Laboratory Evaluation of SDBC, DBC and OGPC Mixes

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***Abstract*: Bituminous mix design is a delicate balancing act among the proportions of various aggregate sizes and bitumen content. For a given aggregate gradation, the optimum bitumen content is estimated by satisfying a number of mix design parameters. This paper presents a laboratory investigations carried out on three types of bituminous mixes SDBC, DBC and OGPC produced by varying aggregate grading in these mixes. Marshall mix design was carried out to determine optimum binder content and Marshall parameters. Indirect tensile strength tests were carried out on cylindrical specimens prepared using standard Marshall compaction technique. The mix parameters that were evaluated include Marshall stability, Indirect tensile strength and Uniaxial compressive strength. Marshall test results indicate higher stability, higher flow, lower air voids and lower optimum binder content for OGPC than SDBC and DBC.**

Keywords: Bitumen; Marshall Stability Test; Indirect Tensile Test; Uniaxial Compressive Strength.

I. INTRODUCTION

Bituminous mixes are commonly used in India and abroad. More than 90% of the surfaced roads of the world are constructed with bituminous mixes. It is possible to construct relatively thin bituminous pavement layers over an existing pavement .Therefore these are commonly adopted as wearing course. There are a wide range of construction materials (type, size and grading of aggregates and type and grade of bituminous binder) and bituminous pavement construction techniques in use. Variations in design and construction types have given rise to the bituminous paving technology. It is well realized that the excessive binder content over an optimum value for a given mix is detrimental to the good performance of the black topped pavements. This is contrary to the role of cement as a binder in the cement concrete mixes, where the excess of the binder does not decrease the strength. Therefore based on the surface area of the aggregates and the technique of construction the optimum binder content may be determined.

In this country, the bituminous construction is by and large adopted on the surface course. In fact till recent years the bituminous construction as a wearing course or as a surface course was considered as the main treatment. Bituminous constructions are also adopted for base and binder courses of pavements on heavy traffic roads. Different from the cement concrete surfacing which would require very high cost of construction and a substantial curing period before opening the road to traffic, the bituminous surfacing has a distinct advantage in this respect. The black top construction is in extensive use in developing nations like, India where the cement as a construction material is in great demand for large number of other engineering projects. Also stage development is possible in the case of bituminous roads, depending on traffic demands. Therefore, aim of this paper will be evaluation of bituminous constructions used in surface course of pavements as:

1. Semi dense bituminous concrete(SDBC),
2. Dense bituminous concrete (DBC) and
3. Open graded premix carpet(OGPC)

The basic difference in the above three bituminous mixes is gradation of aggregates. SDBC is a semi dense graded mixture of coarse aggregates, fine aggregates, mineral filler and bitumen while as in DBC filler is absent and these mixes are designed by appropriate method such as Marshall method. The OGPC mix is designed by increasing the void content in the SDBC followed by suitable proportioning.

The immense demand and depleting sources of bitumen gives us an ominous warning regarding its future cost and ready availability. The traffic on the roads has increased manifold with regard to axle load as well as number of commercial vehicles. The vast expense, wide ranges of climate and different physical characteristics give a continental character to India, which generates quite a number of demands for a pavement engineer to fulfill.

The heavier loads coming on pavement track from the axles of vehicles cause the flexible pavements to deform. Hence compressive stresses are developed in the top layers of pavement (wearing course) which are of small magnitude than tensile stresses developed in the bottom layers (base and sub-base) which cause pavements to develop ruttings, cracks and other defects. Thus we should know the magnitude of these developed stresses and select the best suited mix for a particular axle load configuration. The standard axle load permitted on flexible pavements is 8.6 tons and the legal axle load permitted on pavements is 10.2 tons. However nowadays pavements are subjected to even 30 tons of load. So we should know the stability, tensile strength and compressive strength of pavements and prevent them from failures.

The bituminous mixes of all types, which are used in the flexible pavements, should possess certain desirable properties to cater to the various demands. In addition to proper workability to facilitate placement, the stability, durability, flexibility and skid resistance are the basic properties to which attention has to be given when designing a bituminous mix.

The objective of this study is to know the magnitude of tensile and compressive stresses developed in pavement layers and hence evaluate the stability of pavement. From the strength and stability of pavements select the best pavement for a particular wheel load and environmental conditions.

The preliminary analysis of results as we move from dense to semi dense mix, in general, show decrease in stability, flow value, Split Tensile Strength and Skid Resistance and increase in aggregate stripping.

