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Feasibility Study On Transition From Marshall Mix Design To Superpave Mix Design

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Abstract: **This project deals with the aspects of improving the pavement which to subjected to failure. The cause of failure of pavement is volumetric mix design which causes cracking due to low temperature and liquid-binder specification. Superpave mix design method is designed to replace Marshall Method of mix design. It is a feasibility study on transition from Marshall Method of mix design to Superpave mix design. In super pave design, asphalt pavements are designed to resist thermal cracking and rutting under extreme temperatures. New procedures in the Super pave methodology have been developed to address these problems more effectively through the use of physical tests conducted under laboratory conditions by duplicating more accurate pavement loading and failure conditions in the field.**

Keywords: **pavement, Superpave, Marshall mix, asphalt, cracking, rutting.**

1. INTRODUCTION

A highway pavement consisting of superimposed layers of processed materials above the natural soil sub-grade is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the subgrade. An ideal pavement should also be impervious, long design life with low maintenance cost, smooth surface. Improper design of pavements leads to early failure of pavements affecting the riding quality. Flexible pavements constructed with bituminous material, will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure to a wider area. Hence, the design of flexible pavement uses the concept of layered system and based on overall performance of flexible pavement where stresses produced are kept well below the allowable stress of each layer.

2. SUPERPAVE METHOD OF MIX DESIGN

The purpose of any asphalt mix design method is to determine the optimum proportions of aggregate and asphalt cement to be used in an asphalt pavement mix. Two empirical mix designs methods are traditionally used. These are Marshall and Hveem Methods. Superpave method developed by the Strategic Highway Research Program (SHRP), is being considered for full implementation as a design method. The main advantage of Superpave over currently used mix design methods is that it is performance-based method that implies a direct relationship between Laboratory analysis and field performance after construction. Other design methods are empirical and therefore cannot accurately predict how a pavement will perform after construction.

The Marshall method of mix design had been used for many years and those pavements have performed well, however, with increased traffic and heavier axle loads, it was decided that an improved method of design was needed. The Super pave mix design method was developed to fill this need. A Super pave design system implemented at three levels. The level one method relied totally on volumetric analysis to determine mix proportions. The other levels of Super pave analyses require complex equipment and have not been implemented. There is ongoing research to refine Super pave with respect to quantifying the effects of aggregate size, type and gradation on the mixture and correlating these data with pavement performance.

The Super pave mix design process starts with aggregate evaluation followed by choosing of bitumen and the mixing temperature.

3. LITERATURE REVIEW

A. Anderson.R.M (2007)Characterization of Modified Asphalt Binders in Superpave Mix Design:

This report documents the results of a study on the applicability of Superpave specification (AASHTO MP1, "Standard Specification for Performance Graded Asphalt Binder") and protocols developed for asphalt cements to modified asphalt binders. A survey indicated that, although the majority of state agencies intend to increase future use of modified binders, very little is known about the binders' behaviour. In addition, there are serious concerns regarding their storage stability, aging, and mixing and compaction temperatures. Using advanced rheological characterization of a selected set of binders and mixtures, it was found that the binder specification parameters in the current AASHTO MP1 are not adequate to rank the modified binders according to their contribution to mixture damage. The concepts of viscous flow and energy dissipation were explored in an effort to derive binder parameters. A direct measure of the glass transition behaviour and the use of a design-cooling rate were identified as reliable estimators of the binders’ role in thermal cracking. The concept of low shear viscosity was introduced for the determination of laboratory mixing and compaction temperatures to avoid excessive heating and to consider the shear-rate dependency of modified binders. Revisions to the binder grading system are recommended to include a three-level grading scheme.

B. Charles.R (2009): A Critical Review of VMA Requirements in Superpave:

The low VMA of Superpave mixes can generally be contributed to the increased compactive effort by Superpave gyratory compactor. This has led to the increased use of coarser asphalt mixes (gradations near the lower control points). The inference made was the minimum VMA requirements in Superpave volumetric mix design for these coarse mixes are the same as those developed for the dense mixes designed by the Marshall method. Literature review has indicated that the rationale behind the minimum VMA requirement was to incorporate atleast minimum permissible asphalt content into the mix in order to ensure its durability. Studies have shown that the asphalt mix durability is directly related to asphalt film thickness. Therefore, the minimum VMA should be based on the minimum desirable asphalt film thickness rather than minimum asphalt content because the latter will be different for mixes with different gradations. Mixes with coarse gradation (and, therefore, low surface area) have difficulty meeting the minimum VMA requirement based on minimum asphalt content in spite of thick asphalt films. A rational approach based on a minimum asphalt film thickness has been proposed and validated.

C. Huber.G.A and G.H.Heimen (2009) : Superpave Implementation Phase I:Determination of Optimum Binder Content:

This technical memorandum summarizes the first phase of a research study on the implementation of Superpave mix design for Caltrans. Fifteen Hveem mix designs selected from around the state that are often used in their region were used as the basis of this study. The 15 selected mix designs vary in binder PG-grade, binder type (unmodified, rubber, and polymer), aggregate gradation and mineralogy, and RAP percentage. Based on the Hveem mix designs, Superpave volumetric mix designs were developed for each mix and comparisons were made between mixes developed from both methods. Specifically, the mixes were evaluated to meet the draft Caltrans Superpave volumetric mix design specification which includes the design air-void content, percent VMA, percent VFA and dust proportion as major design components. Details regarding adjustments to and strategies in determining the Superpave optimal binder content for each mix are discussed. A summary of changes and adjustments to Hveem mixes needed to meet Superpave specifications is presented. Recommendations for specimen preparation using Superpave mix design procedures are given.

4. METHODOLOGY

The problem is first identified and the objective is then formulated. The materials such as bitumen and aggregate are collected. The properties of bitumen and aggregate are found by various tests.

Binder tests performed are

- Softening test
- Penetration test
- Ductility test
- Viscosity test
- Specific gravity test
- Dynamic shear rheometer

Aggregate tests performed are

- Impact test
- Abrasion test
- Sieve analysis
- Stripping test
- Specific gravity test
- Water absorption test

After performing the tests for bitumen and aggregate the mix is prepared by both Marshall method and Superpave method. The mix is now tested for determining its properties.

The tests performed for the mix are,

- Density test Marshall
- Stability test dynamic modulus
- Indirect tensile stiffness test
- Moisture susceptibility test

The mix based on Marshall method and Superpave method are compared and the conclusions are arrived.

5. TEST ON AGGREGATE PROPERTIES

A. Aggregate Impact test:

Toughness is the property of a material to resist impact due to heavy wheel load of traffic. Aggregate impact value is the relative measure of the resistance of aggregate to impact.

The mean Aggregate Impact Value (A.I.V) found is 12.5 %. Based on the impact value found, the toughness of aggregate is very tough / strong.

