Effect of Size and Gradation of Crusher Stone and Crusher Dust Particles in Flexible Pavement Construction

Tarun Teja.J.V[#1], Satyanarayana.P.V.V[*2], Arun Kumar.U[#3], Charan Deepak.P[#4]
[#]*PG Student, Professor, Ph.D Scholar & PG Student & Civil Engineering& Andhra University, India*

Abstract

Increasing road network demands huge quantities of natural soils in their construction. to reduce impact on natural soils and inclusion of industrial waste as construction material crusher dust is identified as flexible pavement material, as it is a residue obtained from crushing stone plants. in this connection various percentage of crusher dust were added to crushed stone and parameters like compaction strength were studied. from the test results it is identified that the gradations of crushed stone crusher dust mixes can be effectively used as sub-grade sub-base and base course layers by maintaining high dry densities and CBR values.

Key words*: Crusher dust, Crushed stone, Compaction, CBR.*

I. INTRODUCTION

Inherent qualities of Soils can be readily acceptable as a construction material in civil engineering structures. Due to poor performance at saturated condition these lost their function as geotechnical construction material. Therefore transfer of stress from wheel loads have not effectively taken care by soils in the component layers of the flexible pavements. To meet the requirements of MORTH and IRC specifications crusher dust and crushed stone have been chosen as flexible pavement materials. Crusher dust is a waste product obtained from stone crusher plants with annual production of 23 Lakh tonnes.

A number of researchers have made their contributions for the utilization of above said materials in various geotechnical applications. Soosan et.al (2000, 2001)[9] identified that crusher dust exhibited high shear strength and beneficial for its use as geotechnical material. Sridharan A et.al (2005, 2006)[8] reported that high CBR and shearing resistance values can enhance their potential use as sub-base material in flexible pavements and also as an embankment material. Praveen Kumar et.al (2006)[5] conducted CBR tests on stone dust as a sub-base material. Wood et.al (1993)[10] identified that the physical properties, chemical composition and mineralogy of quarry dust varies with aggregate type and source. Collins R.J et.al (1994)[3] studied quarry dust in highway constructions. Arun Kumar.U et al (2016)[1]studied the effect of crusher dust, crushed stone and tire waste in different layers of flexible pavement component for increased strength characteristics, .Satyanarayana P.V.V. et.al (2013)[6,7]observed improved soil characteristics with addition of crusher dust, Lewis chandra.K, et.al (2013)[4] Studied utilization of Crusher Dust in Geotechnical Applications, Ashok Kumar .R studied et.al(2013)[2] Performance of Crusher Dust in High Plastic Gravel Soils As Road Construction Material. In this an attempt is made to study the interaction between crushed stone crushed dust particle gradations as flexible pavement materials were exposed to compaction strength characteristics.

II. MATERIALS

A. Crusher dust

Crusher Dust was obtained from local stone crushing plants near Visakhapatnam, Andhra Pradesh and subjected to various geotechnical characteristics and results are shown in table-1 and figure-1(a) &1(b)

Table.1Geotechnical properties of Crusher Dust

Property	Values
Gravel (%)	4
Sand (%)	92
Fines (%)	4
a. Silt (%)	4
b. Clay (%)	0
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I.S Classification	SW
Specific gravity	2.66
Optimum moisture content (OMC) (%)	11
Maximum dry density (MDD) (g/cc)	2.02
Angle of shearing resistance(°)	38
California bearing ratio CBR (%) (Soaked)	12
Coefficient of uniformity (Cu)	10.83
Coefficient of curvature (Cc)	1.02
Coefficient of Permeability(k) (cm/s)	$3.4*10^{-3}$