II. MATERIALS USED AND TESTS CONDUCTED

The following material was collected from various sources for conducting the study:

1. 20mm nominal size coarse stone aggregate(Ganderbal)
2. 10mm nominal size coarse stone aggregate(Ganderbal)
3. Stone Dust (4.75mm down size)
4. Sand(Ganderbal)
5. Filler-Cement Ambuja (OPC 43 Grade)
6. Bitumen VG-10 (80/100 penetration grade)

The physical tests were conducted as per the relevant IS code procedures and the DBC, SDBC and OGPC mixes were designed based on MORTH guidelines. The important tests conducted were:

(a) Marshall stability test.
(b) Uniaxial compression test.
(c) Indirect tensile test.

a) Marshall stability test and mix design:

Mix design is to blend the aggregates and bitumen in adequate proportion to fulfill the desired properties. The desirable properties of a good bituminous mix are stability, durability, flexibility, skid resistance and workability.

The necessity of mix design is to know:

a) The proportion of the aggregates
b) Optimum bitumen content

In this paper Marshall method of bituminous mix design is adopted for making OGPC, SDBC and DBC mixes of penetration grade 80/100. In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at a rate of 5cm/min. The test procedure is used in the design and evaluation of bituminous paving mixes. There are two major features of the Marshall method of designing mixes namely,

1. Density – voids analysis
2. Stability – flow test

Calculation of air voids and VMA

After completion of stability and flow test a density and void analysis was made for each series of test specimen. The % of air voids and VMA is calculated by first calculating the bulk density of the specimen and its unit weight.

Therefore all parameters mentioned below are calculated using the appropriate relationships.

1. Marshall stability value
2. Flow value
3. Unit weight
4. Percent voids in total mix
5. Percent voids filled with mineral aggregates (VMA)

b) Uniaxial Compression Test.

For uniaxial compression test 1800gm of aggregates were taken and compaction was done by applying a load of 218.18kg/cm^2 for 2 minutes.

The test is performed on cylindrical specimens with diameter/ height ratio = 1. Normally its carried out at a constant rate of strain though some forms of the test employ a constant rate of increase of load. The size of the specimens used in this investigation was 101.6mm dia. x 101.6mm height. The test was carried out at room temperature and at 4.52mm/min rate of loading. This test provides a method for measuring the compressive strength of compacted bituminous mixtures. It is for use with specimens weighed, batched, mixed, and fabricated in the laboratory, as well as for mixtures manufactured in a hot-mix plant.

c) Indirect Tensile Test:

Indirect tensile strength of the mix is a good indicator of rutting resistance of the mix. Rutting is one of the major causes of premature failure of the flexible pavement and so it should be considered in the design criteria. Indirect tensile testing involves applying a static compressive load across the diametrical axis of the cylindrical specimen. The mechanics of the test are such that a state of tensile stress is achieved across the diametrical plane. The load is applied at a rate of 5.08 cm/min until failure occurrs. The ultimate load is obtained to calculate maximum indirect tensile strength. The static indirect tensile test was carried out as per ASTM:D-4123-82(1995) to study the behavior of Paving mixes at different grading of aggregates The apparatus for conducting Indirect tensile test consists of: a) *Loading press*, capable of applying a compressive load at a controlled deformation rate of 2 in. per minute. *b)Loading strips*, consisting of 0.5 × 0.5 in. square steel bars for 4 in. diameter specimens, and 0.75 × 0.75 in. square steel bars for 6 in. diameter specimens. Machine the surface in contact with the specimen to the curvature of the test specimen.

Indirect tensile test was used, in this study for the characterization of bituminous mixes. Tensile strength was determined on Marshall Specimens cured at room temperature for 7 days and then keeping them at 25°C for 30 minutes before testing. The test involves loading a cylindrical specimen with the compressive loads at the rate

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of 5cm/min that act parallel to and long vertical diametrical plane. Marshall Specimens 101.6 mm in diameter and 63.5 mm in height were used. To distribute the load and maintain a constant loading area, the compressive load was applied through a 12.7 mm wide steel loading strip that was curved at the interface with the specimen and had a radius equal to that of the specimen.

The loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametric plane that ultimately causes the specimen to fail by splitting or rupturing along the vertical diameter. By measuring the applied load at failure, estimate of the mix tensile strength is as follows:

Tensile strength, $S_t = 4p/\pi Dh$

Where

S_t =tensile strength in kg/sq.cm.

