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A STUDY OF EFFECT OF WOOD ASHAND LIMEON CATION EXCHANGE CAPACITY AND UNCONFINED COMPRESSIVE STRENGTH (UCS) OF SOILS

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ABSTRACT: The availability of natural materials for the construction of roads is becoming a challenge in the present days. In order to provide a good alternative material for road construction in place of natural soils like sands, gravels as a sub-grade and fill material. Industrial wastes like bottom ash has been gaining importance which is obtained by burning of coal from natural thermal power plants about 50 million tonnes annually. In this connection effective utilization of bottom ash in geo-technical constructions as a replacement to conventional earth materials needs special attention. The present study aims at evaluating the geo-technical properties of compacted bottom ash-sand mixes for compaction, strength and seepage characteristics are evaluated through a series of CBR, angle of shearing resistance, coefficient of permeability, etc.., by varying the percentage of sand. Based on the experimental results it has been observed that bottom ash-sand mixes attained high strength values
i.e. CBR-10-12% and angle of shearing resistance of 38-39ºcan be used as sub-grade and fill materialwith addition of 30-50% ofsand.
KEYWORDS: Sand, Wood Ash, CBR, Angle of Resistance.

I. INTRODUCTION

Road network plays a major role in the development of the nation. Majority of roads are running on problematic soils such as expansive, soft, marshy and filled up soils. Many of these roads show several type of damages which in turn are unserviceable because of highly deteriorated conditions. Recent methodologies introduce stabilization and other techniques in road components such as sub grade, embankments in raised portions, filling in cut portions with industrialwastes.Bottom ash isone such material to replace natural soils as sub-grades and also as a fill material. The main function of Bottom ash is to give adequate support and to transfer load smoothly such that design period is protected. Bottom ash is a waste material generated by burning of coal in thermal power plants. It is available in huge quantities and more than 50 million tonsannually.

A number of researchers have made their contributions for the utilization of above said materials in various geotechnical applications. A pioneer use of bottom ash was in the production of concrete blocks used to construct many high-rise flats in London in the 1960's. Seals et al. (1972) also performed a series of one dimensional compression tests on West Virginia bottom ash. Majidzadeh et al. (1977) reported that the optimum water content of each ash actually occurred within a range rather than exhibiting a clear optimum values. DiGioiaet al. (1986)2provided typical standard compaction curves for western Pennsylvania bituminous fly ash (class F fly ash) and western US lignite and sub-bituminous fly ash (class C fly ash). Krishna Rao C.V et.al(2004)4studied on Utilization of Industrial wastes in Stabilizing Expansive soils. Kiran Biradar.Bet.al(2014)9 studied on Influence of Industrial wastes on strength parameters of clayey soil. SatyanarayanaP.V.V et.al(2004)8 studied on Industrial wastes as a construction material in rural roads. McLaren and DiGioia (1987)2 investigated the shear strength of fly ash. They compiled a data base of shear strength test results for 51 class F fly ash samples. Hung (1990) investigated the shear strength of Indian bottom ash and boiler slag compacted to different densities using direct shear testing. Cheriaf et al. (1999)1studied the pozzolanic properties of coal bottom ash by chemical and mechanical procedures and positive results were achieved in both cases. Jaturapitakkulet al. (2003)3 evaluated the replacement of cement by bottom ash in mortar and verified the importance of bottom ash grinding on the properties of the final product. Kuramaet al. (2008) Studied cement mortars with coal bottom ash as cement substitute evidenced the benefit of this residue on compressive strength, which is associated to a pozzolaniceffect. Kyu-SeokYeon et al. (2011) studied engineering characteristics of flyashand bottom ashmixes.

II. MATERIALS USED

The materials used in this investigation are bottom ash collected from ash ponds of NTPC, Parwada, Visakhapatnam and Sand was collected from river Godavari.

BottomAsh

Bottom ash was collected from NTPC power plant, Parawada, Vishakhapatnam, Andhra Pradesh. The collected bottom ash was dried and subjected to various geo-technical characterizations such as gradation, compaction, strength etc. The test results are shown in table 1 and fig 1 & 2.

