An experimental study on Ceramic Waste and Reclaimed Asphalt Pavement mixed Granular Sub base for Flexible Pavements

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Abstract - **Presently the exhaustion of natural aggregates has been a significant issue in the development area from which the pavement engineering and construction portion can't be avoided. Given the pavement construction practices, the total interest is colossal to such an extent that blasting, quarrying, crushing and transportation exercises are devouring a ton of energies, yet additionally, the total materials are exhausting quick and are hard to find. In the current pavement construction and engineering practices, the lack of natural raw materials and environmental degradation has led to the use of waste materials in construction practices. The current study is focused on Ceramic Waste and Reclaimed Asphalt Pavement (RAP) mixed Granular Sub base (GSB) in flexible pavements. For this study, a series of experiments were performed to find out the Maximum Dry Density, Optimum Moisture Content, California Bearing Ratio (CBR), and Permeability values at different Proportions of Ceramic Waste and Reclaimed Asphalt Pavement (RAP) mixed with natural aggregate. Besides this, experiments like Specific Gravity, Water Absorption, Aggregate Impact Value, and Bitumen Extraction Test were also conducted. The Granular Sub base (GSB) mix was prepared as per the Ministry of Road Transport and Highways (MORTH) grading. Through the experiments performed it was concluded that though there is a slight decrease in values of Maximum Dry Density, California Bearing Ratio (CBR), and Permeability with an increase in the ceramic waste and RAP content but it can be used in (Granular Sub base) GSB as the California Bearing Ratio (CBR) values are above permissible limits i.e. 30%(for traffic volume>2msa) and 20%(for traffic volume**

keywords - **Aggregates, Construction, Pavement Engineering, Permeability**

1. INTRODUCTION

Presently the use of recycled materials in the construction industry is increasing all over the world due to scarce natural resources and to the development of new methods of construction for a sustainable future. The increasing demand for construction materials as road pavement sub-base and the associated adverse impact on the environment necessitates the search for substitute materials from industries, including waste materials. Use of recycled materials for the construction of roads, pavements, footpaths is increasing all over the world due to their cost effectiveness and environmentally sustainable aspects[2]. The most common recycled materials used in different layers of flexible pavements are Reclaimed Asphalt Pavement (RAP), Recycled Concrete Aggregate (RCA) , Ceramic Waste, Crushed Glass, Marble Dust, Fly Ash, Waste Pumice, Crumb Rubber and Steel Slag.

Asphalt pavements which have reached the end of their service life are frequently rehabilitated by milling the existing pavement surfaces and replacing the milled portion with new hot mix asphalt (HMA). A large amount of recycled asphalt pavement (RAP) is generated every year because of this practice. Literature indicates that 100 % RAP could not produce base course of high quality due to its significant rate dependency and high deformation and creep [4]. To avoid the problems related to the excessive deformations provided using only RAP is necessary to blend it with other type of aggregates, like Construction and Demolitions aggregates, able to strengthen the mixture until reaching a suitable level of resistance to static and dynamic loads[5]. The results of a laboratory study conducted at Sultan Qaboos University indicated that RAP aggregate could be expected to replace virgin aggregate in road sub bases if RAP is mixed with other virgin aggregates [6]. The Algerian government built around 4.5 million houses in the last two decades, which used a million tons of ceramic and marble per annum. Approximately 5–30% of the total quantities produced by ceramic industries were waste materials, which equate approximately 75,000–100,000 tonnes of waste per annum. Moreover, approximately 20% of waste was generated during the overall production of marble [7]. Ceramic materials, which include ceramic tiles and other ceramic products, contribute the highest content of wastes in the construction and demolition wastes. Ceramic tiles have been generated at an increased rate throughout the world today, particularly in Turkey as the leading producer in Europe and China as the world leader. The fact is that each year to approximately 250,000 t of tiles are worn out, while 100 million tiles are used for repairs in the world Because of the large number of waste ceramic tiles being produced in the housing sector, waste ceramic tiles stockpiles constitute environmental risks [8]. The ceramic waste creates serious environmental problems and nearly 30% of the production of ceramic industry is wasted and not reused for any purpose [10]. Cabalar et al. (2016) tested replacing 0, 5, 10, 15, 20, and 30% fractions of the aggregate with CW, and they determined the dry densities and CBR values of road pavement sub-grade [7]. They discovered that increasing CW increased the CBR and dry density values. Electricwala et al. (2013) studied the addition of ceramic dust in the rigid pavement, in which 10, 20, and 30% of the aggregate were replaced by ceramic dust. Their results showed that replacement by ceramic dust was not significant in terms of flexural strength nor decreased the strength of the mixtures [7].

2. SCOPE AND OBJECTIVES

In the present study, an effort has been made to identify the CBR (California Bearing Ratio) Values and Permeability Values of Reclaimed Asphalt Pavement and Ceramic Waste mixed GSB (Granular Sub Base). The compaction factor test was also conducted to determine the Maximum Dry Density and Optimum Moisture Content of the GSB mixes. The GSB is as per MORTH (Ministry of Road Transport and Highways) Grading III. The materials used in this study are 40mm, 20mm, 10mm, Stone Dust, Reclaimed Asphalt Pavement (RAP), and Ceramic Waste. The natural aggregates and Stone Dust Used were procured from Namrup (Assam). The RAP used for this experiment was procured from a nearby Highway project in Kurukshetra (Haryana) where milling operation was in progress. The Ceramic waste for this study was Waste Ceramic Tiles that were procured from NIT Kurukshetra (Haryana). Besides The ceramic tiles waste was obtained by crushing ceramic tiles in Los Angeles Abrasion Testing Machine for about 10 minutes with 12 numbers steel balls.