P = total load at failure in kg

h= specimen height in cm

D = specimen dia in cm

The indirect tensile test was carried out for DBC, SDBC and OGPC mixes at optimum bitumen content.

III. METHODOLOGY

The methodology of this work is classified into two major steps. The first one is the material survey and the other one is the design and data analysis. The overall methodology involves:

1. The testing of the aggregates and binder so as to satisfy their suitability for DBC, SDBC and OGPC mixes.
2. Preparation of the Marshall specimens of bituminous mixes using a suitable proportioning.
3. Carrying out density void analysis and stability flow analysis to get optimum bitumen content for SDBC and DBC.
4. Preparation of samples at optimum bitumen content for tests like indirect tensile tests, uniaxial compression tests for all these mixes.
5. Analyzing the results and comparing how the properties like stability, split tensile strength and stripping change by varying void content from DBC to SDBC to OGPC.
6. Evaluation of pavement and conclusion.

IV. RESULTS AND DISCUSSIONS

The following results were obtained from the tests conducted on DBC, SDBC and OGPC mixes.

A) DBC Mix:

The Marshall Test is used in designing and evaluating bituminous paving mixes, and is widely applied in routine test programmes for the paving jobs. The major features of the Marshall method of designing mixes are to determine two important properties; strength and flexibility. Strength is measured in terms of the 'Marshall stability' of the mix which is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60°C. This temperature represents the weakest condition for a bituminous pavement in use. The flexibility is measured in terms of the 'flow value' which is measured by the change in diameter of the sample in the direction of load application between the start of load and the time of maximum load.The test was conducted as per standard procedure. The properties like theoretical specific gravity (Gt), the bulk specific gravity of the mix (Gm), total air voids (Vv), Voids in Mineral Aggregate (VMA), Voids Filled with Bitumen (VFB), Marshall Stability and Flow value were find and given in the tables 4 and table 5.

Type of grading of aggregate: DBC grade 2, SDBC grade 2. Grade of bitumen: 80/90

Mixing temperature, °C: 150.Compaction temperature:120°C. No.of blows on either side:75 Flow value dial, 1 division: 0.0254mm. Proving ring calibration factor: 5.8

Table 1: Marshall Stability Test Results for DBC Mix

Sample no.	Bitumen content %	Weight, gm		Bulk density (g/cc) G_m	Vv %	Vb %	VMA %	VFB %	Stability value, kg	Flow value in 0.25 mm units
		In air	In water							
1.	4.0	1248	725	2.386	5.914	8.990	14.904	60.359	802	2.3
2.	4.5	1253	735	2.418	3.971	10.208	14.179	71.993	885	2.5
3.	5.0	1257	740	2.431	2.760	11.349	14.109	80.439	961	2.2
4.	5.5	1262	740	2.417	2.660	12.356	15.021	82.258	908	2.4

Bituminous Mix Design:

From excel sheet and tables:

a) Maximum stability, kg = 961at bitumen content, % = 5.2
b) Maximum bulk density, gm/cc = 2.45at bitumen content, % = 5.2
c) Bitumen content at flow value of 3.0mm = 5.15%
d) Design bitumen content: 5.2%

B) SDBC Mix

Table 2: Marshall Stability Test Results for SDBC Mix

Sample no.	Bitumen content %	Weight, gm		Bulk density(G_m)	V_v %	V_b %	VMA %	VFB %	Stability value, kg	Flow value in 0.25 mm units
		In air	In water							
1.	4.0	1243	722	2.386	5.914	8.990	14.904	60.359	792	2.0
2.	4.5	1250	732	2.418	3.971	10.208	14.179	71.993	802	2.2
3.	5.0	1253	738	2.431	2.760	11.349	14.109	80.439	795	1.89
4.	5.5	1260	738	2.417	2.660	12.356	15.021	82.258	681	1.75

Bituminous Mix Design:

From excel sheet and tables:
a) Maximum stability, kg = 812 at bitumen content, % = 5.0
b) Maximum bulk density, gm/cc = 2.25 at bitumen content, % = 5.0
c) Bitumen content at flow value of 3.0mm = 4.35%
d) Design bitumen content: 4.95%

C) OGPC Mix:

The OGPC mix was prepared by simply increasing the voids in SDBC. The composition of OGPC mix is as under:
1. Aggregates of nominal stone size 13.2mm (passing 22.4 mm sieve and retained on 11.2 mm sieve) were used.
2. Aggregates of nominal stone size 11.2mm (passing 13.2mm sieve and retained on 5.6 mm sieve) were used.
3. Bitumen content used is 3.5-5.5 percent.
4. Stone dust and sand as per the proportions required.

