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Comparison of Flexible (Dense Graded) and Porous (Open Graded) Asphalt Surface Course with Stone Dust as a Filler in Marshal Mix Design

K.Shreyas[1] and J.Lavanya[2]
[1]Assistant Professor, [2]Student
[1,2]Department of Civil Engineering
Global Academy of Technology, Bangalore, Karnataka, India
E-mail: shreyasconnect27@gmail.com,
lavanyajayaram93@gmail.com

Abstract - **Bituminous concrete is the surface layer which will be laid to ply the vehicles above it & to transfer the vehicular wheel loads effectively without undergoing any major deformations. The grading of aggregates for bituminous concrete used for the analysis is as per MORTH & gap/open graded for porous asphalt as per NAPA specifications, the analysis done for dense graded asphalt is grade 2 where the nominal size of the aggregates is 13mm as per MORTH specifications. The present study has been taken to evaluate the Marshal property of both Bituminous concrete (Dense graded) & Porous (open/gap graded) asphalt, the tests revealed that there is a significant variation of Optimum binder content for dense graded mix when compared to porous (gap/graded) asphalt surface course. Preliminary tests have been carried out for bitumen & aggregates of specified sizes as per IS standards and results are tabulated. There is a considerable variation of OBC in both open & dense graded mixes where optimum bitumen content is more in dense graded mix when compared to open graded mixes whereas the flow values for open graded mix is more when compared to close graded mixes.**
Keywords: **Flexible pavement, Porous asphalt, storm water, Wearing course, Stability.**

I. INTRODUCTION

A true flexible pavement yields “elastically” to traffic loading; it is constructed with a bituminous-treated surface or a relatively thin surface of hot-mix asphalt (HMA) over one or more unbound base courses resting on a subgrade. Flexural strength is derived from the load-distributing characteristics of a layered system designed ultimately to protect each underlying layer including the subgrade from compressive shear failure.

Storm water will affect the riding quality of pavement surface where there is a considerable reduction in co efficient of friction. A typical porous pavement has an open/gap graded surface over an underlying stone recharge bed. Water drains through the porous asphalt and into the stone bed below, then slowly infiltrates into the soil or natural ground. The contaminants that were on the surface at the time of rainfall are swept along with the storm water through the recharge stone bed, from there they infiltrate into the sub-base & can be drained off effectively.

Porous asphalt (open/gap graded) is an environmentally friendly tool for storm water management. In the natural environment, storm water sinks into soil layer & gets filtered through it and eventually finds its way to streams, ponds, lakes or underground aquifers. This is different from the conventional asphalt course where the storm water is not allowed to penetrate inside the below layers & is sealed at the top surface course. Rainwater and snowfall become runoff which may contribute to flooding of roadways in tropical regions. By adopting the Close graded surface course contaminants are washed from surface layer directly into the shoulder drains without percolating it in to the below layers which leads to clogging of storm water drains.

A comparison of flexible (dense graded) pavement layer with Porous (open graded) flexible surface is done by adopting standard laboratory test methods for the materials which are used in the study. By adopting the open graded mix as a surface course in light traffic areas, the storm water can be drained off effectively also there is a reduction in optimum binder content when compared to conventional dense bituminous concrete layer.

II. REVIEW OF LITERATURE

Deepesh Kumar singh lodhi *et.al* (2016**)** has conducted investigations on gradation of aggregates with respect to Marshal mix design where the attempt is to evaluate the grading of aggregates with respect to MORTH specifications. In the design specifications of aggregate grading, there is a variation of higher & lower grade values where the values are analysed for higher, higher middle, middle, lower middle & lower grades.

Also, the aggregates passing 75-micron sieve has taken as filler material, the material can be stone dust, lime stone, cement, brick dust etc. The aggregates & bitumen are also tested for its physical properties using standard IS specifications & the results are tabulated.

Mohammed Sonebi *et.al* (2016) conducted the studies on gradation of aggregates which are used for the analysis of pervious asphalt layer where the size of aggregate grading will range from 19mm to 9.5mm also there is an increase of permeability which reduces storm water runoff & eventual increase in co efficient of friction of surface layer by allowing water to infiltrate in to the pores effectively. The aggregates which are bigger in size help for the permeability of storm water whereas aggregates smaller than 2.4mm will lead to increase in the strength & durability of pavement.