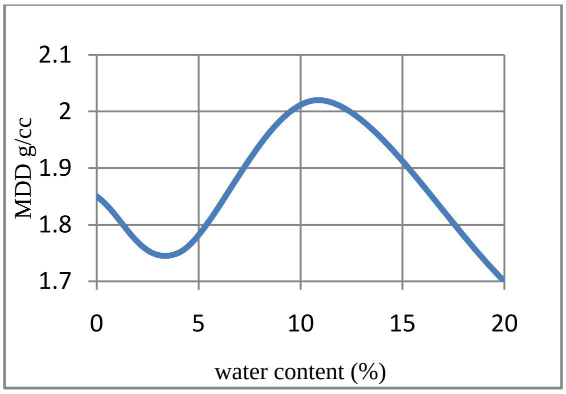

Fig.1 (a) Compaction Curve

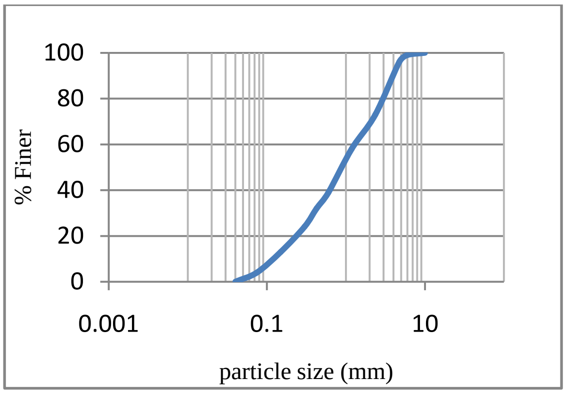

Fig1 (b): Grain size distribution curve

From the test results of crusher dust, the following identifications are made. The grain size distribution of crusher dust shows that it consists of 92% of sand size and 4% of silt size particles. It is equally dominated by particles of coarse, medium and fine sand sizes with rough surface texture. Based on BIS, it is classified as well graded particles with non-plastic fines (SW) with C_u as 10.83 and C_c as 1.02. Compaction characteristics of crusher dust under modified compaction test have an Optimum Moisture Content of 11% and Maximum Dry Density of 2.02 g/cc. From the compaction curve it can also be seen that crusher dust attains higher densities with wider range of moisture contents and increases the workability at high moisture contents. Regarding strength characteristics, it has an angle of shearing resistance (Ø) of 38^0 under un drained condition and CBR of 12% .It has coefficient of permeability of 3.4 $x10^{-3}$cm/sec. Hence it is identified that it has good strength and drainage characteristics.

II. CRUSHED STONE

Crusher Stone was obtained from local stone crushing plants near Srikakulam, Andhra Pradesh and subjected to various geotechnical characterizations.

Table 2: Engineering Properties of Crushed Stone:

PROPERTY	VALUE
Specific gravity(G)	2.8
Angularity number	13
Crushing value (%)	22
Impact value (%)	23
Density in loose state (g/cc)	1.85
Density in dense state (g/cc)	1.76

III. METHODOLOGY

To study the interaction between crushed stone(75-4.75mm) and crusher dust(<4.75) as component layers of flexible pavement, four gradation ranges were identified and these are listed below as granular base course with lower, middle and upper as GB_L, GB_M ,GB_U and WMM as WMM_L ,WMM_M,WMM_U. Where as Sub-base course as GSB_L, GSB_M, GSB_U respectively. These gradations are suspected for gradation characteristics as results are shown in table.3

From the gradation characteristics of particle ranging from 75mm to 0.075mm (base course). It is identified that lower gradation has more wide spread range of particles comparatively middle gradation, where as upper gradation has limited range of particles. These are also reflected in their C_u values decreasing from 73to40. It is also identified that as the percentage of crusher dust is increasing the corresponding parameters such as C_u and C_c are also decreasing

Table 3: Gradation characteristics of 75mm crushed stone

Particle Size (mm)	GB_L	GB_M	GB_U	RANGE
75	100	100	100	100
53	80	90	100	80-100
26.5	55	72	90	55-100
9.5	35	50	65	35-65
4.75	25	40	55	25-55
2.36	20	30	40	20-40
0.425	10	12	15	10-15
0.075	5	5	5	5
D_{10}	0.425	0.3	0.15	0.425-0.15
D_{30}	6.5	2.36	1.5	6.5-1.5
D_{60}	31	15	6	31-6
C_U	73	50	40	73-40
C_C	3.2	1.24	2.5	3.2-2.5

Table 4: Gradation characteristics of 53mm crushed stone

Particle Size (mm)	WMM_L	WMM_M	WMM_U	RANGE
53	100	100	100	100
45	95	98	100	95-100
22.4	60	70	80	60-80
11.2	40	50	60	40-60
4.75	25	33	40	25-40
2.36	15	22	30	15-30
0.600	8	15	22	8-22
0.075	0	3	5	0-5
D_{10}	0.8	0.2	0.1	0.1-0.8
D_{30}	6.5	4	2.2	2.2-6.5
D_{60}	22.4	16	11	22.4-11
C_U	28	80	110	28-110
Cc	2.36	5	4.4	2.36-4.4