Samples were prepared at bitumen content 3.5%, 4.0%, 4.5%, 5.0% and 5.5%. Marshall stability test of OGPC samples was carried out in the similar manner as for SDBC and DBC. The results obtained are as:
a) Maximum stability, kg = 671 at bitumen content, % = 4.0
b) Maximum bulk density, gm/cc = 2.30 at bitumen content, % = 4.0
c) Bitumen content at flow value of 3.0mm = 4.2%
d) Design bitumen content: 4.0%

Table 3: Results of Uniaxial Compression Test at 4.52 mm/min rate of loading (Ultimate load in kg)

Sample no.	DBC		SDBC		OGPC	
	Load at failure(Kg)	Uniaxial compression strength in Kg/cm^2	Load at failure(Kg)	Uniaxial compression strength in Kg/cm^2	Load at failure(Kg)	Uniaxial compression strength in Kg/cm^2
1	600	7.40	450	5.55	400	4.93
2	650	8.02	530	6.54	470	5.80
3	730	9.00	620	7.65	490	6.05
Avg. value		8.14		6.58		5.59

Table 4: Indirect Tensile Strength Test Results for DBC, SDBC and OGPC mixes

Sample no.	DBC		SDBC		OGPC	
	Load at failure(Kg)	Indirect tensile strength in Kg/cm^2	Load at failure(Kg)	Indirect tensile strength in Kg/cm^2	Load at failure(Kg)	Indirect tensile strength in Kg/cm^2
1	1024	23.69	802	15.83	690	13.6
2	1139	22.48	900	17.77	750	14.8
3	1200	20.22	973	19.21	780	15.4
Avg. value		22.13		17.60		14.60

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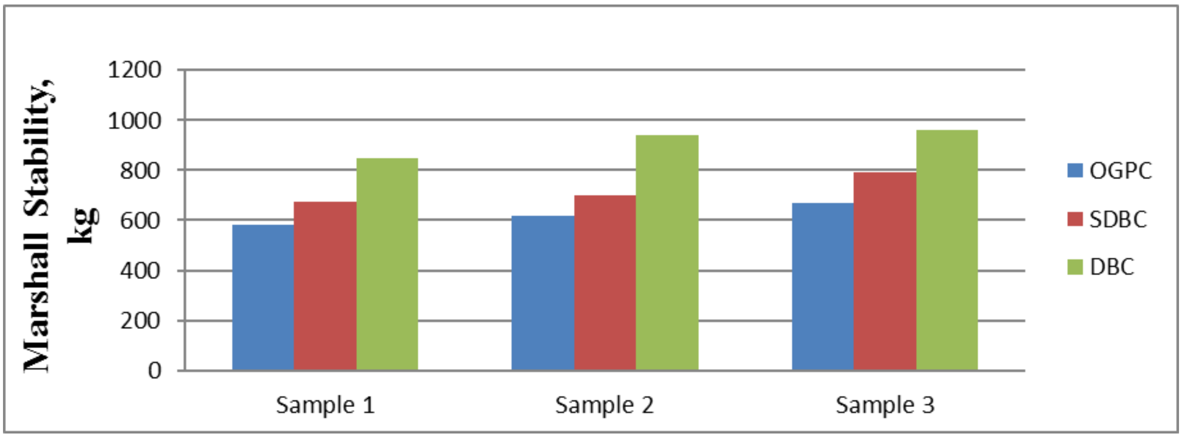

Figure 1: Comparison of Marshall stability for OGPC, SDBC and DBC mixes.

