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Improvement Of Plasticity And Cbr Characteristics Of Gravelly Soils Using Rice Husk Ash-An Agricultural Industrial Waste

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ABSTRACT:

Gravel soils are prominent material for construction of roads. Presence of plastic fines makes gravel soils slushy and losses its function under saturation. To reduce effect of fines and to improve strength characteristics of gravels by Rice Husk Ash was identified as a stabilizer. Percentage of Rice Husk Ash varying from 5-30% was added to the gravel soils and plasticity, compaction and strength characteristics were determinant. From the test results it is identified that plasticity characteristics are decreasing, strength characteristics are increasing and these are reflected in plasticity index and CBR values respectively.

1. 0: INTRODUCTION:

Pavement carries wheel load stresses through various component layers base, sub base and sub grade. These layers should be strong enough to carry these stresses. The thickness of the component layer depends on the quality of material used in these layers. Usually these layers are made up of natural soils, sands, broken stones and gravels etc. Presence of plastic fines make sub base layer to deform under wet condition. To reduce the plastic behavior of fines by stabilization with industrial wastes have been gaining importance to make sub base has good bearing strength. RHA is an industrial waste obtained by burning of rice husk which is approximately 100 million tons annually in India.

Muntohar (2002) studied RHA and Lime in stabilizing Expansive soils, Ali et. al (2004) carried out investigations on Rice Husk Ash on Bentonite soils. Ranjan B. H et. al (1982) studied Rice Husk Ash on Black Cotton Soils. Ramanamurthy and Hari Krishna (2003) studied Morrum soils in Pavement construction. Nunan T. A (1990)

studied Gravel stabilization methods in road construction. Satyanarayana P. V. V et. al (2013) studied High Plastic Gravels stabilized with crusher dust as sub base material and Mohan N. V et. al (2012) studied partial and full replacement of Rice Husk Ash in preparation of clay bricks. Rama Rao et. al (2003) studied Lime, Rice Husk Ash and Gypsum as stabilization in expansive soil to suit as Sub-base material.
In the present investigation Rice Husk has been identified as stabilizer in studying the gravel soils to suit as Sub base material. In this investigation various percentages of Rice Husk are 5%, 10%, 15%,.... etc were added to the gravel soils and studied Plasticity, compaction and CBR characteristics.

2. 0: MATERIALS:

2. 1: GRAVEL SOILS:

Three gravel soil samples were collected from various sources of Visakhapatnam district of Andhra Pradesh i. e., Vishakhapatnam, Anakapalle, and Elamanchili. The collected Gravel soil samples from the sources can be designated as, Visakhapatnam (VG), Anakapalle (AG) and Elamanchili (EG). These samples were tested for Geotechnical Characterization such as Gradation, Compaction and Strength as per IS: 2720 and the results are listed below in the table-1, 2and fig-1(a), 1(b)&1(c).

Table-1: geotechinal properties of gravel soils:

LOCATIONS	% FINER		
PARTICLE SIZE (mm)	**VG**	**EG**	**AG**
75	100	100	100
53	94	96	96
26. 5	78	85	81
9. 5	55	66	60
4. 75	42	54	48
2. 36	33	47	40
1. 18	27	42	35
0. 6	23	38	28
0. 425	22	36	26
0. 3	21	33	25
0. 15	21	30	23
0. 075	20	28	22
0. 01	14	18	14
0. 002	6	10	8

Table-2: Gradation analysis of gravel soils

PROPERTIES	LOCATIONS		
	AG	**VG**	**EG**
Gradation properties			
Gravel(%)	52	58	46
Sand(%)	26	22	26
Fines(%)	22	20	28
Silt(%)	14	14	18
Clay(%)	8	6	10
Index properties			
Liquid limit(%)	38	30	45
Plastic limit(%)	22	20	24
Plasticity index(I_P)	16	10	21
IS classification	GC	GC	GC
Compaction characteristics			
OMC (%)	9. 5	8	12
MDD(g/cc)	2	2. 04	1. 96
Strength characteristics			
CBR (soaked)(%)	19	23	15

