

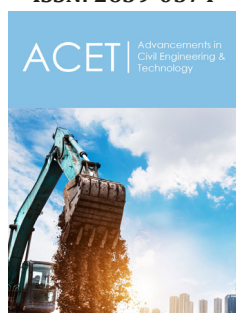
The Engineering Study on the Use of Crushed Stone Aggregate and Crusher Dust Mixes in Flexible Pavements of Karachi-Hyderabad Motorway, Sindh, Pakistan

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Abstract

The development of the country is directly related with the better road communication from mega cities to rural villages. Pakistan is a developing country and has started a grand network of highways, superhighways and motorways in all four provinces along with Kashmir and Northern and northwestern regions bordering china and Afghanistan. Highway Flexible pavements are the most commonly used form of pavements and have four component layers namely Sub-grade, Sub-base and base and surface courses, which are constructed of materials like natural soils, sand, morrum etc., are considered to be costly in terms of construction as well as maintenance. The result of plastic fine sand their sticky characteristics in natural soils hampered the performance of the pavement. To reduce the impact of failures alternative materials are to be investigated. In this connection an attempt is made by using Crushed Stone Aggregate and Crusher Dust as road component materials. Gradation mixes were prepared to meet the specifications of National Highway Authority Pakistan and subjected for various geo-technical characterizations such as gradation, compaction, strength etc. According to the results of strength values of compacted crusher dust and Crushed Stone mixes have been evaluated through a series of CBR tests by varying the crusher dust and sand contents from 10% to 60%. On the other hand, the suitability of compacted crusher dust as a road base and sub-base materials have been verified in accordance with N H A P specifications and findings that 20-30% in place of sand can satisfy the materials used as sub-base and base courses [1-3].

Keywords: Pavement; Highway; Void ratio; CBR; Construction

Introduction

The National Highway Authority (NHA) was created, in 1991, through an Act of the Parliament, for planning, development, operation, repair and maintenance of National Highways and Strategic Roads specially handed over to NHA by the Federal Government or by a Provincial Government or other authority concerned [4]. NHA is custodian of 39 national highways/motorways/expressway/strategic routes having a total length of 12,131kms. This is 4.6% of total national road network i.e. 263,775kms, however, it carries and covers 80% of commercial traffic and N-5 which is bloodline of Pakistan, carries 65% of this load in the country. Being custodian of Highway assets of Pakistan's road network, NHA is committed to provide safe, modern and efficient transportation system. It has been proved as the backbone of Highway network (Countrywide Motorway Network Map), National Highways functions as the backbone of Pakistan's transportation system, plays an important role in the development of micro and macro economy and also developed the national integration by increasing the social and economic dependence among the Provinces [5].

The overall performance of a pavement reflects the proper functioning of the consecutive component layers of a road pavement. The design model, life of the pavement, durability and maintenance cost can be explained by the selection of materials and their characterization. In the construction of highways major component layers are Sub-base, Base courses and their functions are directly reflecting the function of Sub-grades. Before this natural soil, sands, gravel material and Morrum can be frequently used as sub-base materials. The presence of plastic fines and their sticky characteristics hampered the performance of the pavements due

to its imbibition's of moistures and yields continuous plastic strains. To avoid these component layers, reduce thrust on sub-grade and to improve the drainage performance of the sub-base course and durability of the pavement as a whole alternative material like crusher dust fly ash pond ash etc, can be studied. In this study an attempt has been made for the utilization of mechanically stabilized crushed stone and crusher dust mixes as sub-base and base courses [6].

Crushed stone dust or rock flour can be alternatively used in construction of reinforced soil construction such as reinforced earth retaining walls, reinforced soil beds and reinforced flexible pavements as a embankment material due to the stability, free draining nature and good frictional characteristics with synthetic reinforcement. Ilangoana et al. [7] have studied the interaction of usage of rock flour with Geotextile sand reported the potential areas of application [8]. Nagpal et al. [9] identified that crusher dust exhibits high shear strength and is beneficial for its use as a geotechnical material [10,11].

Sabat AK [12] Took experiment upon the effect of quarry Dust in highway construction and found that CBR and angle of shearing resistance values are steadily increased with increase the percentage of Quarry Dust. Praveen et al. [8] performed CBR and tri-axial tests on fly ash, coarse sand, stone dust and riverbed materials for their use in the subbase materials of the flexible pavements. Nanda RP et al. [10] have given the engineering properties of crushed rock dust

and reported that the rock flour can be used as alternative material in place of sand in concrete based on grain size data. Kumar et al. [8] have mentioned that sand can be replaced fully with rock flour. Donza et al. [5] have studied the effect of rock dust and pebble as aggregate in cement and concrete. Räisänen [11] reported that the quality of crushed stone dust depends on the type of parent materials. In this research an attempt is made to study the effect of Crusher Dust and Crushed Stone Mixes in studying their Strength, Gradation and Compaction Characteristics.