Lori Kathryn Schaus (2013) conducted the studies on design of porous pavement, Porous asphalt pavements offer an alternative technology for storm water management. A porous asphalt pavement differs from traditional asphalt pavement design by allowing precipitation and run-off to flow through the structure of pavement. This pavement type functions as an additional storm water management technique. The overall benefits of porous asphalt (Open graded) pavements may include both environmental and safety benefits including improved storm water management, improved skid resistance as well as a potential noise reduction of the vehicles. The objectives of this study were to evaluate several laboratory porous asphalt mix designs for durability and strength in cold climate conditions.

Darshna B Joshi *et.al* (2013) conducted the studies on mix design of marshal by varying binder content to provide sufficient flexibility of the pavement over wheel loads also to avoid premature cracking of pavement due to plying of vehicles & to avoid segregation of materials due to climatic variations.

Hanamant Gadad *et.al* (2016) where the gradation for open or gap graded will be different when compared to close graded with void ratio of 3% for dense bituminous concrete & minimum void ratio of 10 to 20% for open graded mixes as per NAPA specifications.

Robert M Roseen (2014) conducted studies on water quality & hydrological performance of porous (open graded) asphalt pavement, this attempts to evaluate that there was an exceptional water-quality treatment & performance for contaminants like petroleum hydrocarbons, zinc, and total suspended solids with every value are below detection limits.

III. MATERIALS AND METHODOLOGY

Materials used

a. Coarse aggregates of pertaining sieve sizes as per IS standards.
b. Fine aggregates of pertaining sieve sizes as per IS standards.
c. Stone dust as a filler (passing 75 microns IS sieve).
d. Bitumen grade – 60/70.

Methodology

Methodology includes the overview on pavement layer which is a surface course & takes the vehicular wheel loads directly. For both porous (Open graded) asphalt pavement and flexible (Dense graded) pavement, preliminary tests were conducted on the materials used for the study. After completion of preliminary tests as per IS standards & specifications, bituminous mould were casted by varying the binder content for both dense (flexible) & open graded (porous) bituminous layer to conduct Marshall Stability test.

Tests conducted for aggregates

1. Sieve analysis
2. Specific gravity and Water absorption test
3. Aggregate shape test
4. Aggregate crushing test
5. Aggregate impact value test
6. Los Angeles abrasion test

The aggregate gradation was continuous with the maximum aggregate size of 19mm. The gradation & other tests were performed as per ASTM standards with 4 trials on each test & the below table represents the physical properties of studied aggregates.

TABLE 1 TEST ON AGGREGATES

S.No.	Test	Method of test	Average Result	Permissible value
1	Sieve analysis	IS:2720-Pt-4	Fineness modulus = 3.10	-
2	Specific gravity	IS:2386-Pt-3	Bulk specific gravity = 2.50	2.5 to 3.2
			Apparent specific gravity = 2.48	
3	Water absorption	IS:2386-Pt-3	0.51	<2%
4	Aggregate shape test Flakiness index	IS:2386-Pt-1	18%	Max 30%
	Elongation index		21%	
5	Aggregate crushing test	IS:2386-Pt-4	26%	<30%
6	Aggregate impact test	IS:2386-Pt-4	23.92%	<24%
7	Los Angeles abrasion	IS:2386-Pt-4	16%	<30%

TABLE 2 TEST ON BITUMEN

S.No.	Test	Method of test	Average Result	Permissible values
1	Specific gravity	IS:1202	1.0	Min 0.99
2	Ductility test	IS:1208	72cms	Min 40 cms
3	Flash point	IS:1209	197^0C	-
4	Fire point	IS:1209	217^0C	-
5	Penetration test	IS:1203	67	50-70
6	Softening point	IS:1205	55^0C	>47 Degrees

TABLE 3 DENSE GRADED MIX AS PER (MORTH) SPECIFICATIONS FOR GRADE-II

Sieve size in mm	%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

TABLE 4 OPEN/GAP GRADED MIX AS PER (NAPA, 2003) SPECIFICATIONS

Sieve size in mm	%passing
19	100
12.5	85-100
9.5	55-75
4.75	10-25
2.36	5-10
1.18	-
0.6	-
0.075	2-4