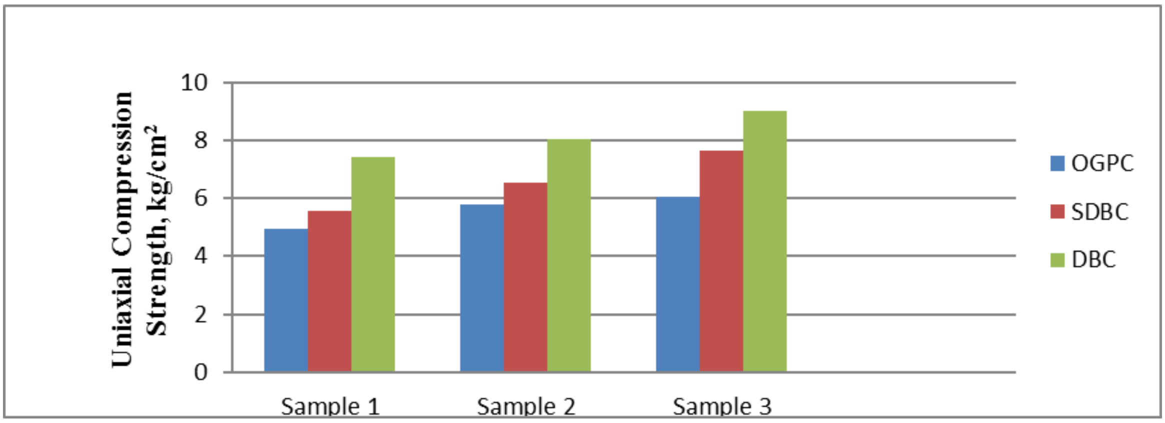

Figure 2 : Comparison of Uniaxial compression strength for OGPC, SDBC and DBC mixes.

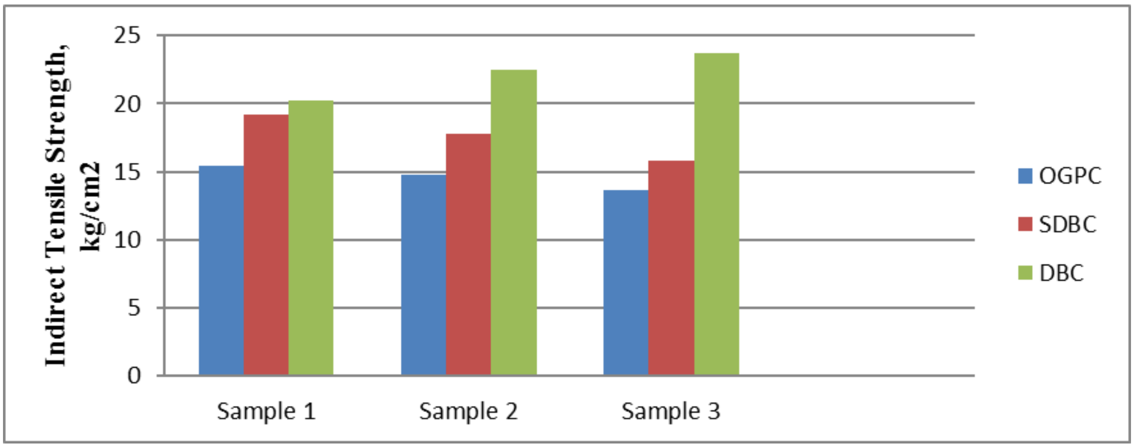

Figure 3: Comparison of Indirect tensile strength for OGPC, SDBC and DBC mixes.

V. CONCLUSION

After carrying out the evaluation of bituminous mixes at room temperature, the following conclusions were drawn:

1. On the basis of tests conducted on aggregates it was found that the aggregates used in bituminous pavements should be definitely tested before use so as to satisfy the proper grading requirements. They should have good crushing strength, abrasion value, impact value and should bear stresses coming from wheels, resist wear due to abrasive action of traffic.
2. Bitumen is used as a binding material as well as water proofing material in pavements so it should be of proper grade and should fulfill requirements as per MORTH.
3. While increasing the void content of the mix by changing the proportioning from SDBC to OGPC, the optimum bitumen content of the mix decreased due to less quantity of bitumen required to coat the less surface area of aggregates with more void content.

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4. The Marshall stability value and hence the properties of the mix show decrease in value from DBC to OGPC due to more voids and no filler.
5. Further decreasing the void content and making it OGPC mix decreased the value of properties and influenced its stability.
6. The study evaluates and reveals the suitability of open, semi-dense and dense graded bituminous mixes, under various site conditions.
7. The analysis of results as we move from dense to open graded mix, in general, show decrease in stability, flow value, Split Tensile Strength and Skid Resistance and increase in aggregate stripping and extent of cracks.
8. The magnitude of tensile and and compressive stresses likely to develop in pavements is more in DBC and less in OGPC.

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