Materials

Crusher Dust sample was obtained from local stone crushing plants near Cadet College Petaro, Jamshoro district, Sindh province of Pakistan some 160km from the capital city of Karachi towards south on Karachi-Hyderabad Motorway. The sample was subjected to various geotechnical characterizations. The results are shown in Table 1 and Figure 1 & 2. Crushed Stone Aggregate was collected from nearby quarries of Karachi Toll Plaza etc. From the physical identification it is observed that crusher dust is a grey color fine aggregate consisting of medium to fine sand size particles and of angular shape with rough surface texture. From the consistency data obtained it is non-plastic and incompressible. From the compaction curve plotted it can be seen that crusher dust attains higher densities with wider variation in moisture content and also increase in workability at higher moisture contents.

Table 1:

Property	Values
Grain size distribution	
Gravel (%)	5
Sand (%)	90
Fines (%)	5
a. Silt (%)	5
b. Clay (%)	0
Consistency	
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I.S Classification	P
Specific gravity	2.64
Characteristics	
Optimum moisture content (OMC) (%)	13
Maximum dry density (MDD) (g/cc)	1.9
Shear parameters	
Angle of shearing resistance(deg)	36
California bearing ratio (CBR) (%) (Soaked)	6
Coefficient of Uniformity (Cu)	15.6
Coefficient of Curvature Cc	2.85

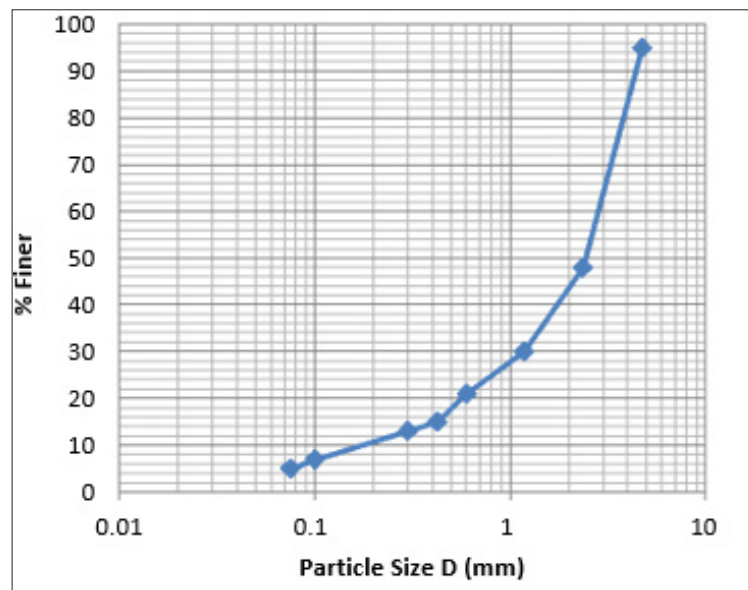


Figure 1: Gradation curve of crusher dust.

