soil. (Singh and Vasaikar, 2016) found that foundation design on black cotton soil (expansive soil) is difficult task to achieve because the structure built on this type of soil break without any signal. They modified the BC soil by lime to stabilize it and added 4 % and 6 % of lime and results were positive.

The existing soil at a particular location may not be suitable for the construction due to poor bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils. The improvement of soil at a site is indispensable due to rising cost of the land, and there is huge demand for high rise buildings. There is a need to concentrate on improving properties of soils using cost-effective practices like treating with industrial wastes those having cementitious value. In this study, materials like Saw Dust Ash (SDA) and Lime are used to improve geotechnical properties of a soil. The focus of the study was mainly on

1. To determine the index properties of clayey soil.
2. To compare the Unconfined Compressive strength and compaction characteristics between clayey soils treated with Saw dust Ash alone then by Lime alone and one treated with mixture of both saw dust and Lime.
3. To find the effectiveness of saw dust ash and lime mixture in clayey Soil.

II. MATERIALS

(i). Soil

The soil samples were collected from location which is about 28 km from Rajouri town. Samples for soil were created in the college of engineering and technology BGSB university geotechnical lab. Various preliminary tests for index properties and strength were determined in the lab beside this sieve analysis were done. Soil samples were obtained from the Dangri area situated at a distance of 25 km from Rajouri (33⁰23'N 74⁰18'E). Prototypes for soils were created

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in the College of Engineering & Technology BGSB University Rajouri J&K Geotechnical Engineering lab. Table 1 shows the properties of the parent soil collected for experiment.

Table 1: Properties of parent soil

S.NO	SOIL PROPERTY	SAMPLE
1	Site from where soil is taken	Dangri (25 Km from Rajouri
2	Colour of Soil	Light Brown
3	Depth at which sample are taken in m	0.1 m to 0.5 m
4	Nature of soil	Clay Type
5	Natural moisture content (w) in %	11.70
6	Specific gravity (G) at 27 °C	2.78
7	Uniformity Co-efficient (C _u)	5.67
8	Co-efficient of Curvature (C _c)	0.96
9	Liquid limit (LL) in %	33.8%
10	Plastic Limit (PL) in %	24.4%
11	Plasticity Index(PI = LL - PL) in %	9.4%
12	PIA = 0.73(LL-20) in %	10.074
13	Classification from plasticity chart	CL
14	Soil type base on PI & PIA (%)	Clay
15	Compression index C _c =0.007(LL-10)	0.166
16	Void Ratio (e)	0.53
17	Liquidity Index	1.35
18	Relative Consistency	2.35
19	Flow Index (FI)	1.035
20	Toughness Index (TI)	9.08
22	Maximum Dry density (MDD) in gm/cc	1.804
23	Optimum Moisture Content (OMC) in %	10.52
24	Shear strength (S) of soil at optimum moisture content in KN/m ²	247.7 KN/m ²
25	CBR values at OMC in %	6.75

(ii) Saw Dust Ash

Saw dust is one such by-product from Timber industries and Wood cutting factories. Saw dust by itself has little cementitious value but in the presence of moisture it reacts chemically and forms cementitious compounds and attributes to the improvement of strength and compressibility characteristics of soils. So in order to achieve both the need of improving the geotechnical properties of clays and also to make use of the industrial wastes, the present experimental study has been taken up.

The Saw dust was collected from local Saw mill in Industrial area, Kheora Rajouri @Rs 2 per Kg. 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. The Saw dust ash (SDA) was then sieved through 600 micron sieves to remove the lumps, gravels, unburnt particles and other materials which are deleterious to soil. The Saw dust ash passing through 600 microns sieve was used for the laboratory work. Figure 1 and Table 2 shows Saw Dust Ash and its properties.