B. Los Angeles Abrasion test:

Resistance to wear or hardness is an essential property for road aggregates, especially when used in wearing course. In order to test the suitability of road stones to resist the abrading action due to traffic, abrasion test is performed and the test values are correlated with pavement performance studies. The average value of Los Angles Abrasion value found is 17.53%.

C. Specific Gravity test:

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Stones having low specific gravity are generally weaker. It is used for making weight-volume conversions and for calculating the void content in compacted bituminous mixes. The specific gravity of coarse aggregates used is **2.72**

D. Bulk and Apparent Specific Gravity test:

The coarse aggregate specific gravity test measures coarse aggregate weight under three different sample conditions:

- Oven-dry (no water in sample).
- Saturated surface-dry (SSD, water fills the aggregate pores).
- Submerged in water (underwater).

Using these three weights and their relationships, a sample's apparent specific gravity, bulk specific gravity and bulk SSD specific gravity as well as absorption can be calculated.

E. Water Absorption test:

Water absorption gives an idea of strength of rock. Stones having more water absorption are more porous in nature and are generally considered unsuitable. Percentage of water absorption found is **0.2%**

F. Stripping value test:

The problem of stripping is experienced when the bituminous pavement layer is subjected to prolonged soaking under water and stripping problem is more predominant in bituminous mixes which are permeable to water. Stripping after 24 hours (in percentage): **100%**

6. TEST ON BITUMEN

A. Specific Gravity of Bitumen:

The specific gravity of semi-solid bituminous material, asphalt cements, and soft tar pitches shall be expressed as the ratio of the mass of a given volume of the material at 25 °C to that of an equal volume of water at the same temperature.

Observation & Calculation:

W1- weight of empty pycnometer

W2- weight of pycnometer + aggregate

W3-weight of pycnometer + aggregate + water

W4-weight of pycnometer full of water

TABLE 6.1: SPECIFIC GRAVITY OF BITUMEN

W1	48.0 g
W2	79.0 g
W3	97.0 g
W4	95.0 g
G_b	**1.069**

B. Softening Point Test on Bitumen:

Bitumen does not suddenly change from solid to liquid state, but as the temperature increases, it gradually becomes softer until it flows readily. The point at which the bitumen flows and changes its state is the softening point. The softening value of bituminous material is 49°C

C. Penetration test on Bitumen:

Penetration test is one of the indirect methods to determine the consistency of pacing grade bitumen, which is very simple test. The penetration value found is 49 mm.

D. Ductility test on Bitumen:

In flexible pavement construction, it is desirable that the bitumen binders used in the bituminous mixes form ductile thin films around the aggregates. The ductility value of bituminous material found is 126mm.

E. Viscosity test on Bitumen:

Viscosity of liquid bituminous binder like bitumen emulsion and tar are determined by indirect method using orifice type viscometers. The viscosity found is 798.75 centipoise and the time taken for 50 cc of the binder to flow is 375 seconds.

F. Dynamic shear Rheometer:

The dynamic shear rheometer (DSR) is used to characterize the viscous and elastic behaviour of asphalt binders at medium to high temperatures. This characterization is used in the Superpave PG asphalt binder specification. The Dynamic Shear Rheometer results are given in Table 6.2.

7. MIX DESIGN

A. Marshall Mix Design:

The mix design determines the optimum bitumen content. This is preceded by the dry mix design discussed in the previous chapter. There are many methods available for mix design which varies in the size of the test specimen, compaction, and other test specifications.

The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen’s plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. The important steps involved in marshal mix design are summarized next.

PREPARATION OF MIX BY MARSHALL METHOD:

Step 1: Proportioning of aggregate by gradation.

TABLE 6.2: Dynamic Shear Rheometer

	1	**2**	**3**	**4**	**5**
RESULT	Pass	Pass	Pass	Pass	Pass
G*/Sin(delta)KPa	8.63	4.2	1.99	1.03	0.509
Phase angle	70.2	85.1	88.1	89	89.3
Complex modulus (KPa)	8.12	4.18	1.99	1.03	0.509
Temperature (^{o}c)	60	66	72	77.99	84
Strain (%)	12.38	11.68	12.09	11.83	11.78
Shear stress	1004.21	488.03	240.632	121.749	60.1249
Frequency (rads/s)	10	10	10	10	10

Step 2: Calculation of amount of Aggregate and bitumen.

TABLE 7.1: PROPORTIONING OF AGGREGATE

Sieve Size											
Aggregate Size	**% agg**	19	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
19	10%	10	2.535	0.21	0.06	0	0	0	0	0	0
13.2	21%	21	20.19	6.13	0.136	0	0	0	0	0	0
6.7	11%	11	11	11	10.17	1.39	0.886	0	0	0	0
2.36	58%	58	58	58	58	48.26	42.46	32.59	23.89	12.006	5.742
Total	100%	100	91.73	75.34	68.36	49.64	43.34	32.59	23.89	12.006	5.742
Specified Limits	100%	100	90-100	70-88	53-71	42-58	34-48	26-38	18-28	12.-30	4.-10

Step 3: Preparation of mould.

Approximately 1200gm of aggregates and filler is heated to a temperature of 175−190°C. Bitumen is heated to a temperature of 121 − 125°C with the first trial percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly mixed at a temperature of 154 −160°C. The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at temperature of 138°C to 149°C. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by +0.5% and repeat the above procedure. The typical Marshall mould is shown in figure 7.1

Fig.7.1: Marshall Mix

Step 4: Testing of the specimen.

TABLE 7.2: MARSHALL STABILITY TEST

Sl. No.	Bitumen content	Wt. in air	Wt. in water	SSD wt.	Density	Stability (KN)	Flow (mm)
1	5.0%	1255.5	736.2	1257.8	2.407	16.78	3.41
2		1246.6	727.0	1248.4	2.391	16.34	3.69
3		1263.3	739.1	1264.6	2.404	15.6	3.47
4	5.5%	1267.2	746.5	1267.7	2.431	16.79	3.00
5		1261.0	721.2	1263.6	2.324	12.04	4.59
6		1239.4	741.0	1240.2	2.483	22.23	4.17
7	6.0%	1289.0	761.3	1289.9	2.439	18.82	4.75
8		1254.1	737.5	1256.0	2.418	17.18	3.35
9		1265.5	748.6	1267.0	2.441	17.5	3.95
10	6.5%	1263.6	748.4	1265.0	2.392	16.61	4.03
11		1276.8	745.0	1279.9	2.387	16.50	4.16
12		1280.3	757.8	1281.4	2.445	16.79	4.33

Step 6: Calculation of V_a, VMA and VFB.