The objective of the experimental study is as follows:

i. To determine various physical properties of materials selected for this study
ii. To find out the density & strength properties of ceramic waste and RAP mixed GSB mixes.
iii. To find the relationship between materials to be used and the strength properties of the mixes.

3. EXPERIMENTAL METHOD

The main testing program includes the

i. Physical Characterization of the materials used in this study[21-22].
ii. Grading the material used as per MORTH Grading III[26].
iii. Preparation of GSB mixes by replacing natural aggregate by RAP by proportion of 10%, 20% and 30% ,Ceramic Waste by proportion of 5%,10% and 15% and finally combining both RAP and Ceramic waste at different proportion at the given percentages above[26].
iv. Performing Compaction Factor Test to determine the Maximum Dry Density and Optimum Percentages at the different proportions of RAP and Ceramic Waste [23].
v. Performing the California Bearing Ratio (CBR) test and Constant Head Permeability Test at the different proportions of RAP and Ceramic Waste [24-25].

Table 1: Experiments Performed

Property	Test Performed	Specified Limits
Specific Gravity	Specific Gravity Test (IS: 2386 Part 3)	-
Water Absorption	Water Absorption test (IS: 2386 Part 3)	Maximum 2%
Strength of Aggregates	Aggregate Impact Test (IS: 2386 Part 4)	40 % for Sub base
Maximum Dry Density& Optimum Moisture Content	Heavy Compaction Factor Test (IS 2720 Part 8)	-
CBR	California Bearing Ratio Test (IS:2720 Part 5)	30% (for traffic Volume>2msa 20 %(for traffic volume<2msa)
Permeability	Permeability Test (IS 2720 Part 17)	-

3.1 Specified Limits for GSB III as per MORTH 2013

Table 2: Percentage of GSB Mix Passing through Sieve Sizes

Sieve Size(mm)	Upper Limit (%)	Lower Limit (%)
53	100	75
26.5	75	55
4.75	30	10
0.075	5	-

3.2 For convenience, the naming of the GSB Mixes is done based on RAP and Ceramic Content in it. The naming of GSB Samples are given in the following table:

Table 3: Naming of the GSB Mixes

Sample	RAP(%)	Ceramic Waste (%)	Sample	RAP(%)	Ceramic Waste
G00	0	0	**G20**	20	0
G01	0	5	**G21**	20	5
G02	0	10	**G22**	20	10
G03	0	15	**G23**	20	15
G10	10	0	**G30**	30	0
G11	10	5	**G31**	30	5
G12	10	10	**G32**	30	10
G13	10	15	**G33**	30	15

4. LABORATORY STUDY

4.1. The Physical Properties of the materials used in the study is given in the following table:

Table 4: Physical Properties of the materials used in the study

Material	Specific Gravity	Water Absorption (%)	Aggregate Impact Value,%
40mm Aggregate	2.66	0.50	18.29
20mm Aggregate	2.74	0.61	13.12
10mm Aggregate	2.76	0.64	13.19
Stone Dust	2.60	NA	NA
RAP	2.59	0.56	12.19
Ceramic Waste	2.35	0.49	NA

4.2. The Grain Size Distribution of Materials is given in the following table:

Table 5: Grain Size Distribution of Materials

Sieve Size(mm)	40mm	20mm	10mm	Stone Dust	RAP	Ceramic Waste
53	100	100	100	100	100	100
26.5	13.68	100	100	100	9.44	96.70
4.75	0	0	1.07	100	8.80	30.70
0.075	0	0	0	5	0	4.20

In the experimental study, for the preparation of GSB Samples, the materials listed above are mixed in a ratio to give the desired proportion of GSB grading III as in Table 2.

4.3. The bitumen content in RAP was **3.09%**

4.4 The Maximum Dry Density, Optimum Moisture Content, CBR & Permeability Values of the GSB mixes are as follows:

Table 4: Maximum Dry Density, Optimum Moisture Content, and CBR & Permeability Values of the GSB mixes

Sample Name	Maximum Dry Density(g/cc)	Optimum Moisture Content (%)	CBR Value (%)	Permeability Test $\times 10^{-3}$ (m/s)
G00	2.4	6.2	61	1.4
G01	2.38	6.5	59	1.36
G02	2.35	6.8	57	1.32
G03	2.32	7.1	52	1.29
G10	2.36	6.3	56	1.35
G11	2.33	6.6	52	1.33
G12	2.27	6.9	49	1.27
G13	2.22	7.2	46	1.24
G20	2.32	6.3	54	1.31
G21	2.28	6.6	51	1.28
G22	2.23	7.0	48	1.25
G23	2.21	7.4	46	1.21
G30	2.25	6.5	52	1.3
G31	2.12	6.7	48	1.26
G32	1.93	7.2	45	1.22
G33	1.91	7.5	41	1.19

5. RESULTS AND DISCUSSIONS

The Physical Properties of the GSB mixes prepared by Replacing Natural Aggregate with Ceramic Waste and RAP lies within the specified limit in the code of Practice i.e., MORTH(2013): Specifications of Road and Bridge Works. From the study, it can be seen that with an increase in the percentages of Ceramic Waste and RAP in the GSB sample the properties such as Optimum Moisture Content and CBR Value is decreasing but the CBR values are within specified limits of MORTH. Also, with the increase in the percentages of Ceramic Waste and RAP Maximum Dry Density Values and Permeability Values were decreasing.

6. CONCLUSIONS

Based on laboratory study it can be concluded that

i. Ceramic Waste and RAP can be used as an alternative to natural aggregate in GSB
ii. This will not only help in the conservation of natural aggregates but will also help in the utilization and disposal of waste materials.

7. REFERENCES

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