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Figure 1: Sawdust Ash

Table 2: Physical Properties of Saw dust ash

Colour	Greyish Black
Specific Gravity	1.885
Fineness	600 microns
Water Absorption	224%
Rate of burning	3 000 gm /hours
Dry density	1.8gm/cc

(iii) Lime

Lime is one of the additives which are widely used in the stabilization of soil. Lime is chemically known as calcium oxide (cao) and commonly known as quick lime. It is a white caustic alkaline crystal at room temperature. The lime used in our study was fined grained hydrated high calcium lime having formulae $ca (oh)_2$. The main contribution of lime to strength of soil is form its ability decrease the apparent amount of fines in a soil causing flocculation and agglomeration of clay particles lime also create cementation between soil particles, higher the surface area of soil the more effective the process of lime cementation. Lime is easily available and thus it was used in our study.

III. METHODOLOGY

(i). Atterberg Limits : They were determined by following the Indian Standard guidelines for parent soil and soil having varied values of 0% to 12% (multiples of 4) of SDA by weight of the total quantity soil taken and Lime as 4, 5 and 6% by weight of the total quantity soil

(ii) Compaction characteristics: Compaction characteristics like dry density and optimum moisture content were determined by Compaction proctor test for parent soil and soil having varied values of 0% to 12% (multiples of 4) of SDA by weight of the total quantity soil taken and Lime as 4, 5 and 6% by weight of the total quantity soil taken by following IS: 2720 (Part 8) 1980.

(iii) Shear Strength: Same percentage of materials which were used in case of compaction characteristics were used in this case as well. Shear strength was determined by following IS: 2720 (Part 10) – 1991

IV. EXPERIMENTAL RESULTS

(1) VARIATION OF ATTERBERG LIMITS OF SOIL REINFORCED WITH LIME AND SDA

liquid limit of soil when it was not stabilized with lime was found out to be 33.8 but it was found that with gradual increase in percentage of lime the liquid limit of the soil was increasing which indicates that even with increased moisture content soil posses some shear strength . The details of liquid limit with varying percentage of lime are shown in figure 2 as far as plastic limit is concerned it was also increasing but to greater extend as compared to liquid limit. Hence when plasticity index was found it was decreasing with increase in percentage of lime in soil. The reduction in plasticity index makes soil friable and more workable furthermore the aggregate formed by flocculation of soil particles behave more or less like silt rather than clay. The swelling potential of soil is also reduced as a result of reduction in

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plasticity index. liquid limit of soil when it was not stabilized with saw dust ash was found out to be 33.8 but it was found that with gradual increase in percentage of saw dust ash the liquid limit of the soil was increasing which indicates that even with increased moisture content soil posses some shear strength . As plastic limit is concerned it was also increasing but to greater extend as compared to liquid limit. Hence when plasticity index was found it was decreasing with increase in percentage of saw dust ash in soil. The reduction in plasticity index makes soil friable and more workable furthermore the aggregate formed by flocculation of soil particles behave more or less like silt rather than clay. When the comparison on the whole between soil stabilized with saw dust ash alone lime alone and combination of saw dust ash and lime was made. It was found that variation in liquid limit of soil when stabilized with saw dust ash was the most but when the soil was stabilized with lime alone liquid limit was increasing from 0 to 4 % lime gradually. but after that light decrease in value of liquid limit was found this may be due to cation exchange and flocculation that bring about rapid change in liquid limit . As far as plasticity index was concerned it was increasing more drastically in soil stabilized with lime then saw dust ash . the plasticity index reduction was found in both lime and saw dust ash stabilized soil, however the reduction in plasticity index in lime stabilized soil was more drastic as compared to sawdust ash stabilized soil which became constant with increase in percentage of sawdust ah in soil .but the deduction in plasticity index was not as much as it was expected hence both lime and saw dust ash were added simultaneously in soil in sawdust ash and the results were found to be very encouraging . The plasticity index was found to be decreasing more drastically in this case then the soil stabilized with lime or saw dust ash alone. The reduction in plasticity index makes soil friable and more workable besides reducing swelling property of soil this can be considered to be a result of addition of saw dust ash, which has higher water absorption affinity.