TABLE 7.3: CALCULATION OF PERCENTAGE OF WEIGHT IN MIX

% bitumen	%wt. of bitumen in mix	%wt. of aggregate in mix
5%	4.76%	95.24%
5.5%	5.21%	94.79%
6%	5.66%	94.34%
6.5%	6.10%	93.9%

For 0% air voids,

$$G_{mm} = \frac{Pmm}{\frac{Ps}{Gse}+\frac{Pb}{Gb}}$$

TABLE 7.4: SPECIFIC GRAVITY

% of bitumen	Theoretical specific gravity	Bulk specific gravity (from table)
5	2.534	2.40
5.5	2.517	2.412
6	2.501	2.432
6.5	2.486	2.408

% of air voids,

$$Va = \frac{(Gmb-G)}{Gth} * 100$$

$$VMA = 100 - \frac{Gmb.Ps}{Gsb}$$

$$VFB = \frac{VMA-Va}{VMA} * 100$$

TABLE 7.5: CALCULATION OF STABILITY PARAMETERS

% of bitumen	V_a	VMA	VFB
5	5.28	15.96	66.9
5.5	4.17	15.94	73.84
6	2.679	15.65	82.88
6.5	3.138	16.87	81.39

Step 7: Graph.

Proportioning of aggregate:

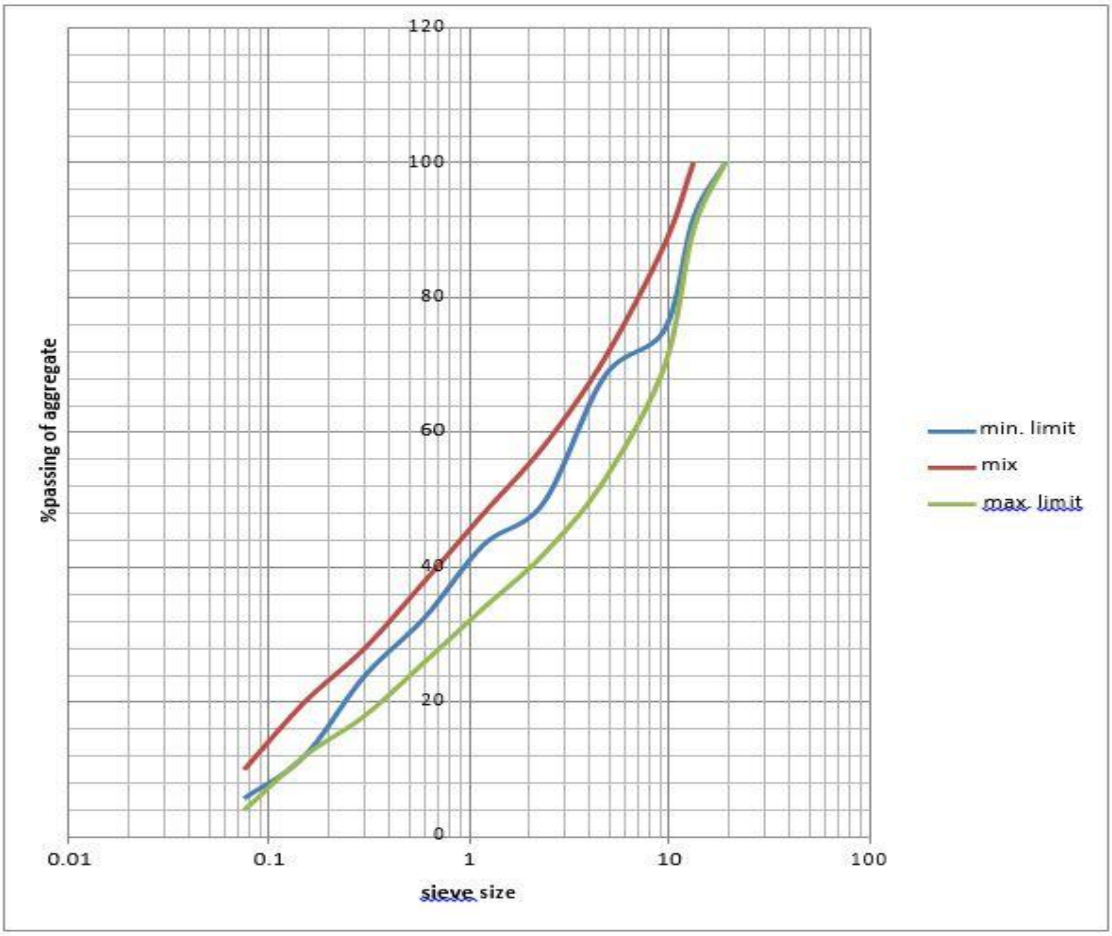
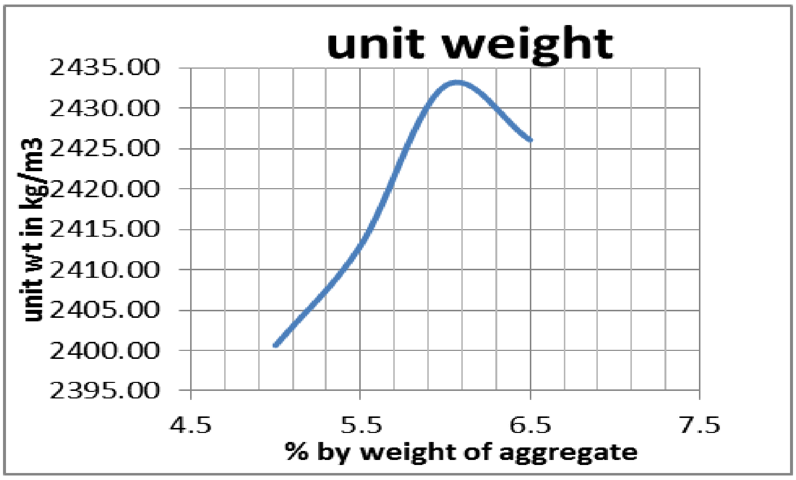
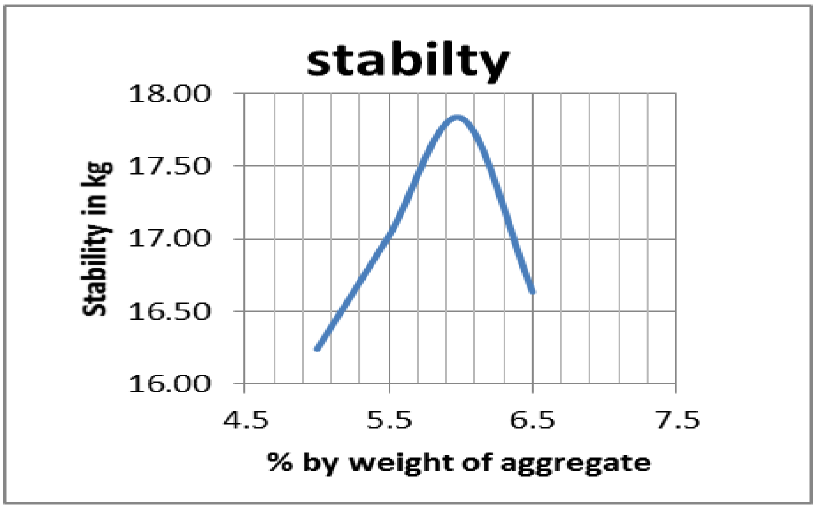