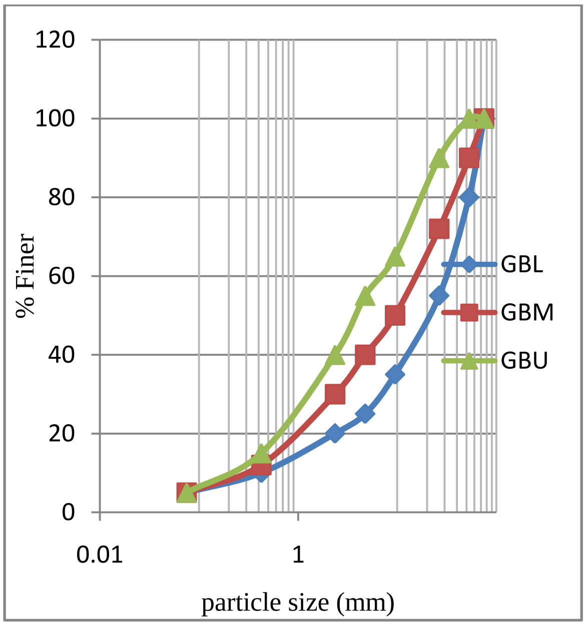

Fig 2: **Grain size distribution curve**

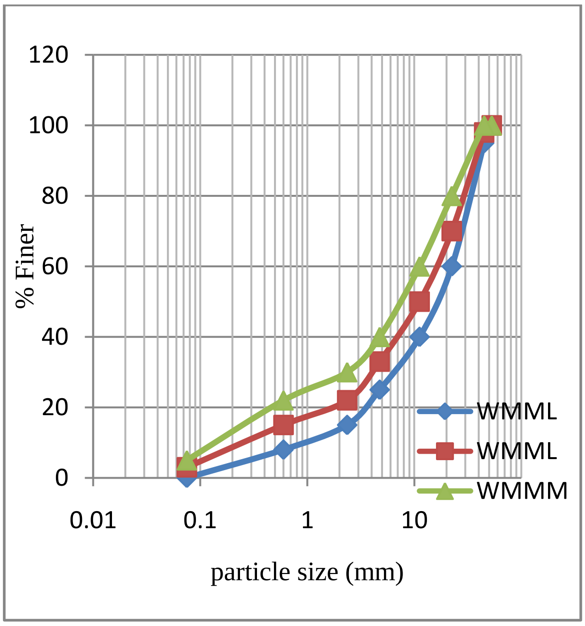

Fig 3: **Grain size distribution curve**

Table 5: Gradation characteristics of 26.5mm crushed Stone

Particle Size (mm)	GSB_U	GSB_M	GSB_L	RANGE
26.5	100	100	100	100
12.5	55	72	90	55-90
9.5	35	50	65	35-65
4.75	25	40	55	25-55
2.36	20	30	40	20-40
0.425	10	12	15	10-15
0.075	5	5	5	5
D_{10}	0.425	0.3	0.16	0.16-0.425
D_{30}	7.5	2.36	1.5	7.5-1.5
D_{60}	13	10.8	7	7-13
C_u	30.59	37.86	43.75	30.59-43.75
C_c	10.18	1.72	2.01	2.01-10.18

Table 5: Gradation characteristics of 26.5mm crushed Stone

Particle Size (mm)	GSB_U	GSB_M	GSB_L	RANGE
12.5	100	100	100	100
9.5	75	60	90	60-90
4.75	25	41	55	25-55
2.36	20	30	40	20-40
0.425	10	13	15	10-15
0.075	5	5	5	5
D_{10}	0.425	0.26	0.2	0.425-0.2
D_{30}	5.2	2.4	1.4	1.4-5.2
D_{60}	7.8	9.5	5.4	5.4-9.5
C_u	18.4	36.53	27	18.4-27
C_c	8.15	2.33	1.814	8.5-1.814