Table 1: Gradation Characteristics of Bottom Ash

Grain size distribution	
Gravel (%)	0
Sand (%)	92
Fines (%)	08
a. Silt(%)	08

b. Clay(%)	0
Consistency Characteristics	
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I.S Classification	SPN
Specific gravity	1.8
Compaction characteristics	
Optimum moisture content (OMC) (%)	25
Maximum dry density (MDD) (g/cc)	1.1
Strength Parameters	
Angle of shearing resistance(deg)	36
California bearing ratio (CBR) (%) (Soaked)	6.0
Coefficient of permeability(k, cm/s)	$4.5x10^{-3}$

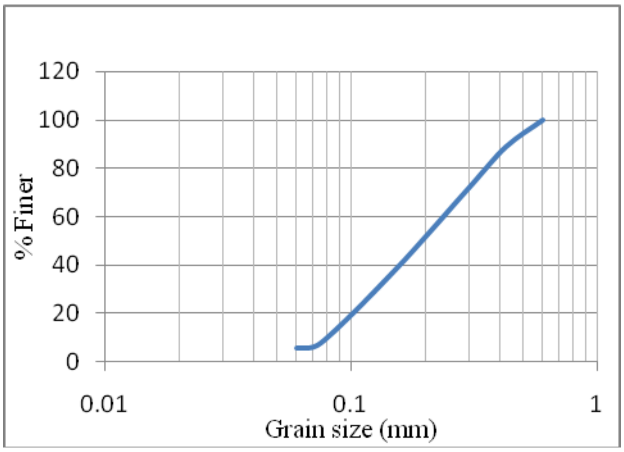

Fig 1: Gradation Curve of Bottom Ash

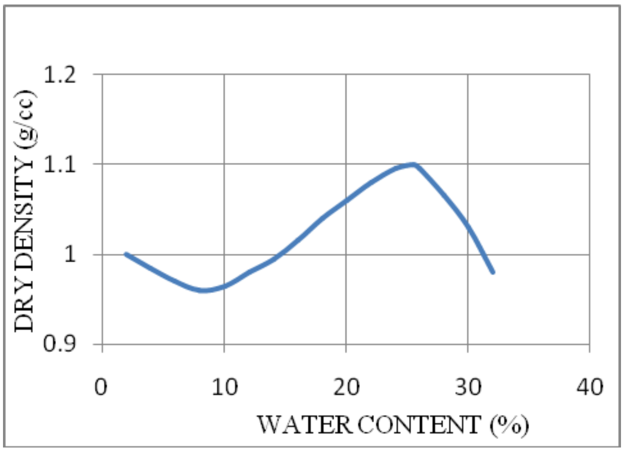

Fig 2: Compaction Curve of Bottom Ash

From the test results of bottom ash, the following identifications are made. The grain size distribution of bottom ash shows that it consists 92% of sand size particles and 8% of silt particles. Majority of Bottom ash particles are medium to fine sand ranges with rough surface texture. The gradation also shows that it comes under Zone III as per IS 383-1970. From the consistency data, it is identified that it is non plastic and incompressible. Compaction characteristics of bottom ash under modified compaction test have an Optimum Moisture Content of 25% and Maximum Dry Density 1.1 g/cc. From the compaction curve, it can be seen that bottom ash attains higher densities with wider variation in moisture content. Regarding strength characteristics, it has an angle of shearing resistance (Ø) of 36 degrees under undrained condition and CBRof6%and coefficient of permeability as $4.5x10^{-3}$cm/sec.

Sand

Sand was collected from river Godavari, Andhra Pradesh. The collected sand was dried and subjected for various geo-technical characterization such as gradation, compaction characteristics, strength, permeability etc. the test results as shown in table 2 and fig 3 and4.