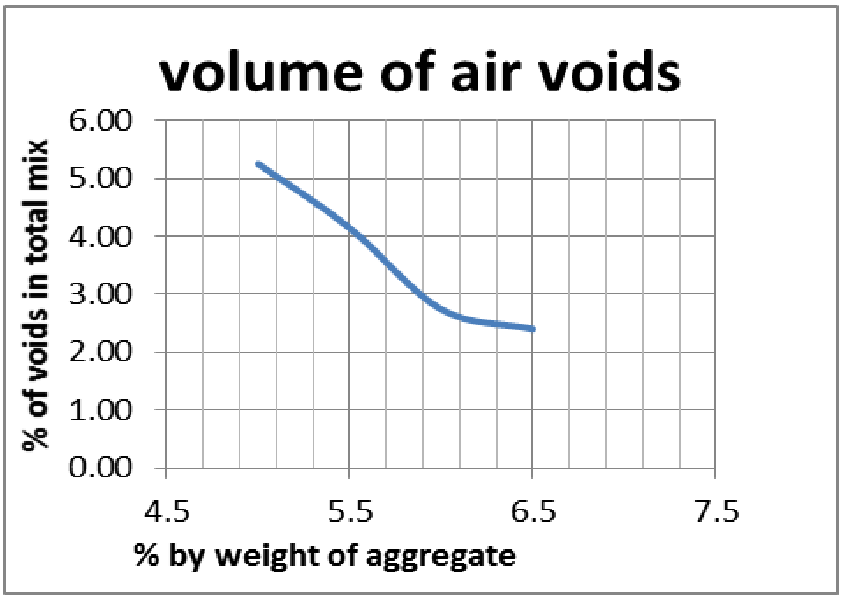
Fig.7.2: Graph of proportioning by sieve analysis



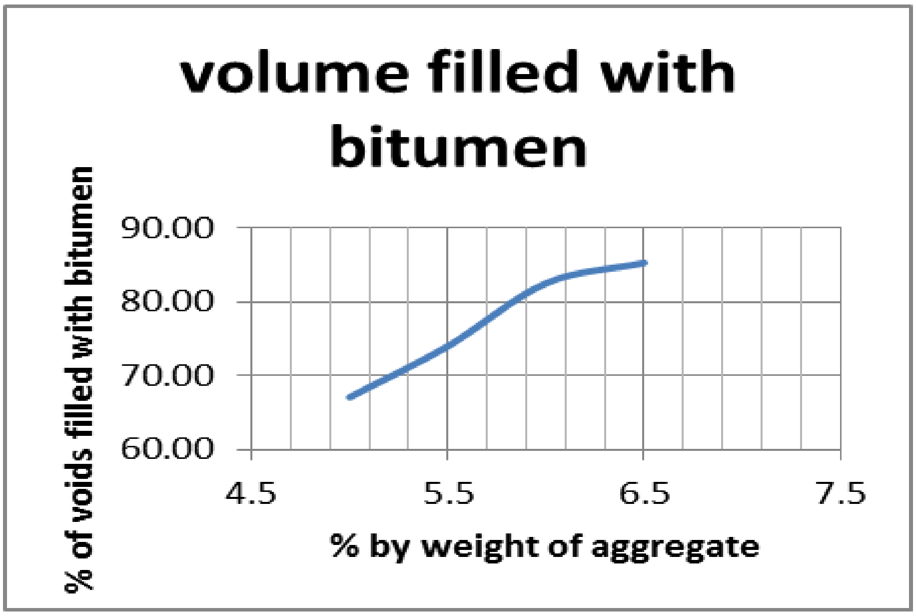
(a)Unit Weight of Mix



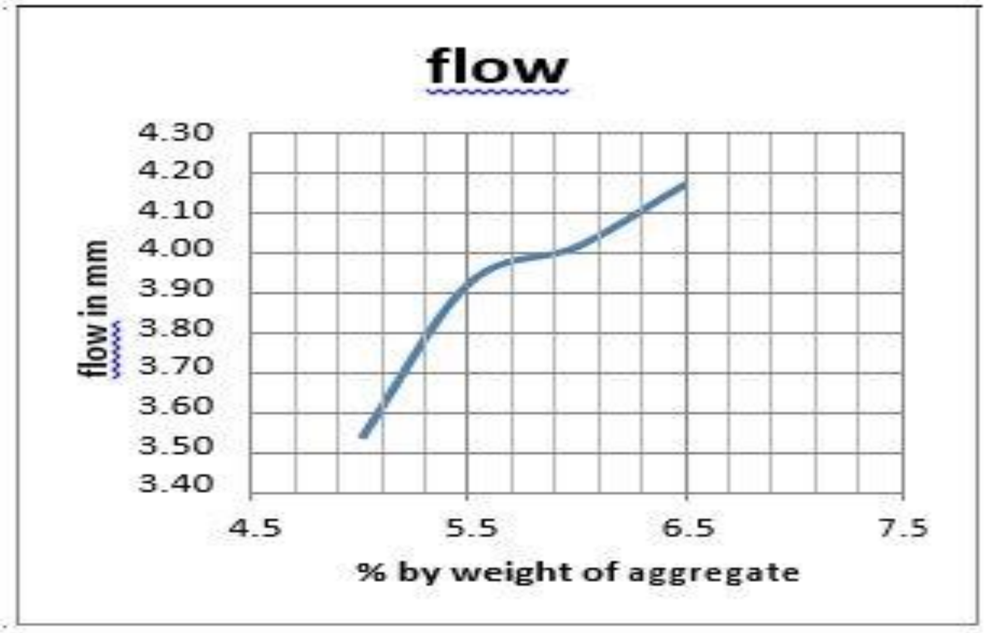
(b) Stability of Mix



(c) Volume of Air Voids in Mix



(d) Volume Filled with Bitumen



(e) Flow in mix

Fig.7.3. (a), (b), (c), (d), (e) Graphs for various parameters

B. Superpave Mix design method:

The Superpave method, like other mix design methods, creates several trial aggregate-asphalt binder blends, each with different asphalt binder content. Then, by evaluating each trial blend's performance, optimum asphalt binder content can be selected. In order for this concept to work, the trial blends must contain a range of asphalt contents both above and below the optimum asphalt content. Therefore, the first step in sample preparation is to estimate optimum asphalt content. Trial blend asphalt contents are then determined from this estimate.

The Superpave gyratory compactor was developed to improve mix design's ability to simulate actual field compaction particle orientation with laboratory equipment.

Each sample is heated to the anticipated mixing temperature, aged for a short time (up to 4 hours) and compacted with the gyratory compactor, a device that applies pressure to a sample through a hydraulically or mechanically operated load. Mixing and compaction temperatures are chosen according to asphalt binder properties so that compaction occurs at the same viscosity level for different mixes. Key parameters of the gyratory compactor are:

- Sample size = 150 mm (6-inch) diameter cylinder approximately 115 mm (4.5 inches) in height.
- Load = Flat and circular with a diameter of 149.5 mm (5.89 inches) corresponding to an area of 175.5 cm^2 (27.24 in^2).
- Compaction pressure = Typically 600 KPa (87 psi).
- Number of blows = varies.
- Simulation method = the load is applied to the sample top and covers almost the entire sample top area. The sample is inclined at 1.25^o and rotates at 30 revolutions per minute as the load is continuously applied. This helps achieve a sample particle orientation that is somewhat like that achieved in the field after roller compaction.