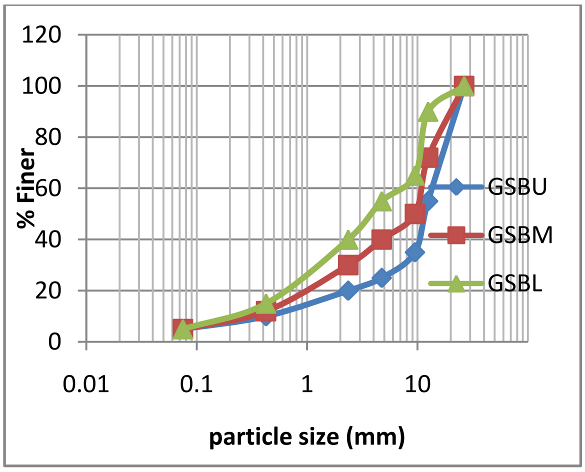

Fig 4: Grain size distribution curve

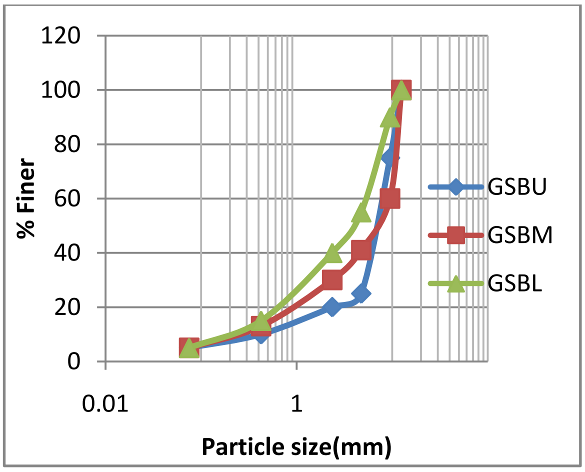

Fig 5: Grain size distribution curve

From the gradation characteristics of wet mix macadam (WMM), it is identified that lower gradation has wide spread range of particles comparatively upper and middle gradations. This character is also reflected in gradation characteristics such as D_{60}, D_{30} and D_{10}. These values are decreasing from lower to upper gradations.

In case of GSB gradations for 26.5-0.075mm and 12.5-0.075mm the same trend of results were obtained.

IV. RESULTS AND CONCLUSIONS:

A. Compaction characteristics

The gradation mixes meant for component layers of flexible pavements have been subjected for compaction characteristics by performing modified proctor test as per IS 2720:(part 8-1983) and the results are shown in table and figure.

From the test results, it is identified that if the size of the crushed stone particles is increasing OMC values are increasing and MDD values are also increasing, with respect to increasing the percentage of crusher dust. The same trend was continued up to 40% and then decrease in MDD and increase in OMC values were observed. The same phenomenon was observed with respect to all gradations of varying sizes of 75.00 mm, 53.00 mm, 26.5 mm, 12.5 mm -0.075 mm. Increase in dry densities are due to attainment of more solids of crushed stone and crusher dust particles in a given volume at a given compaction energy and obtainment of dense condition. Decrease in dry densities are due to development of honeycombing structure with less occupation of crusher dust and crushed stone particles relatively less dense condition.

Increase in OMC is due to requirement of more water to coat the particles of crushed stone and crusher dust in given volume for their mobilisation to attain dense condition. As the percentage of crusher dust is increasing, the relative occupation of crusher dust with respect to crushed stone particles is increasing and leads to requirement of more water needed to mobilize the particles in given volume and the gradations are dominated by the behaviour of crusher dust particles.

Table 7: Compaction Characteristics of various Gradation mixes.

WMM Mixes	75mm		53mm		26.5mm		12.5mm	
	OMC (%)	MDD (g/cc)	OMC (%)	MDD (g/cc)	OMC (%)	MDD (g/cc)	OMC(%)	MDD(g/cc)
(1)WMM$_L$	3.8	2.19	3.9	2.17	3.8	2.18	4	2.16
(2)WMM$_M$	4.5	2.24	4.1	2.19	4.3	2.2	4.7	2.2
(3)WMM$_U$	5.2	2.16	4.2	2.18	4.8	2.19	5.2	2.18