Table - 2 Geotechnical Properties of Sand

Grain size distribution	
Gravel (%)	0
Sand (%)	99
Fines (%)	1
a. Silt(%)	1
b. Clay(%)	0
Consistency Characteristics	
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I.S Classification	SP
Specific gravity	2.66
Compaction characteristics	
Optimum moisture content (OMC) (%)	6
Maximum dry density (MDD) (g/cc)	1.82
Shear parameters	
Angle of Shearing Resistance	35
California bearing ratio (CBR) (%)	8
Coefficient of uniformity (Cu)	3.25
Coefficient of curvature (Cc)	0.94

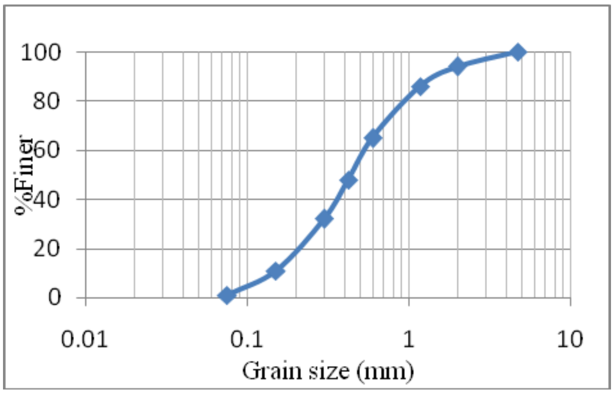

Fig 3: Grain Size Distribution Curve of Sand

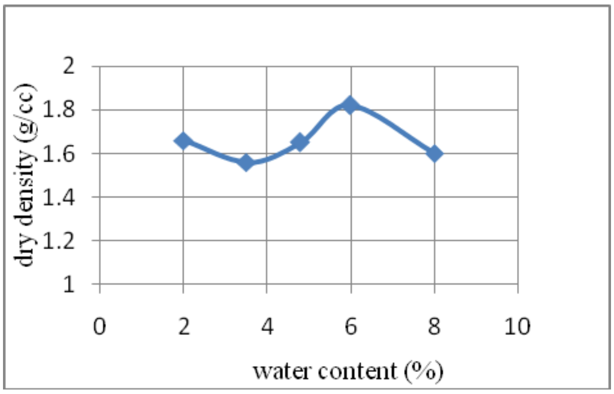

Fig 4: Compaction Curve of Sand

From the test results of sand, the following identifications are made. The grain size distribution of crusher dust shows that it consists of 99% of sand size and 1% of silt size particles. Majority of Sand particles are coarse to medium sand ranges with rough surface texture. Based on BIS, it is classified as poorly graded particles with non-plastic fines (SP). Compaction characteristics of sand under modified compaction test have an Optimum Moisture Content of 6% and Maximum Dry Density 1.86 g/cc. Regarding strength characteristics, it has an angle of shearing resistance (Ø) of 35 degrees under undrained condition and CBR of 6%. From the test data it is also identified that it has high density and high shear strengths characteristics.

Bottom Ash and Sand Mixes

Various percentages of sand such as 10%, 20%, 30%........100% were added to bottom ash and their mixes are listed below in table-4.3 and subjected for geotechnical characteristics like compaction, angle of shearing resistance and CBR tests as per IS2720.

Table -3 Various Percentages of Sand + Bottom Ash Mixes

Sand (%)	100	90	80	70	60	50	40	30	20	10	0
Bottom Ash (%)	0	10	20	30	40	50	60	70	80	90	100
Mixes	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11

III. RESULTS ANDDISCUSSIONS

Compaction Characteristics Sand and Bottom AshMixes

Mixes of Bottom ash and Sand such as M1, M2......M11 subjected to heavy compaction by compacting the samples with a rammer of 4.89 kg, five layers each layer subjected to 25 blows and their optimum moisture contents and maximum dry densities were determined as per IS 2720 part-8. The results are shown in table 4 and fig 5 &6.

