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Bitumen Concrete Mix Design Using Cement and Phosphogypsum as Filler Materials

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Abstract— *Fillers play an important role in engineering properties of bituminous paving mixes. Conventionally stone dust, cement and lime are used as fillers. An attempt has been made in this investigation to assess the influence of non-conventional and cheap fillers such as phosphogypsum (which is a waste product generated for phosphoric acid industries in large quantities discussed later) in combination with cement in asphalt paving mixes. It has been observed as a result of this study that asphalt mixes with these non-conventional fillers result in satisfactory Marshall Properties though requiring a bit higher bitumen content, thus substantiating the need for its use. The fillers used in this investigation are likely to solve the problem of solid waste disposal of the environment to a very large extent. In this study we have worked out the optimum percentage of cement and phosphogypsum to be mixed in bitumen which gives best results in Marshall Stability Test. The combination of both optimum values are then taken to prepare the Asphalt mix for paving flexible pavements. The various results obtained live upto the expectations and are tabulated later on.*

Keywords— ***Phosphogypsum, Filler, Cement, Bitumen, Concrete.***

I. INTRODUCTION

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment; as well as reliable performance of the in-service highway can be achieved. Two things are of major considerations in this regard – pavement design and the mix design. The study emphasizes on the mix design considerations. A good design of bituminous mix is expected to result in a mix which is adequately strong, durable and resistive to fatigue and permanent deformation and at the same time environment friendly and economical. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions of material combinations and finalizes the best one. This often involves a balance between mutually conflicting parameters. Bitumen mix design is a delicate balancing act among the proportions of various aggregate sizes and bitumen content. For a given aggregate gradation, the optimum filler content (Phosphogypsum and cement) content is estimated by satisfying a number of mix design parameters.

II. NEED OF STUDY

The need of study lies in the fact that millions of tones of Phosphogypsum is generated every year as a waste in phosphoric acid industries, the disposal of which is a major problem. Blending phosphogypsum with bitumen to be used in asphalt brings the solution to this problem of waste disposal.

III. METHOD AND MATERIALS

The materials used in this study work along with their desired characteristics are stated under.

Table 1: Materials and their properties

Material	Desired Properties
Coarse Aggregate	The coarse aggregate should have good crashing strength, abrasion value, impact value. Its function is to bear stresses coming from wheels. It has a resist wear due to abrasive action of traffic.
Fine	It shall be fraction passing 600 microns and

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aggregate	retained on 75 microns sieve consisting of crushed stone or natural sand. Its function is to fill up the voids of the coarse aggregate
Fillers	It shall be fraction passing 600 microns and retained on 75 microns sieve consisting of crushed stone or natural sand. Its function is to fill up the voids of the coarse aggregate.
Aggregate Characteristic	The mineral aggregates most widely used in bitumen mixes or crushed stone, slag, crushed or uncrushed gravel, sands and mineral fillers. Since mineral aggregates constitutes of approximately 88% to 96% by weight and approximately 80% by volume of the total mix. Their influence upon the final characteristics of bituminous mixes is very great. Desirable aggregate characteristic gradation and size appropriate to type of constructions, strength and toughness, cubical shape, low porosity, Proper surface texture, Hydrophobic characteristics.

The gradation aggregates used in this project are as per IRC grading 2 as given in the following:

table (MORTH: Specifications for Road and Bridge works 2003):

Table 2: IRC Grading 2 for bituminous concrete mixes

Grading	2
Nominal Aggregate size	19mm
Layer thickness	30-45mm.
I.S. sieve	Cumulative Percentage by weight of total aggregate passing
19	100
13.2	79-100
9.5	70-88
4.75	53-71
2.36	42-58
1.18	34-48
0.6	26-38
0.3	18-28
0.15	12-20
0.075	4-10
Bitumen content by mass of total mix Bitumen Grade (penetration)	5.0-7.0 VG 30
Bitumen	60/70 grade of bitumen has been used

IV. EXPERIMENTAL INVESTIGATIONS & RESULTS

1. Penetration Test:

The consistency of bitumen cement is measured by the penetration test.A weighted needle (100 g) is allowed to bear on the surface of a dish of bitumen of standard test temperature (770 F) for a given length of time (5 sec). The depth of penetration of needle into the bitumen is termed as the penetration of the bitumen and is measured in units of 0.1mm.The needle penetrates farther into soft bitumen than into the harder grades, and thus the lower the penetration, the harder the bitumen. The test performed to check the penetration value of bitumen is tabulated as under:

Table 3: Penetration Test details of bitumen sample

	Sample 1				**Sample 2**			
Readings	Test 1	Test 2	Test 3	Mean value	Test 1	Test 2	Test 3	Mean value
Penetrometer dial readings								
Initial	0	0	0	0	0	0	0	0
Final	6.6	5.7	6.9	6.4	4.8	6.4	6.8	6.0
Penetration Value	66	57	69	64	48	64	67	60

Mean Penetration value = 6.2

Grade of Bitumen =60/70

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2.Specific Gravity

Specific gravity is used to calculate voids in the compacted bituminous mix and to adjust quantities in mixture. Specific gravity of bitumen is found to be 1.05 by balance method.