The Superpave gyratory compactor establishes three different gyration numbers:

1. **$N_{initial}$**. The number of gyrations used as a measure of mixture compactability during construction. Mixes that compact too quickly (air voids at $N_{initial}$ are too low) may be tender during construction and unstable when subjected to traffic. Often, this is a good indication of aggregate quality – HMA with excess natural sand will frequently fail the $N_{initial}$ requirement. A mixture designed for greater than or equal to 3 million ESALs with 4 percent air voids at N_{design} should have at least 11 percent air voids at $N_{initial}$.
2. **N_{design}**. This is the design number of gyrations required to produce a sample with the same density as that expected in the field after the indicated amount of traffic. A mix with 4 percent air voids at N_{design} is desired in mix design.
3. **N_{max}**. The number of gyrations required to produce a laboratory density that should never be exceeded in the field. If the air voids at N_{max} are too low, then the field mixture may compact too much under traffic resulting in excessively low air voids and potential rutting. The air void content at N_{max} should never be below 2 percent air voids.

8. PREPARATION OF MIX BY SUPERPAVE METHOD

Step 1: Determination Of apparent and Bulk Specific Gravity

TABLE 7.6.SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE

total sample taken, S	60
wt. of pycnometer, D	52
wt. of pycnometer + water, B	115.6
wt. of pycnometer + sample	112.6
wt. of pycnometer + sample + water, C	150.9
oven dry wt., A	111

TABLE 7.7: SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE

agg size	dry wt of agg	wt in SSD	wt in water	oven dry wt	Gsb	Gssd	Gsa	Absorption
19	3000	3007.7	1979.5	2993	2.91	2.93	2.95	0.49
13.2	3000	3006.3	1888.9	2977.5	2.66	2.69	2.74	0.97
6.7	2000	2004.5	1260.1	1982	2.66	2.69	2.75	1.14
2.36	60				2.39	2.43	2.53	1.69

Step 2: Proportioning for Superpave mix.

TABLE 7.8: PROPORTIONING OF SUPERPAVE MIX

		Sieve Size									
Aggregate Size	**% agg**	**19**	**13.2**	**9.5**	**4.75**	**2.36**	**1.18**	**0.6**	**0.3**	**0.15**	**0.075**
19	24	24	6.084	0.504	0.132	0	0	0	0	0	0
13.2	10	10	9.615	2.92	0.065	0	0	0	0	0	0
6.7	16	16	16	16	14.79	2.016	1.288	0	0	0	0
2.36	50	50	50	50	50	41.6	36.6	28.1	20.6	10.35	4.95
Total	100	100	81.699	69.424	64.989	43.616	37.888	28.1	20.6	10.35	4.95

TABLE 7.9: COMBINED SPECIFIC GRAVITY

Agg. Size	% agg	Gsb	Gssd	Gsa
19	24	0.70	0.70	0.71
13.2	10	0.27	0.27	0.27
6.7	16	0.43	0.43	0.44
2.36	50	1.19	1.21	1.27
total	**100**	**2.59**	**2.62**	**2.69**

Combined Gse = Gsb + 0.8 (Gsa-Gsb)

Gse = 2.62 + 0.8(2.69 – 2.59)

Gse = 2.67

Step 3: Evaluation of V_{ba}, V_{be}, W_s, P_{bi}.

$$V_{ba} = \frac{Ps(1-Va)}{\left(\frac{Pb}{Gb}+\frac{Ps}{Gse}\right)} * \left(\frac{1}{Gsb} - \frac{1}{Gse}\right)$$

V_{be} = 0.081 - 0.02931 [ln(0.76)]

V_{be} = 0.089

$$Pbi = \frac{Gb(Vbe+Vba)}{(Gb(Vbe+Vba))+Ws} * 100$$

$$Ws = \frac{Ps(1-Va)}{\left(\frac{Pb}{Gb}+\frac{Ps}{Gse}\right)}$$

TABLE 7.10 (A): CALCULATION OF P_{bi}

Gse	**2.67**
(Pb/Gb)+(Ps/Gse)	0.402
Ps* (1-Va)	0.912
(1/Gsb)-(1/Gse)	0.008
Vba	**0.018**
Vbe	**0.089**
Ws	**2.268**
Gb*(Vbe+Vba)	0.115
(Gb*(Vbe+Vba))+Ws	2.383
Pbi	**4.820**

TABLE 7.10 (B): CALCULATION OF BITUMEN

% Bitumen	Bitumen weight	No. of mould
4.50%	202.5	2
5.00%	225	2
5.50%	247.5	2
6.00%	270	2