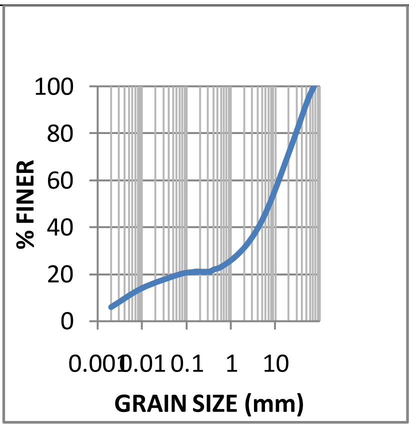

Fig-1(a): Gradation curve of VG

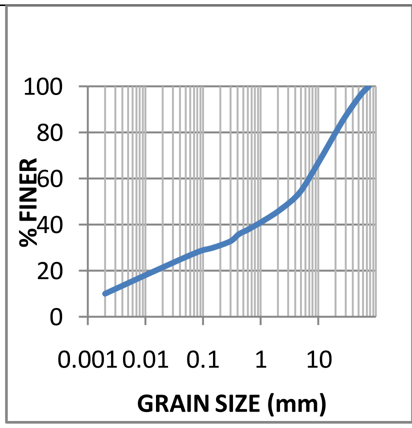

Fig-1(b): Gradation curve of EG

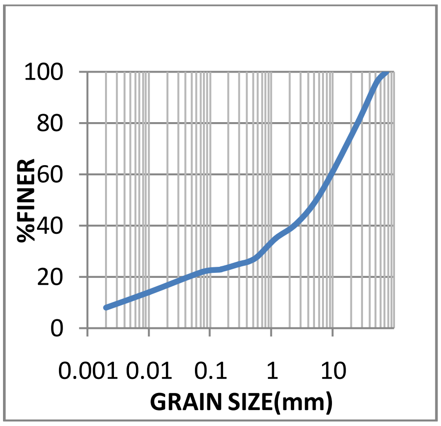

Fig-1(c): Gradation curve of AG

From the gradation test analysis IS 2720: part 4 (1975) all the three gravel soils are dominated by gravel particles (>4. 75 mm) as major constituents (48-58%) and fines (<0. 075 mm) are varying 22-28%, out of which Clay particles are 6-10%.

From the consistency test data as per IS 2720: part 5 (1970) data Anakapalle and Visakhapatnam gravels exhibited medium Plastic characteristics (I_P= 7 to 15) where as Elamanchalli and Anakapalli (I_P>15) exhibited high plastic characteristics. According to MORTH (Table 400), to meet the specification of Sub-base material, I_P<6 and W_L< 25. All the three gravel soils have not satisfying the above specifications.

From the compaction test data as per IS 2720-part: 8 (1983) it is identified that Vishakhapatnam, Anakapalli Gravel soils attained high Maximum Dry Density with less optimum moisture contents, where as Elamanchili Soil attained low maximum dry density with high optimum moisture content. Attainments of high densities are due to interaction of more solids with less water with respect to the amount of fines occupied in a given volume.

From the test IS 2720-part: 16 (1987) results it is identified the high CBR values obtained for Visakhapatnam, Anakapalli Gravels and Elamanchili gravels has less value which are less than 30 and cannot suit as sub base material, as per MORTH specifications.

2. 2 Rice Husk Ash:

Rice husk ash (RHA) was collected from Tekkali, Srikakulam, Andhra Pradesh. The collected Rice husk ash was dried and subjected to various geo-technical characterizations such as gradation, compaction, strength, permeability etc., and the test results are shown in table-2 and Fig 2.