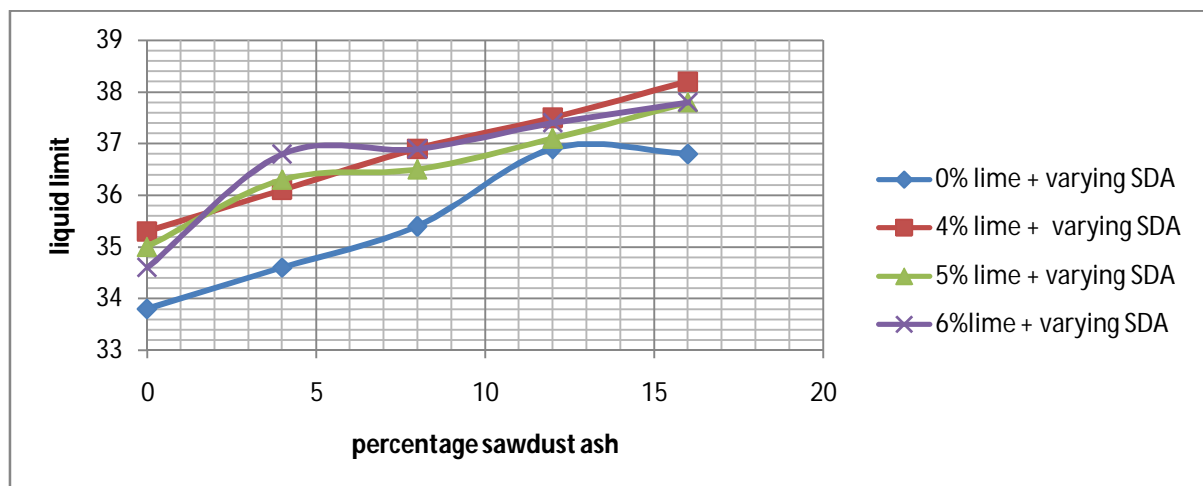


Figure 2: variation of Atterberg limits

(ii) Variation of compaction Characteristics

The variation in maximum dry density and optimum moisture content with Saw Dust Ash content (%) is shown in figure 4.24 and figure 4.26 respectively. The maximum dry density decreases from 1.81g/cc to 1.55 g/cc, 1.38 g/cc and 1.365 g/cc on addition of 4%, 8% and 12% Saw Dust Ash respectively. However, the optimum moisture content increases from 11% to 13.2%, and 25.7% on addition of 4% and 8% Saw Dust Ash but decreases to 12.1% on addition of 12% Saw Dust Ash. Dry unit weight in various soils mixed with Saw Dust Ash decreases with an increase in the percentage of Saw Dust Ash, while the optimum moisture content increases. A decrease in the dry unit weight may be due to the lower specific gravity of the saw dust ash, while an increase in the optimum moisture content may be as a result of water needed to be hydrated.

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The variation in maximum dry density and optimum moisture content with lime content is shown in figures 4.25. The maximum dry density decreases from 1.87g/cc to 1.65g/cc, 1.58 g/cc and 1.51 g/cc on addition of 4%, 5% and 6% lime respectively. However, the optimum moisture content increases from 10.52% to 11%, and 12.14% on addition of 4%, 5% and 6% lime. Dry density in various soils mixed with lime decreases with an increase in the percentage of lime, while the optimum moisture content increases. A decrease in the dry unit density may be due to the lower specific gravity of the lime even lower than saw dust ash, while an increase in the optimum moisture content may be as a result of water needed to be hydrated. Figure 3 and 4 shows variation of MDD and OMC.