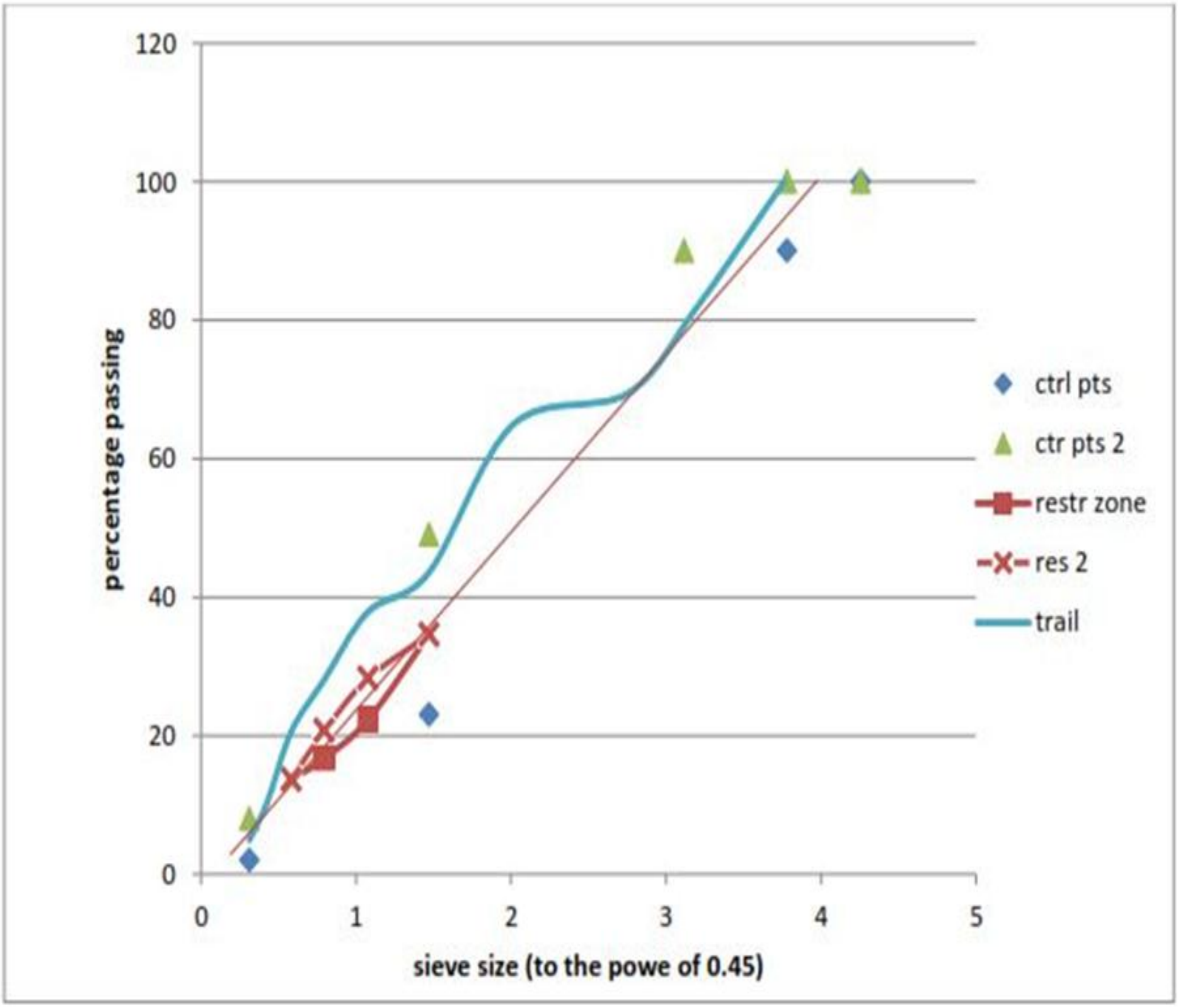


Fig.7.4: Graph of proportioning for Superpave mix

Step 4: Preparation of mould.

Typically, samples are compacted to N_{design} to establish the optimum asphalt binder content and then additional samples are compacted to N_{max} as a check. Previously, samples were compacted to N_{max} and then $N_{initial}$ and N_{design} were back calculated. The specified number of gyrations in the Gyratory compactor as shown in figure 7.5 (a) for $N_{initial}$, N_{design} and N_{max} the required densities as a percentage of theoretical maximum density (TMD) for $N_{initial}$, N_{design} and N_{max} are determined. The Superpave mould after compaction is shown in figure 7.5 (b).

(a)

(b)

Fig.7.5 (a): Gyratory Compactor, (b) Superpave mix

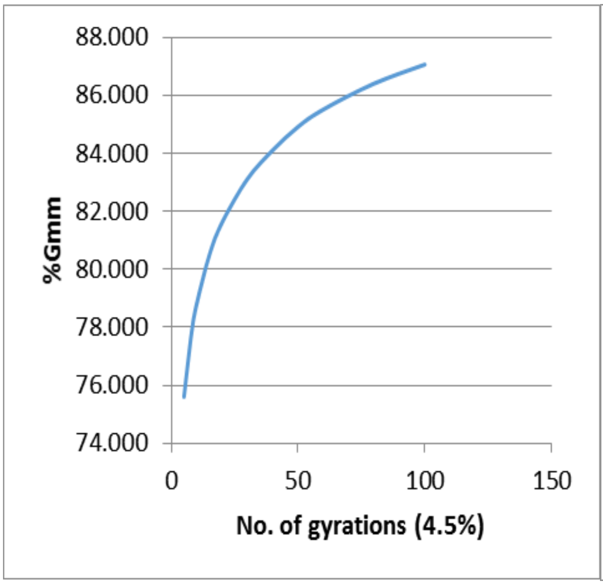
Step 5: Evaluation of density, height and G_{mm}.

TABLE 7.11(A): THEORETICAL SPECIFIC GRAVITY

Th. Specific gravity	
% bitumen	**Gmm**
4.50	2.511
5.00	2.495
5.50	2.479
6.00	2.464

TABLE 7.11(B): CALCULATION FOR WEIGHT IN MIX

% bitumen	Wt. of bit. in mix	Wt. of agg in mix
4.500	4.306	95.694
5.000	4.762	95.238
5.500	5.213	94.787
6.000	5.660	94.340



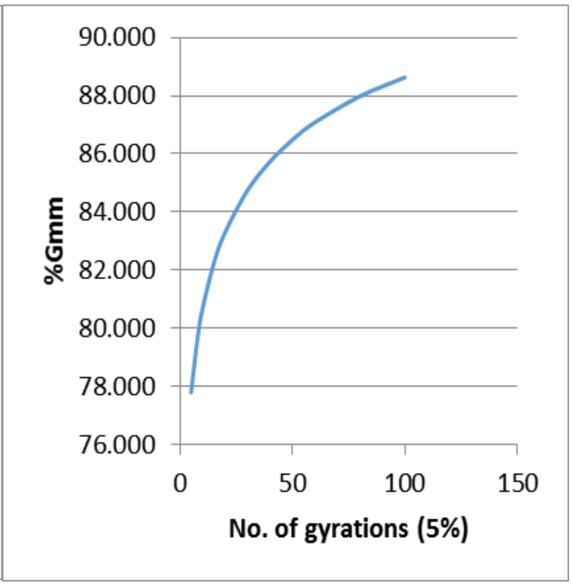


Fig.7.6 Graph for %G_{mm} of mix (i)

Fig.7.6 Graph for %G_{mm} of mix (ii)

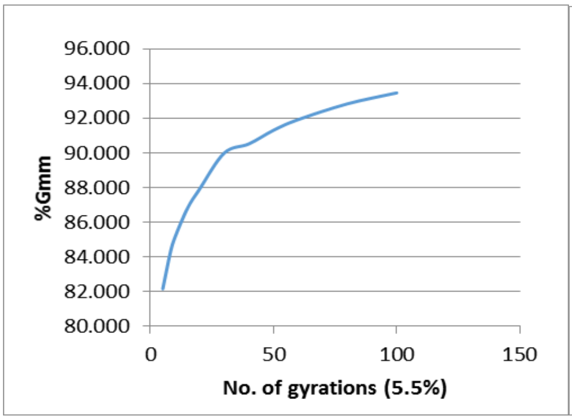


Fig.7.6 Graph for %G_{mm} of mix (iii)