Table 2: Geotechnical properties of RHA

Property	**Values**
Gravel sizes (%)	0
Sand sizes (%)	84
Fines (%)	16
a. Silt sizes (%)	16
b. Clay sizes(%)	0
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I. S Classification	SM
Specific gravity	1. 8
Optimum moisture content (OMC) (%)	38
Maximum dry density (MDD) (g/cc)	0. 7
Angle of Shearing Resistance	36
California bearing ratio (CBR) (%)	8
Coefficient of uniformity (Cu)	9. 14
Coefficient of curvature (Cc)	1. 75
Coefficient of permeability (k) cm/sec	$1.78*10^{-3}$
Volume of RHA per 10gm of mass per cc	35

Table 3: Chemical properties of RHA:

Chemical Compound	percentage
SiO_2	97. 69
Al_2O_3	0
Fe_2O_3	0. 22
CaO	0. 29
MgO	0
Na_2O	0. 41
K_2O	1. 39

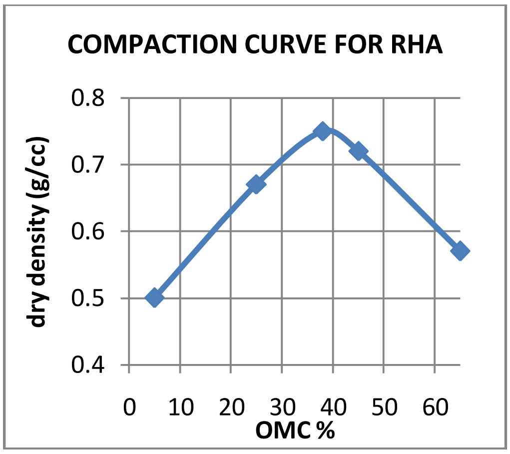

Figure 2: Compaction curve of RHA

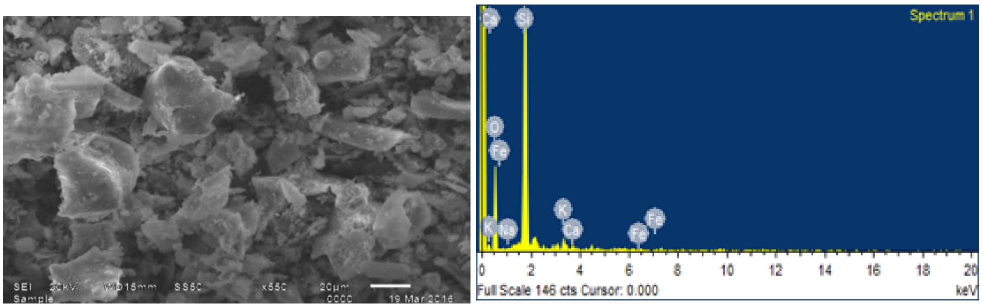

FIG-3(a) &3(b): SEM analysis of RHA particles

From the test results of Rice husk ash the following identifications are made. Majority of Rice husk ash particles are under fine sand range and of angular shape with rough surface texture. The gradation also shows it comes under zone IV. Based on BIS it is classified as poorly graded silty sandy nature with non-plastic and incompressible fines are named as (SM) with C_u=9. 14 and C_c=1. 75.

Compaction characteristics of Rice husk ash under Modified Proctor test have OMC of 38% and MDD of 0. 7 g/cc. From the compaction curve it can be seen that Rice husk ash attained lower dry densities for wide variation in moisture contents. Regarding strength characteristics it has an angle of shearing resistance (Ø) of 36 degrees under un-drained condition and CBR of 8% and has good drainage characteristics with coefficient of permeability as 3. 4 * 10^{-3}cm/sec. RHA attained low densities due to low specific gravity, porous nature and distribution of uniform size of particles.

Chemical analysis of Rice Husk Ash was carried out using Scanning Electron Microscope (SEM), it is observed that silica(SiO_2) as the major compound of 97% and oxides of calcium, iron, potassium, sodium are minor compounds.