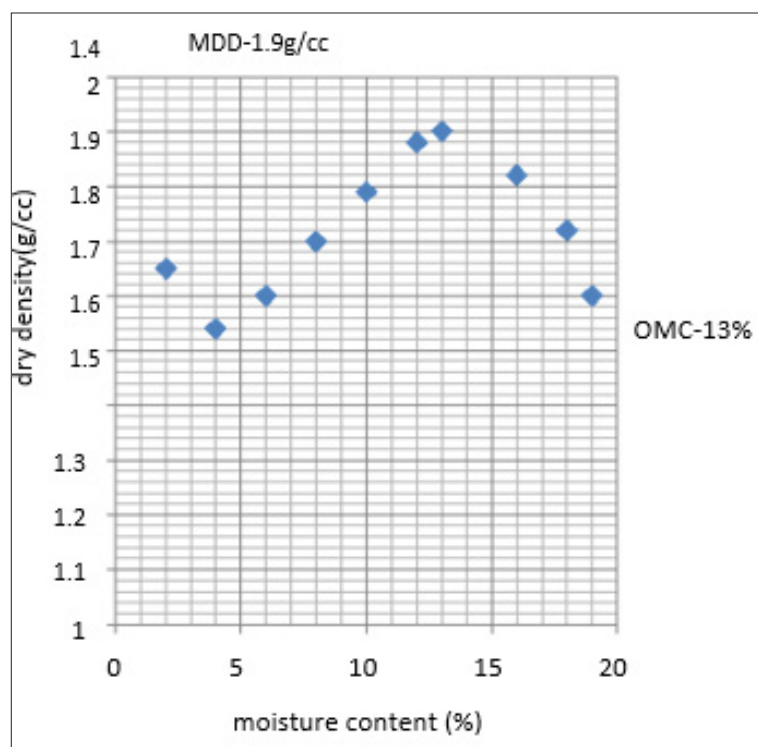


Figure 2: Compaction curve of crusher dust.

Methodology

Crushed stone aggregate was obtained from nearby stone crusher plants of Cadet College Petaro (Field Picture). After brushing the aggregate, it was washed and dried. A set of sieves such as 53mm, 26.5mm, 9.5mm etc. have identified for the gradation of stone aggregate and for the fine aggregate 4.75mm, 2.36mm,

0.425mm, 0.075mm sizes were identified. Various percentages of stone aggregate were added to the Crusher Dust as listed below and also the percentage of Crusher Dust. Stone aggregate mixed with Crusher Dust was graded to various gradation mixes in accordance with NHA Pakistan specifications and named as C1, C2, C3, C4, C5, and C6 (Table 2).

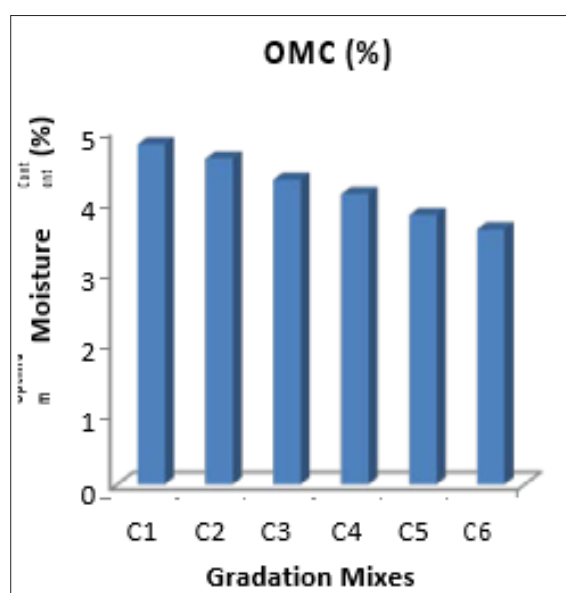
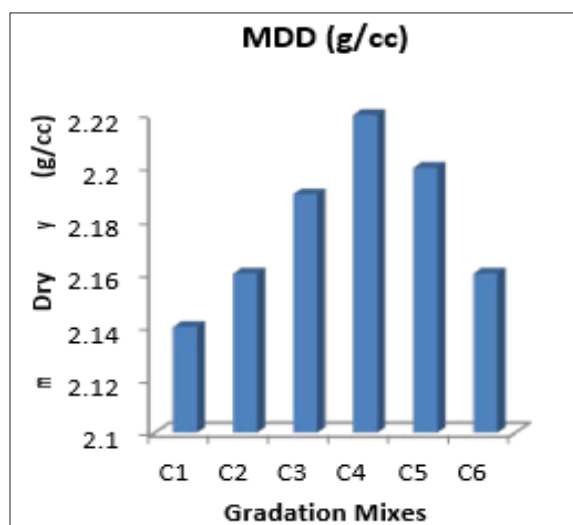
Table 2:

Sieve Sizes(mm)	Stone Aggregate Sizes			Crusher dust/	Gradation Mixes
	53-26.5mm	26.5-9.5mm	9.5-4.75mm	<4.75mm	
Percentage of stone aggregate	10	10	20	60	C 1
	20	20	20	40	C 2
	20	20	20	40	C 3
	20	20	30	30	C 4
	20	30	30	20	C 5
	30	30	30	10	C 6

Result and Discussion

characterizations such as gradation, compaction, strength (CBR), void ratio etc. The results are listed below Table 3 and Figure 3-6.