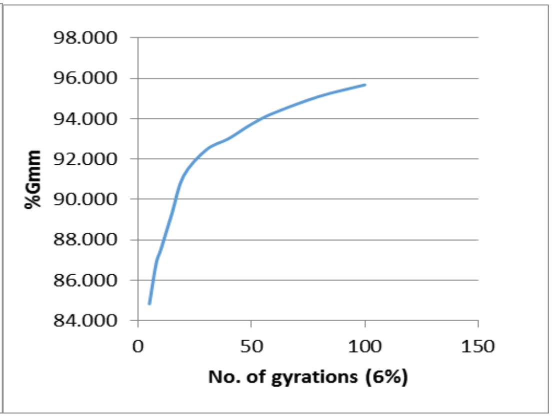
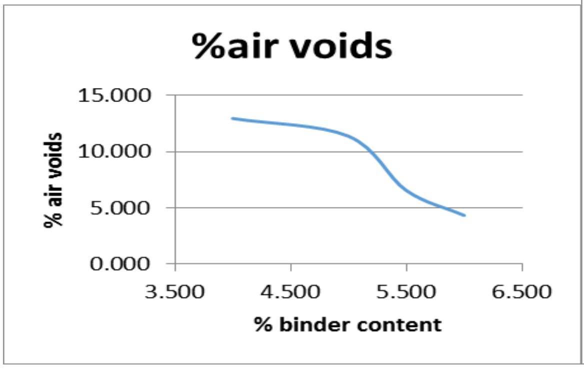


Fig.7.6 Graph for %G_{mm} of mix (iv)

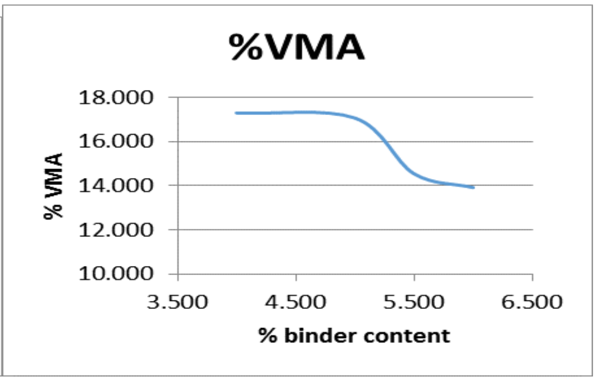
Step 6: Evaluation of V_a, VMA, P_b, VFA, P_{be}, dust proportions.

TABLE 7.12: EVALUATION OF BINDER CONTENT AND DUST PROPORTIONS

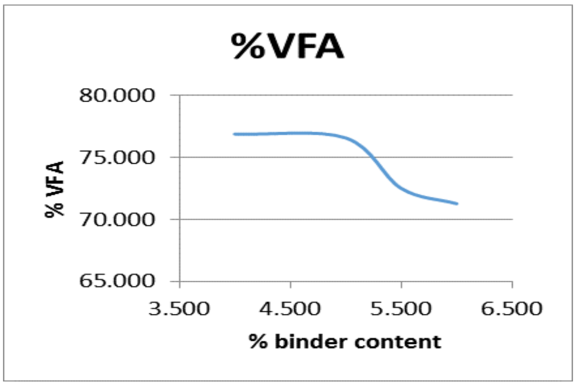
% bitumen	4.000	5.000	5.500	6.000
%G_{mm} @ N_{des}	87.059	88.631	93.457	95.674
G_{mm} (th)	2.511	2.495	2.479	2.464
%G_{mm} @ $N_{initial}$	75.601	77.795	82.170	84.837
P_s	0.957	0.952	0.948	0.943
G_{sb}	2.585	2.585	2.585	2.585
P_{bi}	4.820	4.820	4.820	4.820
G_{se}	2.673	2.673	2.673	2.673
G_b	1.069	1.069	1.069	1.069
$P_{(0.075)}$	4.950	4.950	4.950	4.950
%V_a	12.941	11.369	6.543	4.326
%VMA @initial	19.090	18.545	15.054	13.984
$P_{b,e}$	8.396	7.767	5.837	4.950
C	0.200	0.200	0.200	0.200
%VMA, e	17.302	17.071	14.545	13.919
%VFA, e	76.881	76.568	72.499	71.261
%G_{mm},e @initial	84.542	85.165	84.713	85.163
P_{be}	8.383	7.755	5.824	4.937
Dust Proportions	0.590	0.638	0.850	1.003



(a) Percentage of air voids



(b) Volume of mineral aggregate



(c)Voids filled with bitumen

Fig.7.7. (a), (b), (c) Graph for various parameters

Step 7: Check for criteria.

For 4% air voids, the optimum binder content is 5.8%

% VMA = 13% (Minimum for nominal mix)

% VMA for 5.8% is 14.169

% VFA = 65% to 75% (for nominal mix)

For 5.8 %, %VFA is 71.261

% Gmm at Ninitial = less than 89 % (for nominal mix)

% Gmm at Ninitial = 83.236 for 5.8%.

Dust proportion = 0.6 to 1.2 (for nominal mix)

For 5.8%, Dust Proportion is 0.9112.

8. TEST FOR PERFORMANCE OF SUPERPAVE

A. Dynamic Modulus Test:

Dynamic modulus tests apply a repeated axial cyclic load of fixed magnitude and cycle duration to a test specimen. Test specimens can be tested at different temperatures and three different loading frequencies. The dynamic modulus test can be advantageous because it can also measure a specimen's phase angle (φ), which is the lag between peak stress and peak recoverable strain. The dynamic modulus test setup is shown in figure 8.1.

Fig.8.1: Dynamic Modulus Test Setup

TABLE 8.1: DYNAMIC MODULUS TEST

Frequency	25	10	5	1	0.5	0.1
Cycle Number	200	200	100	20	15	11
Dynamic Load	0.654102	0.593653	0.65476	0.607972	0.656734	0.656734
Dynamic Shear	83.28288	75.58628	83.38142	77.40942	83.61794	83.61794
Recover Rate	6.17E-06	6.55E-06	6.48E-06	6.78E-06	9.45E-06	9.45E-06
Permanent	1.07E-06	3.20E-06	6.32E-06	3.81E-06	2.21E-06	2.21E-06
Dynamic Modulus (MPa)	13543.22	11606.83	5.33E-06	11574.82	11206.14	10201.13

B. Moisture Susceptibility Test:

For Moisture sensitivity test as per AASHTO T283, samples were tested for dry and wet conditions at OBC. The dry set was stored at 25 ^{o}C in an environmental chamber for 2 hours before testing. The wet set was first placed in water bath maintained at 60 ^{o}C for 24 hours and then placed in an environment chamber at 25^{o}C for 2 hours. The load was applied at the rate of 50 mm/min by loading a Marshall specimen with compressive load acting parallel to and along the vertical diametric loading plane. The moisture sensitivity is determined as a ratio of the average tensile strengths of the wet and dry tensile strength of the specimens. The Indirect Tensile Strength (ITS) is calculated from the equation given below:

$S_t = 2 p/\pi d t$

where, P = load (kg),

d = diameter of specimen (cm),

t = thickness of specimen (cm).