3. 0 Results and Discussion:

To meet the MORTH (Table 400) specifications about close graded sub-base material it is necessary to modify the fines with respect to Plasticity i. e., (I_P<6) and Liquid Limit i. e., (W_L<25%). As CBR of the gravel soil should be greater than 30. In this connection RHA has been selected from Tekalli, Srikakulam district and studied the interaction between RHA particles and gravel soils.

3. 1 Performance of Gravel RHA Mixes:

3. 2 Gravel-RHA mixes of Anakapalli Soil:

To study the performance of Gravel-RHA mixes various percentages of RHA such as 5, 10, 15, 20, 25 and 30 by the Dry weight of soil masses were added and subjected to various Geotechnical Characterizations such as Plasticity characteristics like Liquid Limit and Plastic limit and Compaction Characteristics like Optimum Moisture Content, Maximum Dry density and Strength (CBR) etc., were identified and the results are shown below Table-4 and fig-4(a), 4(b), 4(c), 4(d)

Table 4: Geotechnical properties of Gravel-RHA mixes:

RHA %	(W_L)	(W_P)	I_P	OMC (%)	MDD (g/cc)	CBR (%)
0	38	22	16	9. 5	2	19
5	34	22. 5	11. 5	10	1. 98	22
10	28	23	5	10. 6	1. 96	26
15	23	NP	NP	11. 3	1. 94	31
20	NP	NP	NP	12	1. 91	36
25	NP	NP	NP	13	1. 88	34
30	NP	NP	NP	14. 2	1. 85	30

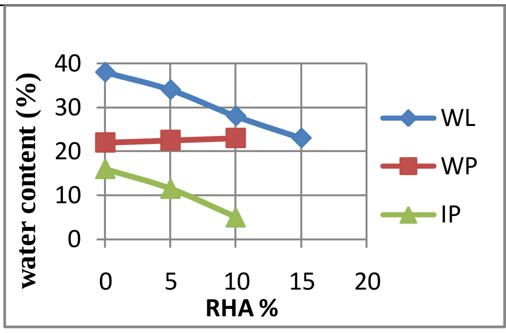

Figure 4(a): RHA % Vs Consistency limits

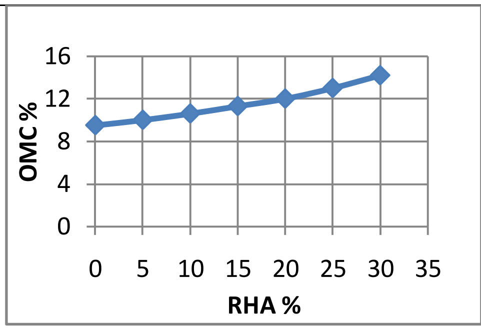

Figure 4(b): RHA % Vs OMC

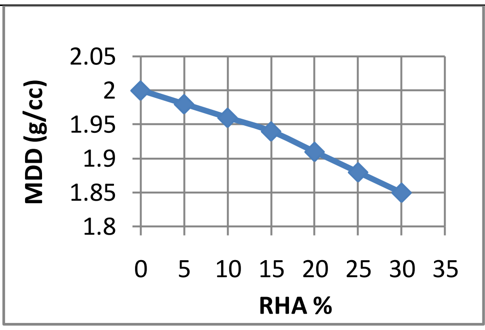

Figure 4(c): RHA % Vs MDD

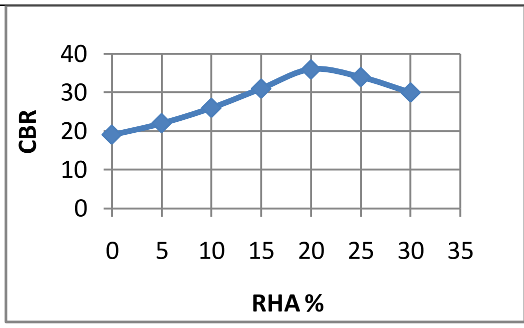

Figure 4(d): RHA % Vs CBR

From the consistency test data it is observed that addition of RHA decreases Liquid Limit and Plasticity Index values. The trend has continued up to 15% of RHA, beyond this a true non-plastic behavior was observed. Further increasing the percentage of RHA make fines of the gravel soil attained the behavior of RHA. The plasticity characteristics of the gravel soil is purely depend on the percentage of particles less than < 425 µm and specifically less than 75 µm. In the given soil composition the percentage of fines are 22%, and the main contribution for development of plasticity characteristics is due to clay content 8%. This composition by addition of RHA 15%