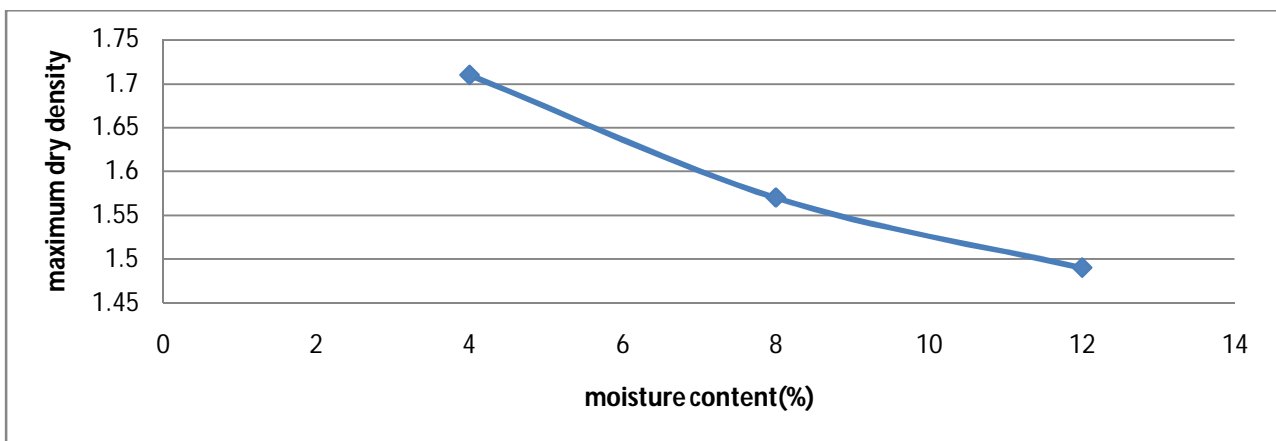


Figure 3: maximum dry density vs moisture content at 4%, 8% and 12% SDA

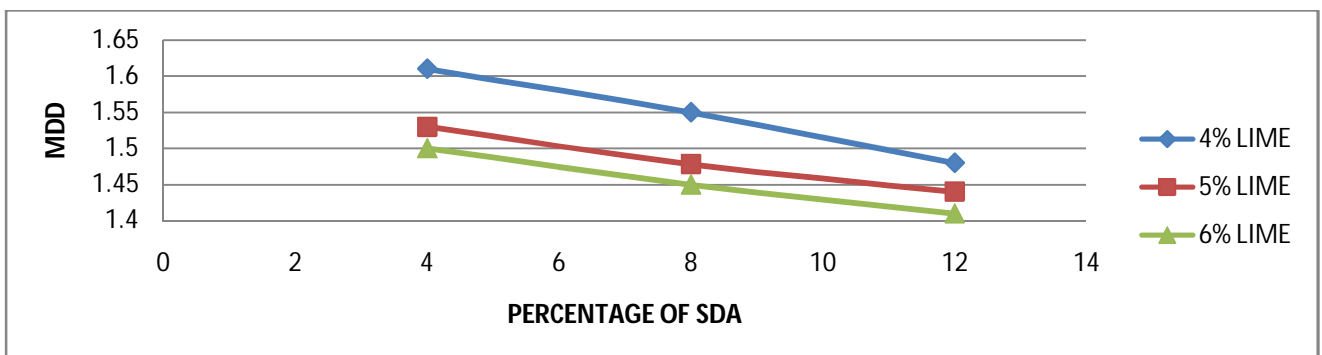


Fig 4: variation of MDD with SDA

(iii) Unconfined Compressive Strength

The variation in unconfined compressive strength with Saw Dust Ash content is shown in figure 4.28. Shear strength increases from 247.7 KN/m² to 313.14 KN/m² on addition of 4% Saw Dust Ash. Whereas, it decreases to 184.428 KN/m² and 182 KN/m² on addition of 8% and 12% Saw Dust Ash respectively. consistency of a clayey soil can be determined as follows: 0-25 KN/m² indicates very soft, 25-50 KN/m² is soft, 50-100 KN/m² is medium soft, 100-200 KN/m² is stiff, 200-400 KN/m² is very stiff and greater than 400 KN/m² indicates hard clay. From the study area: consistency of plain clayey soil and clayey soil with 4% SDA content is very stiff whereas clayey soil with 8% and 12% SDA is stiff. The variation in unconfined compressive strength with lime content is shown in figure 4.29. Compressive