TABLE 8.2: MOISTURE SUSCEPTIBILITY TEST

Sl.No.	**Condition**	**D**	**T**	**P**	**St**	**Average**
1	dry	100	66.5	1260.0	0.1206	0.1206
2		100	65.0	1255.2	0.1230	
3		100	64.0	1249.4	0.1240	
4	wet	100	64.5	1124.13	0.11095	0.11095
5		100	66.0	1120.1	0.1080	
6		100	66.5	1009.3	0.0966	

The tensile strength ratio is determined as follows.

$$TSR = \frac{\text{Tensile Strength of wet specimen}}{\text{Tensile Strength of dry specimen}}$$

$$TSR = \frac{0.11095}{0.1206} \text{ x } 100 = 92\ \%$$

C. Indirect Tensile Stiffness Modulus Test:

The tensile properties of bituminous mixtures are of interest to pavement engineers because of the problems associated with cracking. Although SMA is not nearly as strong in tension as it is in compression, SMA tensile strength is important in pavement applications. The indirect tensile strength test (IDT) is used to determine the tensile properties of the bituminous mixture which can further be related to the cracking properties of the pavement. Low temperature cracking, fatigue and rutting are the three major distress mechanisms. A higher tensile strength corresponds to a stronger cracking resistance. At the same time, mixtures that are able to tolerate higher strain prior to failure are more likely to resist cracking than those unable to tolerate high strains. The experimental setup is shown in figure 8.2.

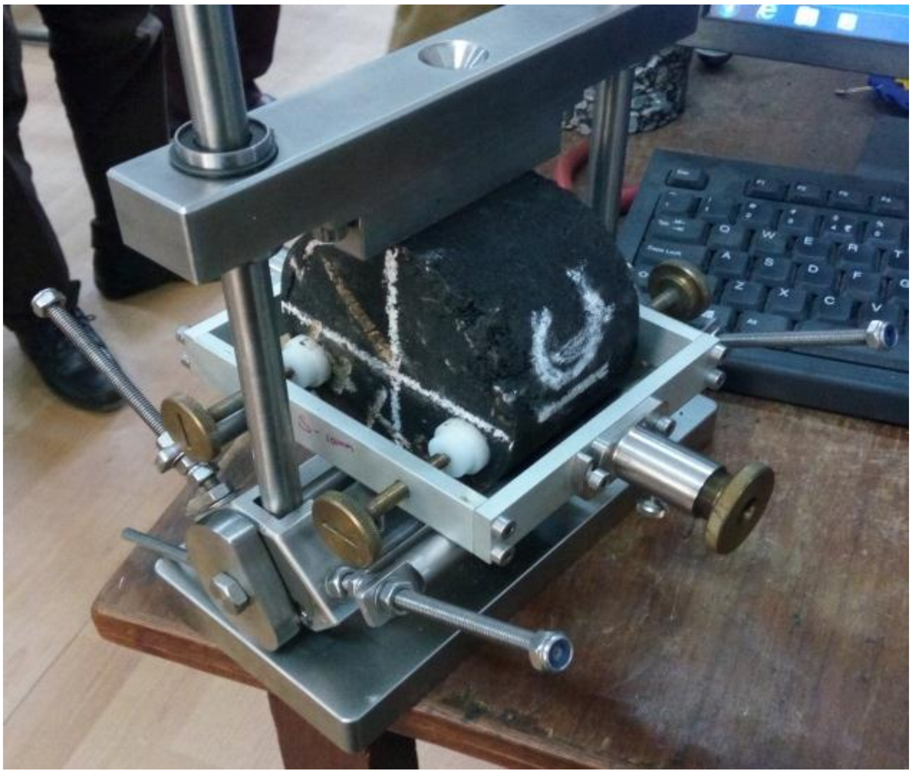


Fig.8.2: Indirect Tensile Stiffness Modulus Test

TABLE 8.3: INDIRECT TENSILE STIFFNESS MODULUS TEST

Characteristics	Marshall mix		Superpave mix	
	Phase 1	Phase 2	Phase 1	Phase 2
Vertical Force (KN)	0.97	0.87	1.20	1.20
Horizontal Stress (KPa)	94.5	84.7	117.3	117.4
Rise-Time(ms)	129	128	122	123
Horizontal Deformation(Microns)	5.2	5.0	5.4	5.3
Load Area Factor	0.620	0.612	0.624	0.601
Stiffness Modulus(MPa)	1806	1659	2132	2157

D. Marshall Stability Test:

TABLE 8.4: MARSHALL STABILITY TEST

Sl. No.	Bitumen content	Wt. in air	Wt. in water	SSD weight	Density	Stability (KN)	Flow (mm)
1	5.6% (Marshall)	1244.5	734.1	1264.5	2.429	14.35	3.95
2		1267.4	747.7	1268.8	2.432	15.43	3.63
3		1275.8	751.4	1276.5	2.429	13.45	3.58
4	5.8% (Superpave)	1255.9	747.7	1257.1	2.465	14.12	3.15
5		1269.4	760.6	1269.6	2.494	15.88	3.48
6		1259.9	754.2	1260.3	2.489	17.12	3.59

The Marshall test indicates that the Superpave mix design has greater stability of 15.788 KN than that of Marshall Mix design of 14.41 KN.

9. COMPARISON OF MARSHALL AND SUPERPAVE DESIGN OF MIX DESIGN

TABLE 9.1: COMPARISON OF MARSHALL AND SUPERPAVE DESIGN OF MIX

MARSHALL METHOD	SUPERPAVE METHOD
Marshall test for stability and flow was designed to stress the entire sample rather than just a portion of it. It facilitates rapid testing with minimal effort.	Superpave was created to make the best use of asphalt paving technology and to present a system that would optimize asphalt mixture resistance to permanent deformation, fatigue cracking and low temperature cracking.
It is an empirical method and the proportions are determined by trial and error method.	It is a field oriented method and delivers much accurate field conditions.
The bitumen is classified based on the viscosity grade which enables the test of bitumen only on 60 °C and 135 °C	The key parts of the process are the Performance Graded (PG) system for specifying the properties of the asphalt binder under all possible temperatures until failure.
The Marshall design of mix is comparatively less feasible and less durable.	The Superpave design of mix is comparatively more feasible and more durable.
The compaction method does not provide Information about the compactability of the mixture.	The Superpave Gyratory Compactor provides information about the compactability of the particular mixture by capturing data during compaction.
The impact compaction used with the Marshall method does not simulate mixture densification as it occurs in real pavement.	The Superpave gyratory compactor stimulates mixture densification as it occurs in real pavements.

10. CONCLUSION

The aggregate and the binder were tested for its properties. The mix was designed by Marshall Method and Superpave Method of mix designs. The two types of mixes were compared by performance tests like Marshall Test and Indirect Tensile Stiffness Test.

- The Marshall test indicates that the Superpave mix design has greater stability of 15.788 KN than that of Marshall Mix design of 14.41 KN.
- The Indirect Stiffness Tensile Modulus test indicates that the Superpave mix design has more stiffness modulus than Marshall Mix design.

Thus, it is concluded that adoption of Superpave mix design method provides advantages of extended paving temperature, reduction in fumes/odour and less plant wear and performs better than the Marshall Mix design method

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