makes the soil to attain a low liquid limit value i. e, W_L< 25% and low Plasticity index i. e., I_P<6.

From the compaction test results it is identified that as the percentage of RHA is increasing the optimum moisture content values are continuously increasing and Dry Density values are continuously decreasing. A steady increase in OMC was observed at early dosages i. e, 15% and beyond this dosage a rapid increase was observed. The increase in optimum Moisture Contents are due to replacement of Silt and Clay particles by RHA particles which increases the intake of moisture and decreasing dry densities are due to occupation of more RHA solids with respect to soil particles.

The percentage of RHA increasing CBR values up to 20% and then decreasing. Attainment of maximum values up to 20% dosage are due to occupation of more solids in the given volume and effective interaction between the RHA particles and fine and coarser particles of Gravel soil which offer more shearing resistance against compression.

3. 3: Gravel-RHA mixes of Visakhapatnam Gravel Soils:

To study the performance of Gravel-RHA mixes various percentages of RHA such as 5, 10, 15, 20, 25 and 30 by the Dry weight of soil masses were added and subjected to various Geotechnical Characterizations such as Plasticity characteristics like Liquid Limit and Plastic limit and Compaction Characteristics like Optimum Moisture Content, Maximum Dry density and Strength (CBR) etc., were identified and the results are shown below Table-5 and fig-5(a), 5(b), 5(c), 5(d)

Table 5: Geotechnical properties of Gravel-RHA mixes:

RHA %	(W_L)	(W_P)	(I_P)	OMC (%)	MDD (g/cc)	CBR (%)
0	30	20	10	8	2. 05	23
5	25	21	4	8. 6	2. 03	28
10	NP	NP	NP	9. 2	2	34
15	NP	NP	NP	10	1. 97	33
20	NP	NP	NP	11	1. 95	31
25	NP	NP	NP	12. 5	1. 93	27

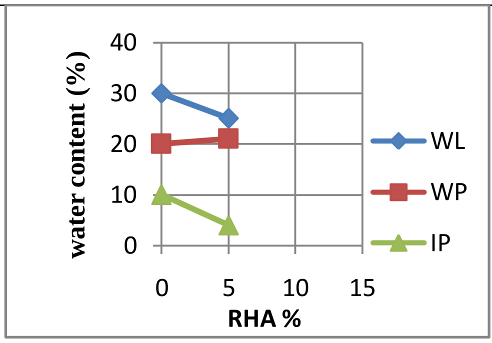

Figure 5(a): RHA (%) Vs Consistency limits

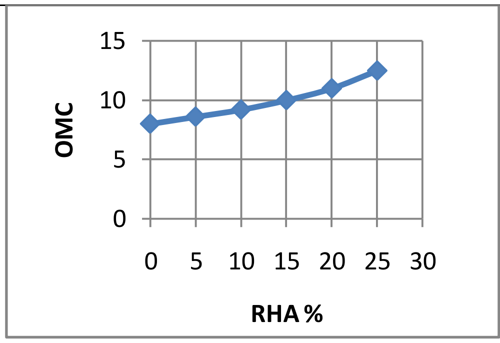

Figure 5(b): RHA (%) Vs OMC (%)