The gradations mixes were subjected to various geotechnical

**Figure 3:****Figure 4:**

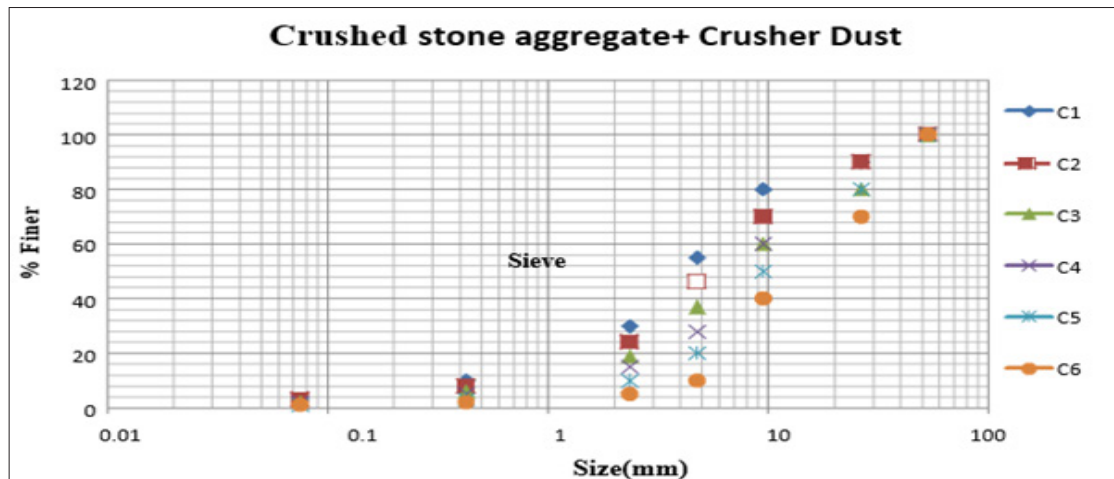


Figure 5:

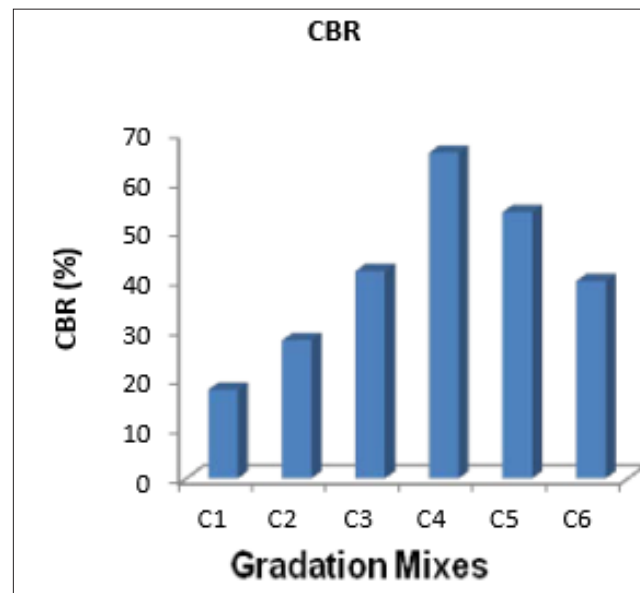


Figure 6:

Table 3:

Crushed Stone Aggregate + Crusher Dust Gradation (percentage finer)						
Gradation sieve sizes (mm)	C1	C2	C3	C4	C5	C6
	(CSA40-CD60%)	(CSA50-CD50%)	(CSA60-CD40%)	(CSA70-CD30%)	(CSA80-CD20%)	(CSA90-CD10%)
53	100	100	100	100	100	100
26.5	90	90	80	80	80	70
9.5	80	70	60	60	50	40
4.75	55	46	37	28	20	10
2.36	30	24	19	15	10	5
0.425	10	8	6	5	3	2
0.075	3	3	2	2	1	1

Compaction characteristics						
OMC (%)	5.8	5.4	4.8	4.5	4	3.6
MDD (g/cc)	2.12	2.15	2.18	2.22	2.2	2.16
Strength						
CBR Soaked	18	28	42	66	54	40
Void Ratio (e)	0.28	0.27	0.26	0.22	0.27	0.3
Gravity (Gc)	2.71	2.73	2.75	2.78	2.8	2.82
Voids (%)	21.8	21.2	20.7	20.1	21.4	23.4