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stress increases from 247.7KN/m² to 342.21 KN/m² on addition of 4% lime and 342.21KN/m² to 359.7KN/m² on addition of 5% lime. The compressive stress decreased from 359.7KN/m² to 333.2 KN/m² on addition of 6% lime. . According to Das (2000), consistency of a clayey soil can be determined as follows: 0-25 KN/m² indicates very soft, 25-50 KN/m² is soft, 50-100 KN/m² is medium soft, 100-200 KN/m² is stiff , 200-400 KN/m² is very stiff and greater than 400 KN/m² indicates hard clay. From the study area: consistency of plain clayey soil and clayey soil with 4% lime , 5% lime and 6% lime fall under the category of stiff clays. Tests result suggest that even the ultimate compressive strength of soil decreased slightly when concentration of lime was increased from 5% to 6%, however one can notice that the compressive stress show higher value with 6% lime then at 5 % lime when soil is subjected to less axial strain. As mentioned earlier lime here acts as activator in the whole process of stabilization. Lime not only decreases the plasticity index but also involves in the process of pozzolanic reaction making soil matrix more stable. It is observed that compressive strength increases from 247.7KN/m² to 342.21 KN/m² when soil was added with 4% lime alone and it increased from 247.7 to 313.14 KN/m² when SDA was added alone. When we added both SDA and lime the compressive strength increased to 342.21KN/m². Hence there is a substantial increase in the compressive stress when both lime and SDA are used in equal proportion of 4% each. With 4% lime, 8% SDA and 4% lime, 12% SDA compressive strength changed from 359.7KN/m² to 333.298 KN/m² respectively. With (5% lime + 4% SDA), (5% lime + 8% SDA) and (5% lime + 12% SDA) compressive strength changed from 377.88KN/m² to 428.26KN/m² to 342.90KN/m². With (6% lime + 4% SDA), (6%lime + 8% SDA) and (6% lime + 12%SDA) compressive strength changed from 342.216KN/m² to 359.758KN/m² to 333.298KN/m². It was found from the test result that the maximum value of compressive strength was obtained when 5% lime and 8% SDA was used in the parent soil. It was also observed when the concentration of SDA is increased from 8% to 12% rapid fall in the compressive strength was observed.