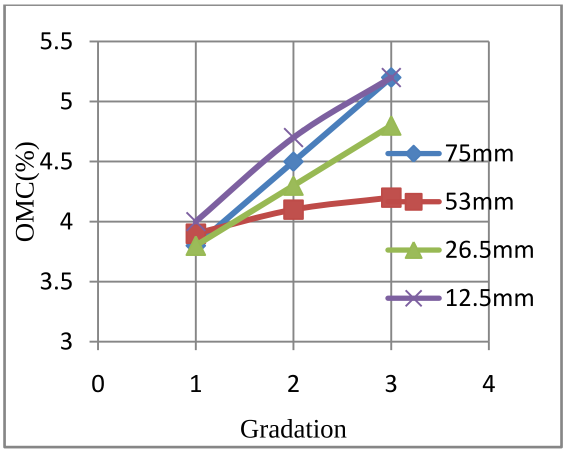

Fig.6 OMC curves for various gradations

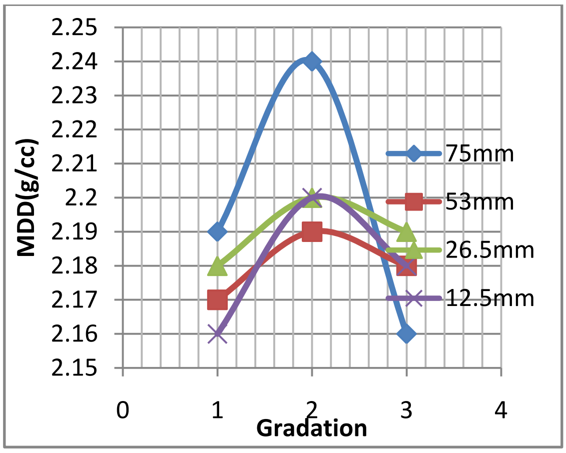

Fig.7 MDD curves for various gradations

B. California bearing ratio characteristics

To know the CBR values of the gradation mixes meant for component layers of flexible pavements have been subjected for CBR characteristics by preparing sample at their modified proctor densities as per IS2720: (part 16-1987) and the results are shown in table and figure.

From the test results, it is identified that if the size of the crushed stone particles are increasing CBR values are also increasing. For 12.5mm gradation the CBR values are in the range of 38-52, For 26.5mm gradation the CBR values are in the range of 48-68, For 53mm gradation the CBR values are in the range of 110-118, For 75mm gradation the CBR values are in the range of 110-138 respectively. The Increase in CBR values are due to occupation of more solids of crushed stone and crusher dust particles in a given volume at a given compaction energy and attainment of dense condition offers high frictional resistance against penetration.

Table 8: CBR Characteristics of various Gradations mixes

WMM Mixes	75mm	53mm	26.5mm	12.5mm
	CBR (%)	**CBR (%)**	**CBR (%)**	**CBR (%)**
(1)WMM$_L$	120	110	54	38
(2)WMM$_M$	138	118	68	52
(3)WMM$_U$	110	114	48	42

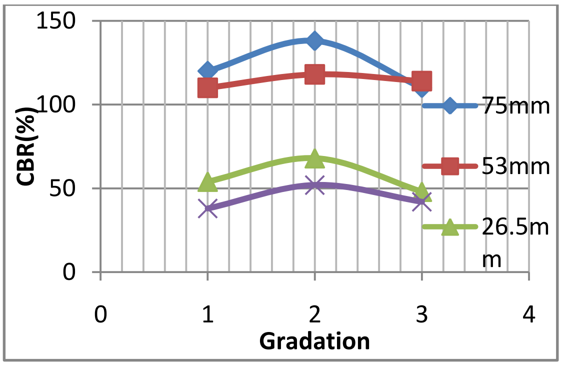

Fig 7: CBR curves

V. APPLICATIONS

1. Crusher dust is a coarse grained material with non plastic characterisation and attained high dry densities 2.02(g/cc), Angle of shearing resistance (φ) 38^0 and CBR of 12 % can be individually used as sub-grade, fill and embankment material.
2. 12.5mm-0,075 mm gradations attained CBR values in the range of 38-52%which are greater than 30% can be used as Sub-base material.
3. 26.5mm-0.075mm gradation with well graded features have CBR values in the range of 48-68 % and can be effectively used as Sub-base course and can be used as Base course(>60) for low volume roads.
4. 75-0.075mm gradation can be effectively used as Base course material as they with standing CBR in the range of 110-138%.
5. 53-0.075mm gradation can be effectively used as Base course material as they with stand CBR in the range of 110-118%.

VI. CONCLUSIONS

Inherent qualities of crusher dust invite to use it as Sub Grade material and fill materials. Gradation mixes of crushed stone –crusher dust can also be used as Sub-Base and Base courses with respect to their gradations as they are with stand high strength values in terms of CBR.

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