Specific gravity of Filler

Two fillers are being used in this study namely cement (Gr.-43) and Phosphogypsum. The specific gravity of cement is found to be 3.15 and that of phosphogypsum is found to be 2.4 by pycnometer method.

Specific Gravity of Aggregate

The specific gravity of aggregates was found to be 2.67.

The results of various tests performed on the materials are tabulated as under:

Table 4: Tests performed on materials

Parameter	Observed Value
Mean Penetration value of bitumen	6.2
Grade of bitumen	60/70
Specific gravity of bitumen	1.05
Ductility Test (mm)	49.33
Specific gravity of Filler (OPC Gr. 43)	3.15
Specific gravity of Filler (Phosphogypsum)	2.4
The specific gravity of aggregates	2.67
Crushing Value of aggregate (%)	13
Los Angeles abrasion test (%)	22.08
Water absorption of aggregates (%)	3.15

3. Marshall Stability Test:

The objective of bituminous paving mix design is to develop an economical blend of aggregates and bitumen. In the developing of this blend the designer needs to consider both the first cost and the life cycle cost of the project. Considering only the first cost may result in a higher life cycle cost. Marshall Method of mix design has been adopted in this study. Accordingly aggregates with the grading 2 of IRC and bitumen 60/70 having properties as described in the preceding paragraphs have been used.

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of a bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50mm/minute. The two major features of Marshall Method are Density Void Analysis and Stability Flow Test.

The marshall stability of mix is defined as the maximum load carried by the specimen at a standard test temperature of 60ºC. The flow value is the deformation that the test specimen undergoes during loading upto maximum load. Flow is measured in 0.25 mm units. In this test, an attempt is made to obtain optimum binder content for the type of aggregate mix used.

Marshall Test Data Compilation:

Type of Grading aggregate = B

Mixing Temperature = 60ºC

Number of blows = 75

Grade of Bitumen VG 30

Compaction temperature 27ºC

Table 4: Marshall Test Data Sheet

Filler	Cement (Gr.-43)			Phosphogypsum			Optimum Combination
BITUMEN	1%	1.5%	1.5%	6%	8%	10%	1.5% OPC + 8% Phosphogypsum (by Wt.)
STABILITY PROPORTION							
Stability (kg.)	810	1076	964	1806	2286	2139	2590
Flow Value (mm)	1.6	2.3	3.1	1.8	2.21	2.53	3.45
Unit Wt. (g/cc)	2.18	2.24	2.22	2.41	2.4	2.36	2.38
% air void	8.01	4.68	4.31	2.03	0.83	1.26	1.65
VMA (%)	18.39	17.48	19.11	13.5	14.54	16.99	15.2

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Bituminous mixes containing marble dust as filler displayed maximum stability at 6% content of bitumen, having an increasing trend upto 6% and then gradually decreasing. The unit weight/bulk density also displayed a similar trend with flow value being satisfactory at 6% content of bitumen.

Results of Marshall Stability Test:

Parameters	Cement (Gr. 43)	Phosphogypsum	Optimum Combination
Optimum content in bitumen (%)	1.5	8	1.5% Cement and 8% Phosphogypsum
Stability (kg.)	1076	2286	2590
Flow Value (mm)	2.3	2.21	3.45
Unit Weight (g/cc)	2.24	2.4	2.38
% Air Voids	4.68	0.83	1.65
VMA	17.48	14.54	15.25

V. CONCLUSIONS

1. Bituminous mixes containing combination of cement and phosphogypsum as filler is found to have Marshall properties much better as compared to those of conventional fillers.

2. Bituminous mixes containing OPC as filler displayed maximum stability at 1.5% content of bitumen having an increasing trend upto 1.5% and then gradually 3. Bituminous mixes containing phosphogypsum as filler showed maximum stability at 8% bitumen content displaying an ascending trend up till 8% and then decreasing, the flow value showed an increasing trend and similar was the trend shown by unit weight or bulk density, the percentage of air voids obtained were seen to be decreasing with increase in bitumen content thus from here we can say that 8% bitumen content, satisfactory results are obtained.

4. The combination of these above two results is considered and results are summarized in Table 5. These results are clearly better.

5. From the above discussion it is evident that phosphogypsum generated as waste material can be utilized effectively in making of bitumen concrete mixes for paving purposes.

6. Further modification in design mixes can result in utilization of phosphogypsum as filler in bituminous pavement thus solving the waste material disposal substantially resulting in utilization of industrial space being consumed in disposal of industrial wastes.

7. Though stone dust being conventional filler however marble dust can be utilized in its place effectively thus solving the waste material disposal substantially resulting in utilizing of industrial space being consumed in disposal of industrial wastes.

8. The cost effectiveness of these non conventional filler specimens can be realized after performing a cost analysis of these non-conventional materials against the conventional specimens resulting in reduction of the construction cost considerably.

9. It is evident that with further tests phosphogypsum generated as waste material can be utilized effectively in making of bitumen concrete mixes for paving purpose.

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