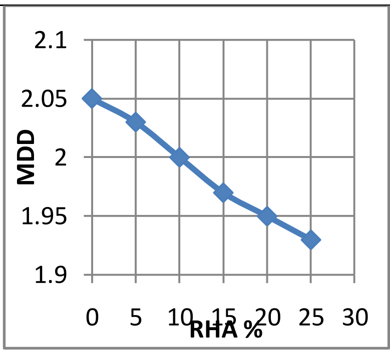

Figure 5(c): RHA (%) Vs MDD

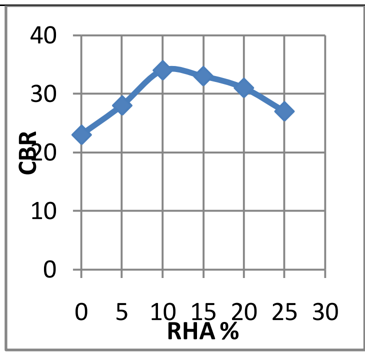

Figure 5(d): RHA (%) Vs CBR

From the consistency test data it is observed that addition of RHA decreases Liquid Limit and Plasticity Index values and the trend has continued up to 5%, beyond this a true non-plastic behavior was observed. Further increasing the percentage of RHA make fines of the gravel soil attained the behavior of RHA. The plasticity characteristics of the gravel soil are purely depending on the percentage of particles less than < 425 µm and specifically less than 75 µm. In the given soil composition the percentage of fines are 20%, and the main contribution for development of plasticity characteristics is due to clay content 6%. This composition by addition of RHA 5% makes the soil to attain a low liquid limit i. e., W_L= 25% and low Plasticity index value i. e., I_P<5.

From the compaction test results it is identified that as the percentage of RHA is increasing the optimum moisture content values are continuously increasing and the Maximum Dry Density values are continuously decreasing. A steady increase in OMC was observed at early dosages i. e., 5% and beyond this dosage a rapid increase was observed. The increase in optimum Moisture Contents are due to replacement of Silt and Clay particles by RHA particles which increases the intake of moisture and decreasing dry densities are due to occupation of more RHA solids with respect to interaction fines of gravel particles.

The percentage of RHA increasing CBR values up to 10% and then decreasing. Attainment of maximum values up to 10% dosage are due to occupation of more solids in the given volume due to the effective interaction between the RHA particles and fines and coarser particles of Gravel soil which offer more shearing resistance against compression.

Gravel-RHA mixes of Elamanchili Gravel Soils:

To study the performance of Gravel-RHA mixes various percentages of RHA such as 5, 10, 15, 20, 25 and 30 by the Dry weight of soil masses were added and subjected to various Geotechnical Characterizations such as Plasticity characteristics like Liquid Limit and Plastic limit and Compaction Characteristics like Optimum Moisture Content, Maximum Dry density and Strength (CBR) etc., were identified and the results are shown below Table-6 and fig-6(a), 6(b), 6(c), 6(d)

Table 6: Geotechnical properties of Gravel-RHA mixes:

RHA (%)	(W_L)	(W_P)	(I_P)	OMC (%)	MDD (g/cc)	CBR (%)
0	45	24	21	12	1. 96	15
5	42	24. 5	17. 5	12. 4	1. 94	18
10	37	25	12	13	1. 92	22
15	30	26	4	13. 7	1. 9	28
20	23	NP	NP	14. 5	1. 87	33
25	NP	NP	NP	15	1. 84	31
30	NP	NP	NP	16	1. 82	29

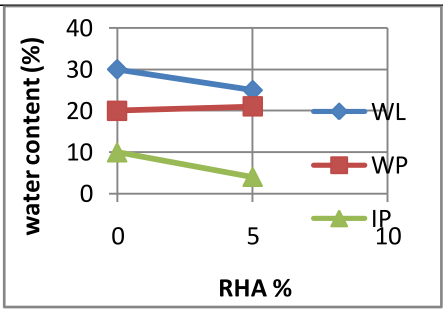

Figure 6(a): RHA (%) Vs Consistency limits

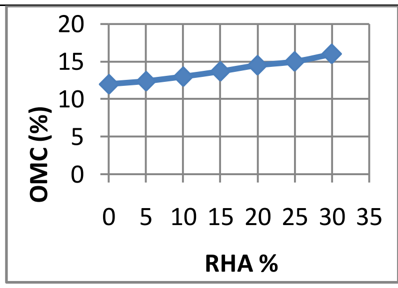

Figure 6(b): RHA (%) Vs OMC (%)