Table 4: Compaction Characteristics of Sand and Bottom Ash Mixes

SAND (%) +BOTTOM ASH (%)	OMC(%)	MDD(g/cc)
100+0	6.0	1.82
90+10	7.0	1.75
80+20	8.4	1.69
70+30	10.0	1.62
60+40	11.8	1.54
50+50	13.8	1.44
40+60	16.0	1.34
30+70	18.5	1.24
20+80	20.8	1.18
10+90	23.0	1.14
0+100	25.0	1.10

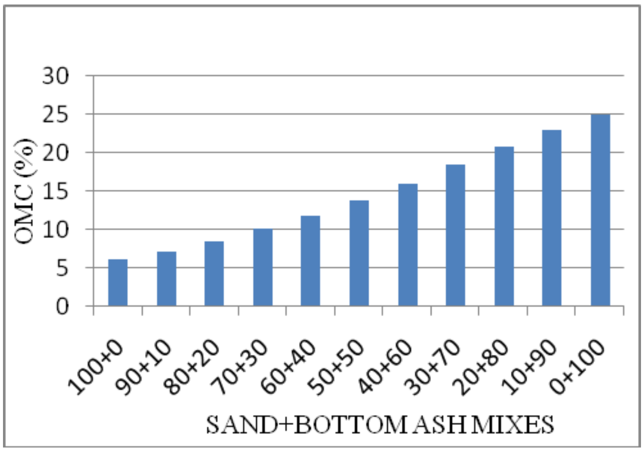

Fig 5: Variation of OMC for and Sand Bottom Ash Mixes

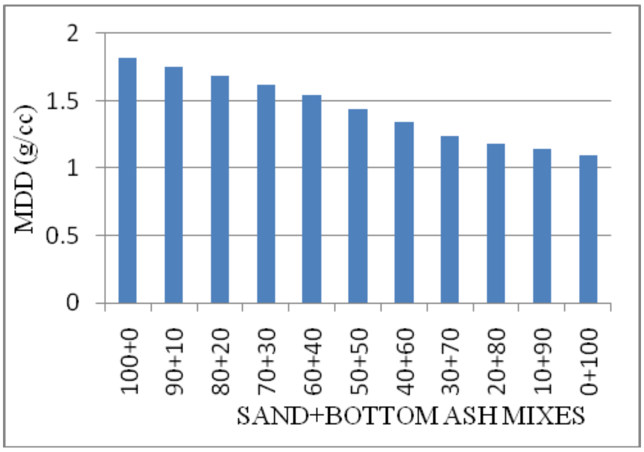

Fig 6: Variation of MDD for Sand and Bottom Ash Mixes

From the test results it is identified that as the percentage of Bottom ash is increasing OMC values are increasing (6-25%) and MDD values are decreasing (1.82-1.6 g/cc). A steady increase in OMC was up to 30 % of Bottom ash and above 40 % a rapid increase was observed. At earlier dosages the impact of bottom ash is less and sand particles are dominating in the given mixes resulting less increase in water requirements to coat the particles to coat particles to effective rolling, whereas at higher percentages 60% and above the behaviour of bottom ash particles are dominating resulting more water is needed to coat the particle to roll in the corresponding mixes.

Regarding maximum dry densities at earlier dosages of bottom ash (40%)a steady decrease in maximum dry densities were observed (1.82 – 1.62 g/cc) , at high dosages (60%) and beyond a rapid decrease in maximum dry densities were observed. This is due to dominating behaviour of sand particles at early dosage and domination of Bottom ash particles at higher dosages. It is also seen that size and shape, nature and specific gravities of sand and bottom ash particles are responsible for attainment of high optimum moisture contents and low maximum dry densities.

Angle of Shearing Resistance

Various percentages of bottom ash and sand mixes were compacted at their maximum dry densities in the shear box apparatus and tested at a strain rate of 1.25 mm/min as per IS 2720-part 13(1986) values and the results are shown in table 5 and fig 7.