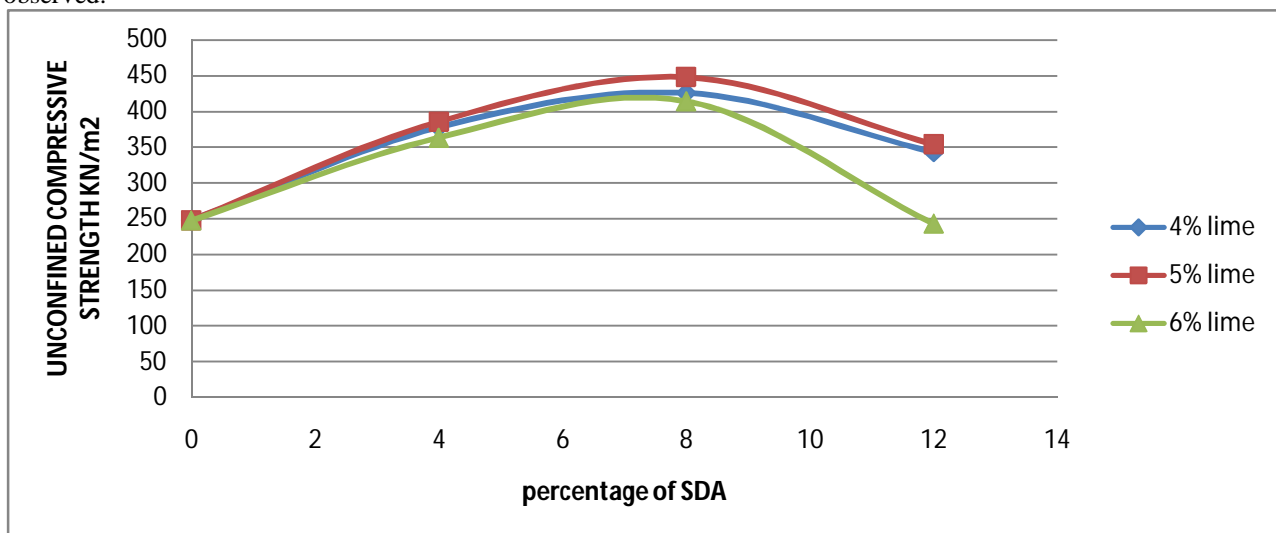


Figure 5: variation of unconfined compressive stress with lime & SDA

V. CONCLUSION

The physical properties and engineering characteristics of virgin soil were studied, which includes moisture content, Atterberg's limits, compaction characteristics and unconfined compressive strength. The addition of Saw Dust Ash (SDA) improved the properties of the virgin soil, making it good for sub-base material whereas on addition of lime the plasticity index reduced drastically when compared with the soil stabilized with sawdust ash alone.

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1. The decrease in dry density on addition of lime and sawdust ash both can be well related to the fact that the density of these substances is less than soil. However the density of the fine ground hydrated lime ($\text{Ca}(\text{OH})_2$) is very less about 1.2 g/cc therefore dry density decreases to a greater extent when soil is added with lime alone as compared to the addition of SDA alone .
2. Tests result also suggest that much increase in unconfined compressive strength is seen when both lime and sawdust ash is used as a stabilizer in this substantial increase in the compressive strength of soil can be understood by the fact that the main protagonist in the process is the lime which is also present the sawdust ash .
3. Lime soil reactions are complex and primarily involve a two step process. The primary reaction involves cation exchange and flocculation/agglomeration that bring rapid textural and plasticity changes. The altered clay structure as a result of flocculation of clay particles due to cation exchange and pozzolanic reaction result in more friable and workable soils. The whole process of stabilization involves application of lime first then addition of sawdust ash in the field. Thus the lime turns out to be an activator in this whole process of stabilization.
4. The use of lime in soil alongside Saw dust ash further reduces the plasticity index and hence the swelling. The unconfined compressive strength was found to be increasing a little by addition of sawdust ash in soil but when soil was mixed with both lime and sawdust ash the strength of soil increases drastically. Thus making the resulting soil more workable, settlement free and stabilized.
5. It is observed that the plastic limit of the clayey soil has been increased from 24.4% to 25.58%, 26.2% and 27.45% on addition of 4%, 8% and 12% SDA respectively making soil more workable. It was observed that liquid limit first increased from 33.8% to 35.3% and then decreased to 35% and 34.6% on addition of 4%, 5% and 6% lime respectively. the decrease in plastic limit was more with lime then with SDA
6. It is observed that when both SDA and lime was added plasticity index decreased drastically making soil more workable.
7. It is observed that the maximum dry density reduced to the least value of 1.37KN/m^2 when both SDA and lime is used with a proportion of 6% lime and 12% SDA
8. It is observed that the maximum compressive strength of stabilized soil is obtained when 5% lime and 8% SDA is used. Thus it is concluded that saw dust ash is a satisfactory stabilizing agent for clayey soils. The utilization of the industrial wastes like saw dust ash is an alternative to stabilize the soil for various construction purposes however this study clearly shows that when an activator like lime is added to the sawdust ash the results are very encouraging. One can easily realize after the results that with small percentage of activator, SDA an industrial waste can be efficiently used in soil stabilization. This can reduce construction cost of the roads particularly in the rural areas of developing countries like India.

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