Tests conducted for bitumen

1. Specific gravity test
2. Ductility test
3. Flash and fire point test
4. Cone penetration test
5. Softening point test

Bitumen used to prepare the mix was 60/70 penetration grade with 4 trials on each test as per the IS standards & the average results are tabulated above:

Experimental design

Mix design

In this study, Marshal mix design has been used to determine the optimum binder content as per ASTM standards where the gradation mid-point is taken as the % passing values for the analysis. The mixes were prepared for 5 different combinations & checked for OBC from 4% to 6 % by total weight of mixture at an increment of 0.5% both for dense graded & open graded asphalt mixtures. The mix were compacted by applying 75 blows on each face for both dense & open graded asphalt mix using Marshall rammer. The Marshall Stability test is conducted on compacted cylindrical specimen of both dense & open graded friction course mix of diameter 101.6mm and thickness 63.5mm.

Marshal stability & flow value, volume of voids & bulk or mass density has been tested by keeping 3% stone dust as a constant filler material for all the mixes. Marshal stability test were based on ASTM standards conducted at 60 degrees & a loading rate of 50 mm/min for each mix type. Optimum binder content from the above studies after adding correction factor to the specimens is 5.5% for dense graded mix & 5.0% for open graded mixes.

IV. RESULTS AND DISCUSSION

Stability

According to MORTH specifications fourth revision minimum stability value should be 9 KN for Flexible pavement (dense graded mixes) & 8.2KN for Porous asphalt (open graded mixes) for a desired temperature of 60 degrees.

For both open & dense graded mixes, there is an increase in value of stability when there is an increase of bitumen content up to a certain point than there is a reduction of stability values. In the study for Flexible pavement (Dense graded mix) the maximum stability value obtained is for 5.5% of optimum bitumen content (OBC) whereas for Porous asphalt (open/gap graded) value of OBC is 5.0%.

TABLE 5 STABILITY VALUES FOR DIFFERENT BITUMEN CONTENT FOR OPEN & DENSE GRADED MIX

S.No.	Bitumen content in %	Stability in KN	
		Open graded Mix	Dense graded mix
1	4.0	8.4	9.1
2	4.5	9.2	10.2
3	5.0	10.6	11.9
4	5.5	8.9	12.9
5	6.0	8.5	10.6

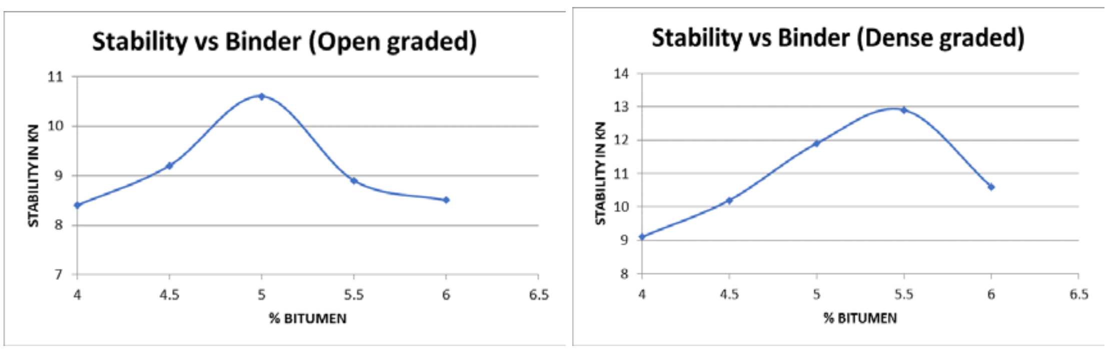

Fig.1 Comparison between stability values for open & dense graded asphalt mix

Flow values

According to MORTH specifications fourth revision minimum & maximum flow values will range in between 2 to 4 mm for both open & dense graded mixes. Whereas the Open graded mix shows more flow values when compared to dense graded mixes.In the present analysis, even though for both open & dense graded mix the value lies in between the standard range of MORTH specifications, it is observed that due to increase in bitumen content there is a general increase in flow values. The flow value for Porous asphalt (open graded mix) is 4.07mm when compared to Flexible pavement (dense graded mix).