Table-5 Variation of Angle of Shearing Resistance for Various Sand + Bottom Ash Mixes

MIXES	**SAND (%) + BOTTOM ASH (%)**	**Ø(deg.)**
M1	100+0	35
M2	90+10	36
M3	80+20	37
M4	70+30	38
M5	60+40	39
M6	50+50	38
M7	40+60	38
M8	30+70	37
M9	20+80	37
M10	10+90	36
M11	0+100	36

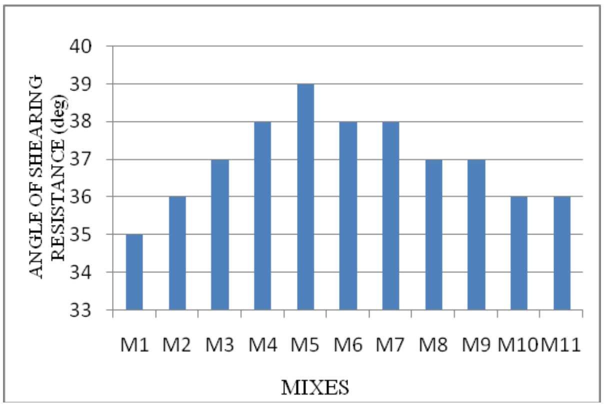

Fig-7 Variation of Angle of Shearing Resistance for Various Sand + Bottom Ash Mixes

From the experimental data it is observed that as the percentage of bottom ash is increasing in the given sand-bottom ash mixes the angle of shearing resistance values are increasing up to 40%andthen decreasing. It is also observed that the angle of shearing resistance values reached to 39 degrees for 40% dosage of bottom ash and decreased to 36 degrees for 100 % of bottom ash. A steady increase was observed up to 40% followed by a steady decrease up to 100% dosage of bottom ash. Maximum values attained at a dosage of 40%. Increase in angle of shearing resistance values are due to the development of frictional resistance between sand and bottom ash particles by filling up of formed voids by the lower sizes of sand and bottom ash particles. Hence a combination of bottom ash and sand particles mobilizes more frictional resistance than individual bottom ash and crusher dust particles undershearing.

California BearingRatio

Samples of bottom ash and sand mixes were compacted in the CBR mould at their maximum dry densities and soaked for four days and tested at a strain rate of 1.25 mm/min and the results are shown in table 7 and fig 10.

Table 6: Variation of CBR for Sand+Bottom ash Mixes

MIXES	**SAND (%)+ BOTTOM ASH(%)**	**CBR(%)**
M1	100+0	8
M2	90+10	9
M3	80+20	10
M4	70+30	11
M5	60+40	12
M6	50+50	11
M7	40+60	10
M8	30+70	9
M9	20+80	8
M10	10+90	7
M11	0+100	6

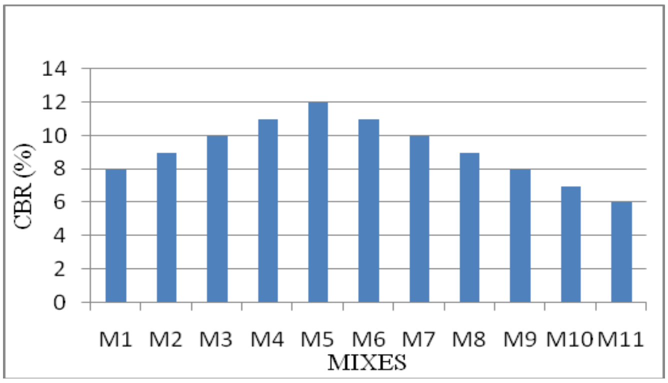

Fig 8: Variation of CBR for Sand+Bottom ash Mixes

From the experimental data as shown in table 7 and fig 10, it is observed that the mixes of sand and bottom ash have attained high CBR values in the range of 10-12. As the percentage of bottom ash is increasing in the mixes, frictional resistance values are increasing reflecting in achievement of high CBR values followed by less penetration against compression. At higher percentages of bottom ash (>40%) lower values of CBR were obtained reflecting the behaviour of bottom ash particles. Hence a dosage 20-40% bottom ash can be effectively used for sub-grade and fill materials.

Seepage Characteristics

To know the seepage characteristics of the Bottom- sand samples were tested in constant head test as IS 2720 and test results are shown below the table 8 and fig 11.