Compaction characteristics

For the purpose of knowing the compaction characteristics of the designated gradation mixes C1, C2, C3, C4, C5 and C6 Modified proctor compaction test was performed as per standard Proctor test, ASTM D698 and AASHTO T 99 test methods and the results are shown in Table 3 and Figure 3 & 4. From the results of compaction test data, it is identified that maximum dry densities values are increasing with decrease in percentage of crusher dust with respect to Crushed Stone aggregate up to 25-20% and decreasing i.e. 2.12g/cc to 2.22g/cc and 2.22g/cc to 2.16g/cc respectively. Contemporarily it is also identified that OMC values are decreasing with decrease in percentage of crusher dust i.e., from 5.8 to 3.6%. Notable decrease in optimum moisture contents can be explained as at the higher percentages of crusher dust more water is needed to coat the crusher particles as it depends on composition, size and shape of crusher dust particles and at lower percentages less water is required due to less quantities of crusher dust particles available in the mixes. Attainment of lower and higher maximum dry densities can be explained in the following way. At higher percentages of crusher dust (50-60%) with respect to crushed stone aggregate more number of voids are opened up and all these not properly filled by crusher dust sediments forming honey combed structures with higher void ratios, at lower percentages of crusher dust(<20%) opening up of voids are taking place and crusher dust particles are not sufficient to fill up these voids

resulting in development of honey combed structures. Effective replacement attained at 20-30% of crusher dust is due to filling up of formed voids partly with smaller size coarse aggregate and remaining by crusher dust particles responsible for attainment of higher densities. For a range of 20-30% of crusher dust addition, the gradation mixes became densely compacted with attainment of less void ratios and high densities.

Particle size distribution curves

For the above gradation mixes C1, C2, C3, C4, C5 and C6 particle size distribution curves and their results were developed, and these are shown in Table 4 and Figure 5. From the test results it is observed that increase in the percentage of crusher dust decreases Cu and Cc values i.e. notable variation between Cu values from 11.04 to 4.04 and Cc values from 2.72 to 0.75 respectively. At higher percentage of crusher dust with respect to aggregate a wider variation in range of particles have been observed these may lead to higher values of Cu and Cc whereas at lower percentage of crusher dust lesser variation in range of particles have been observed and these may lead to lower values of Cu and Cc and make the mixes honey combed and less dense. Between the range of 20 and 30% of crusher dust the concerned gradation mixes try to maintain well graded conditions with dense packing in addition to shape and size of crusher dust particles may also be responsible for generation of these values.

Table 4: Grain size parameters.

Crushed Stone Aggregate + Crusher Dust						
Particle Size(mm)	C1	C2	C3	C4	C5	C6
	(CSA40-CD60%)	(CSA50-CD50%)	(CSA60-CD40%)	(CSA70-CD30%)	(CSA80-CD20%)	(CSA90-CD10%)
D10	0.43	0.59	0.94	1.5	2.3	4.7
D15	0.8	1	1.6	2.5	3.5	5.6
D30	2.36	2.9	4	5.1	6.6	8.2
D60	4.75	6.5	9.5	10	13	19
Cu	11.04	11.01	10.1	6.67	5.65	4.04
Cc	2.72	2.19	1.79	1.73	1.45	0.75

California bearing ratio test

The collected Crushed Stone aggregate and crusher dust was dried and taken to the required proportions for the designated mixes C1 to C6 and compacted at their maximum dry densities in the CBR moulds and soaked for 4 days. After completion of the required soaking period the samples were tested in the CBR test apparatus at a strain rate of 1.25mm/min as per ASTM D1883-05 Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils. From the test results of CBR the following identifications were made. According to results as the percentage of crusher dust decreases CBR values are increasing. It is clear that maximum values have been obtained at 30% dosage i.e. 66, a little decrease was observed from 30-20%. Let us consider the other parameters such as void ratio, percentage voids and maximum dry densities into account, it is found that a value of 20-30% crusher dust make the gradation mix ratio dense and offer more shear strength due to mobilization of friction resistance under compression.

Suitability of the gradation mixes a sub- base, base course materials

Comparing gradation mixes C1 to C6, with the gradation mixes of NHA Pakistan sub-base courses it is identified that at higher percentages of crusher dust these mixes are nearing to Grade-II and Grade- of close graded mixes and at lower percentages of crusher dust these are nearing to Grade-I. It can also be seen that the majority of the gradation mixes satisfying the Grades of coarse graded granular sub-base materials. Hence, the gradation mixes of crusher dust and Crusher stone aggregate with an addition of 20-30% with respect to Crusher stone Aggregate attaining CBR value greater than 50 can be recommended as Base course and Sub-base course materials and the mixes having CBR greater than 30 can be used as Sub-base material.

Conclusion

As per the results the sizes of crusher dust sediments are mostly of medium to fine sand sizes uniform gradation of particles and of

slightly lower specific gravities have closer packing with respect to crusher stone aggregates resulting higher densities and CBR values can be used as Sub-base base courses in flexible payment constructions.

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