TABLE 6 FLOW VALUES FOR DIFFERENT BITUMEN CONTENT FOR OPEN & DENSE GRADED MIX

S.No.	Bitumen content in %	Flow value in mm	
		Open graded Mix	Dense graded mix
1	4.0	2.1	1.7
2	4.5	2.4	2.3
3	5.0	3.0	2.7
4	5.5	3.4	3.1
5	6.0	4.07	3.6

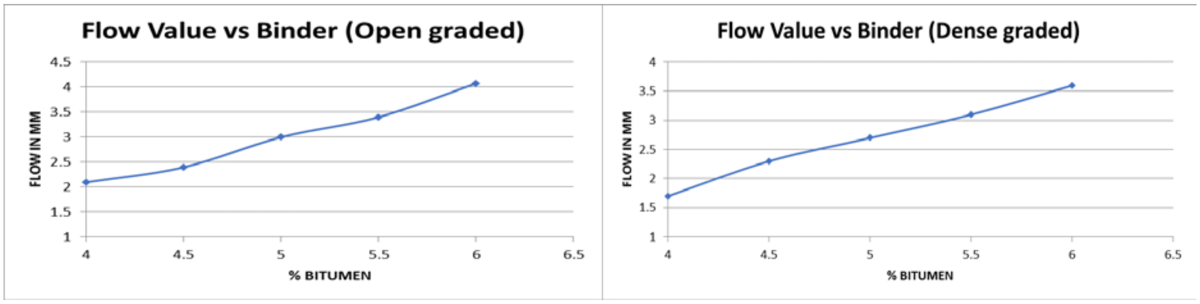

Fig.2 Comparison between Flow values for open & dense graded asphalt mix

Volume of voids

According to MORTH specifications the volume of air voids in open graded bituminous mix will be more when compared to dense graded asphalt mixes. The present study due to low bitumen content there is an increase in air voids in the mixture for both dense & open graded mixes. Air voids for dense bituminous mix for a bitumen content of 4% is 3.75% when compared to open graded bituminous mix which is 4.3%.

TABLE 7 % VOIDS OF DIFFERENT BITUMEN CONTENT FOR OPEN & DENSE GRADED MIX

S.No.	Bitumen content in %	% Voids	
		Open graded Mix	Dense graded mix
1	4.0	4.3	3.75
2	4.5	3.9	2.8
3	5.0	3.1	2.3
4	5.5	2.6	1.92
5	6.0	2.1	1.69

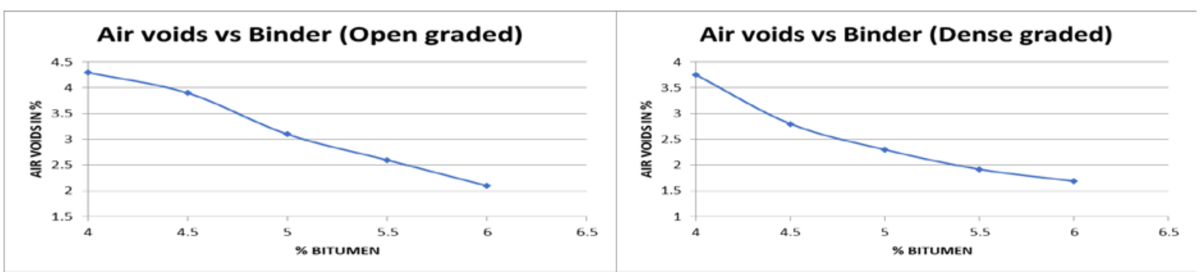

Fig.3 Comparison between % Air voids for open & dense graded asphalt mix

Bulk density/Unit weight

At a certain limit bulk density or mass density of the tested bituminous specimens of (Porous asphalt) open graded mix is less when compared to conventional Flexible pavement mix (Dense graded mix).