Table -7: Variation of Seepage Characteristics for Various Sand + Bottom Ash Mixes

Mixes	Sand (%) + Bottom ASH (%)	Coefficient of permeability (Cm/sec)
M_1	100+0	2.8×10^{-2}
M_2	90+10	2.2×10^{-2}
M_3	80+20	1.4×10^{-2}
M_4	70+30	9.8×10-3
M_5	60+40	9.0×10^{-3}
M_6	50+50	8.4×10^{-3}
M_7	40+60	7.8×10^{-3}
M_8	30+70	7.0×10^{-3}
M_9	20+80	6.0×10^{-3}
M_{10}	10+90	5.2×10^{-3}
M_{11}	0+100	4.5×10^{-3}

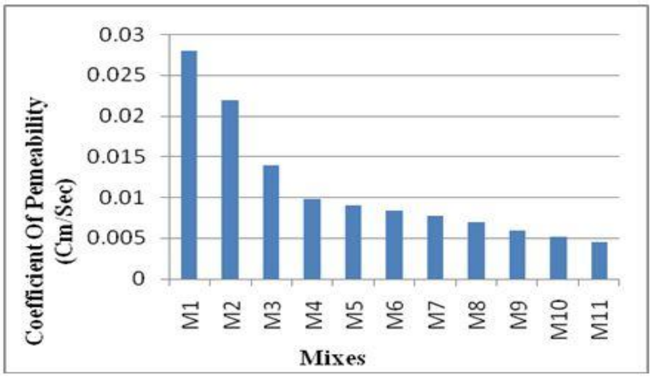

Fig-10:Variation of Seepage Characteristics of Various Sand+ Bottommixes

From the test results it is identified that as percentage of Bottom ash is increasing coefficient of permeability decreasing. Compaction condition of sand-bottom ash mixes reduces the size of voids. Hence coefficient of permeability decreasing

IV. APPLICATIONS

Industrial wastes have number of applications in civil engineering. In the present investigation industrial waste like bottom ash was mixed with sand and were tried for bulk utilization of Bottom ash in geotechnical applications such as road, embankment and fillmaterial. Bottom Ash is obtained from burning of coal. It is nearly 30% of coal ashes. It is also non plastic and incompressible material. It is dominated by fine sand size particles (<0.425mm) and comes under poorly graded material. Though it is dominated by very limited size particles, due to its nature of particles (porous) and low specific gravity .it attained high angle of shear resistance values (360) at low maximum dry density. It has the specific advantage of accepting wide range of moisture by maintaining dry densities which are nearer to the maximum dry density. To blend the above advantages sand and bottom ash mixes were verified with identified that 30% to 40% these are dominated by sand behaviour and at high dosages (>70%), it is dominated by bottom ash behaviour. These mixes achieved high CBR (12%) and angle of shearing resistance (390) values. High dry densities (>1.5g/cc), high angle of shearing resistance (390),and high CBR (12%) values. Hence 20-40% of Bottom ash can be used as alternative to sand in sub grade, fill and other geotechnicalapplications.

V. CONCLUSIONS

- Bottom ash attained low densities (1.1 g/cc) by maintaining higher water content (25%) with angle of shearing resistance (36 ^{0}) and CBR (6%) values, whereas sand has high dry densities (1.82 g/cc) at (6%) moisture content with angle of shearing resistance of (35 $^{0)}$and CBR of(8%).
- As the percentage of bottom ash is increasing in the sand and bottom ash mixes strength values like angle of shearing resistance (ϕ) increased to $39^{0}$and CBR to 12%. High strength values are attained due to filling up of formed voids in the mixes by lower sizes of bottom ash and sand particles.
- 30% - 50% bottom ash can be considered as effective utilization in the sand – bottom ash mixes by maintaining high strength values against shear andcompression.
- High values of CBR > 10% and high angle of shearing resistance values $\phi > 37^{0}$ by maintaining high moisture contents and high densities $\Upsilon_d > 1.4$ g/cc of these sand- bottom ash mixes can be used as sub-grade, fill and embankment material..

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