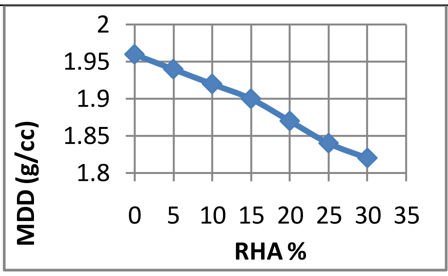

Figure 6(c): RHA (%) Vs MDD

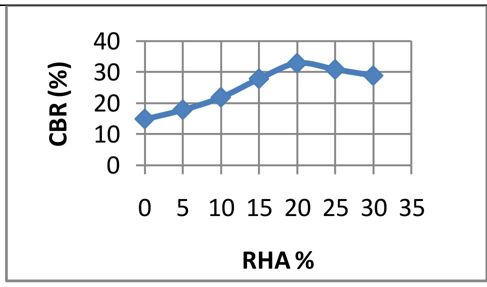

Figure 6(d): RHA (%) Vs CBR

From the consistency test data it is observed that addition of RHA decreases Liquid Limit and Plasticity Index values. The trend has continued up to 20% of RHA, beyond this a true non-plastic behavior was observed. Further increasing the percentage of RHA make fines of the gravel soil attained the behavior of RHA. The plasticity characteristics of the gravel soil is purely depend on the percentage of particles less than < 425 μm and specifically less than 75 μm. In the given soil composition the percentage of fines are 26%, and the main contribution for development of plasticity characteristics is due to clay content 10%. This composition by addition of RHA 20% makes the soil to attain a low liquid limit values i. e, $W_L < 25\%$ and low Plasticity index value i. e., $I_P<5$.

From the compaction test results it is identified that as the percentage of RHA is increasing the optimum moisture content values are continuously increasing and the Maximum Dry Density values are also continuously decreasing. A steady increase in OMC was observed at early dosages i. e., 15% and beyond this dosage a rapid decrease was observed. The increase in optimum Moisture Contents are due to replacement of Silt and Clay particles by RHA particles which increases the intake of moisture and dry densities are due to occupation of more RHA solids with respect to interaction fines of gravel particles.
The percentage of RHA increasing CBR values increases up to 20% and then decreasing. Attainment of maximum values up to 20% dosage are due to occupation of more solids in the given volume due to the effective interaction between the RHA particles and fine and coarser particles of Gravel soil which offer more shearing resistance against compression.

SUMMARY AND APPLICATIONS:

These gravel soils (AG, VG andEG) obtained low CBR values which are mainly due to the quantity of plasticity characteristics, the percentage of gravel particles and the interaction between fines and coarser particles of gravel soils.
Addition of RHA reduces the plasticity characteristics which in terms develops better bond between RHA and gravel particles. The degree of plasticity demands the quantity of RHA particles. To digest plasticity index of 10-21% requires 10-20% of RHA at these range of dosage of RHA to the gravel soils attained CBR values in the range of 33-36%.
Addition of 10-20% of RHA make the gravel soils in meeting the requirements of MORTH specifications (w_L<25%, I_P<6, CBR>30) to suit as Sub-base material in road construction.

CONCLUSION:

Gravel soils could attain high CBR values to suit as Sub-base coarse materials presents of plastic fines hampers the feature under saturation. Addition of 10-20% RHA could meet the requirements of MORTH specifications to suit as Sub-base coarse material due to the high volume nature of RHA.

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