TABLE 8 UNIT WEIGHT OF DIFFERENT BITUMEN CONTENT FOR OPEN & DENSE GRADED MIX

S.No.	Bitumen content in %	Unit weight in gm/cc	
		Open graded Mix	Dense graded mix
1	4.0	2.03	2.31
2	4.5	2.09	2.34
3	5.0	2.31	2.37
4	5.5	2.19	2.4
5	6.0	2.13	2.32

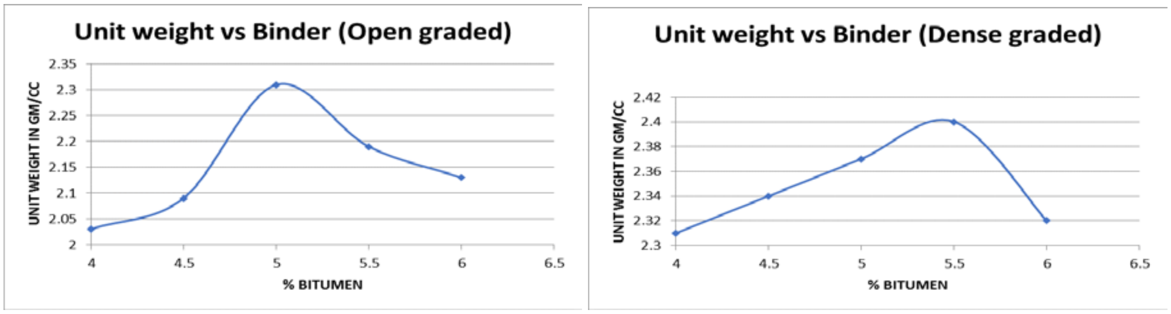

Fig.4 Comparison between Unit weight for open & dense graded asphalt mix

V. CONCLUSION

Based on the various laboratory tests as per IS standards between Flexible pavement (Dense graded) & Porous asphalt mix (Open graded mix) the following results conclude that:

1. When there is a comparison of both the mixes for %bitumen & flow values, the stability value for Dense graded mix is more when compared to the stability values of open graded mixes.
2. The Optimum binder content (OBC) for dense graded mix is 5.5% & 5.0% for open graded mix which lies in between the prescribed limits as per MORTH specifications.
3. The flow values due to higher concentration of Coarser material in open graded mix is more when compared to dense graded mix due to the concentration of finer materials in the Marshal mix.
4. Generally, the percentage of air voids due to less bituminous content will be more for both the mixes but in the present study concentration of air voids is more in open graded mix when compared to dense graded mixes.
5. Bulk or mass density due to presence of air voids & gap graded aggregates the values are less for open graded mix when compared to dense graded aggregates.

REFERENCES

[1] Deepesh Kumar singh lodhi, R.K Yadav, "*Effect of gradation of aggregates on Marshal properties of SDBC mix design*", IJRET, Vol.5, No.2, Feb-2016.

[2] Ministry of road transport & highways (MORTH), "*specification for roads & bridges*" fourth revision, Indian roads congress, New Delhi. 2001.

[3] Robert M Roseen, "*Porous Asphalt Pavements*", Journal of Environmental Engineering, ASCE, January 2012.

[4] Mohammed Sonebi, Mohamed Bassuoni, Ammar Yahia "*Pervious Concrete: Mix Design, Properties and Applications*" RILEM Technical Letters 1: pp. 109 – 115, 2016.

[5] *Darshna b.joshi, 2 prof. a. k. patel" optimum bitumen content by marshall mix design for DBM*" Vol. 2, No.2, Nov 12 to Oct 13.

[6] Lori Kathryn Schaus, "*Design of Porous pavement*", Journal of Transportation Engineering, ASCE, February 2013.

[7] Hanamant Gadad, Mr. Manjunatha S, Mr.Shiva Prasad N, "*Open Graded Friction Course by Marshall Mix Design Approach and Its Performance Studies*" *IJSRD - International Journal for Scientific Research & Development| Vol. 4, No.3, 2016*.

[8] Robert M Roseen, "*Water quality and hydrologic performance of a Porous Asphalt Pavement*", Journal of Building materials, ASCE, July 2014.

[9] National Asphalt Pavement Association, "Porous Asphalt Pavement", National Asphalt Pavement Association, Lanham Maryland, 2003.

[10] Shu Wei Goh, "*Mechanical properties of Porous Asphalt pavement*", ASCE, January 2009.

[11] Dipanjan Mukherjee, "*Manage storm water by using porous pavement*", ASCE, March 2008.

[12] James H Houle and Kristopher H Houle, "*Types of pavements*", Journal of Transportation Engineering, ASCE, May 2009.