INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES &MANAGEMENT

ASPHALT MIX DESIGN COMPARING PROPERTIES OF BITUMINOUS CONCRETE MIXES USING MORTH AND SUPERPAVE GRADATIONS FOR HEAVILY TRAFFIC LOADS

K.Jagan Mohan Reddy[*1] & M.Durga[*2]
[*1&2]Asst Professors, Dept. of Civi Engineering, Noida International University

---

ABSTRACT

Asphalt paving mixes designed by the marshal mix method have been failing prematurely on our roads. One of the reasons for such failure is inadequate initial compaction. Densities achieved under 75- blow Marshall compaction in the laboratory do not simulate the field densities of the mix after it has undergone secondary compaction due to traffic. When the air voids in the mix decrease to below 3 percent during such densification and as the viscosity of asphalt in the mix decreases sharply in summer, the mix permanently deforms as a rut under the wheel loads.

Three factors contribute to good performance of an asphalt mix carrying heavy axle loads in hot climates. They are adequate initial compaction so that secondary compaction under traffic is minimized, sufficient asphalt content for durability of the mix and enough air voids in the mix for its stability. all the three factors are influenced by the VMA of the mix. A high aggregate shape and surface texture influence the VMA to same but it is largely influenced by the aggregate grading dense grading give rise to low VMAS and open grading to high VMAs.

This research suggests a modification to the marshal design procedure for the design of asphalt mixes. Thee modification involves adjusting the aggregates grading to achieve higher VMA values for creating more space to incorporate higher asphalt contents and checking the mixes for 'refusal density' for ensuring its stability under secondary compaction due to traffic .

So, to solve the problems due to heavy traffic loads and the Environmental effects , atmospheric effects such as seasonable effects on pavement(asphalt) we are investigating using Super pave technology testes in laboratory to solve this issues. Superpave and Marshall mix designs using local aggregates were done to study the suitability of the Superpave mix design as compared with the Marshall mix design for low-volume roads, especially shoulders... Mix samples were compacted in the Superpave gyratory compactor with the applicable number of gyrations and were compacted with the Marshall hammer by using 200 blows per face.

Keywords: *Marshall mix design, super pave ,traffic loads conditions.*

I. INTRODUCTION

Introduction to Mixture Design

The top layers of a flexible pavement, particularly the surface course has to withstand high stress conditions and wear and tear due to traffic loads. In addition the surface course is exposed to adverse climatic factors including temperature variations, water, etc. Therefore properly designed high quality hot bituminous mixtures are laid on the surface course of flexible pavements so as to sustain heavy traffic loads, wear and tear and high-speed vehicle movements requiring good surface texture to provide adequate skid resistance in wet condition. The high quality bituminous mixes (commonly known as hot mix asphalt or HMA) consist of well graded hard aggregates and suitable bituminous binder of correct proportion. The bituminous mixture is prepared in a hot mix plant using the mineral aggregates and binder in appropriate proportion as per mix design, at suitable mixing temperature. The mix is spread with a paver, rolled and finished at the suitable compacting temperature to the specified density and surface profile (C.E.G. Justo et al, 2009).

HMA mix design is the process of determining what aggregate to use, what asphalt binder to use and what the optimum combination of these two ingredients ought to be. When aggregate and asphalt binder are combined to produce a homogenous substance, that substance, HMA, takes on new physical properties that are related to but not identical to the physical properties of its components. Aggregate, binder and final mix samples are shown in figure 1.1 (NCHRP 2011). Mechanical laboratory tests can be used to characterize the basic mixture or predict mixture properties. HMA mix design has evolved as a laboratory procedure that uses several critical tests to make key characterizations of each trial HMA blend. Although these characterizations are not comprehensive, they can give the mix designer a good understanding of how a particular mix will perform in the field during construction and under subsequent traffic loading.

Mix design is meant to simulate actual performance to the extent possible. Then, from reasonable certainty) what type of Mix design is question and how it will perform. HMA manufacturing, construction and this simulation we can predict (with best for the particular application in question and how it will perform.

There are substantial differences between laboratory and field Conditions. Certainly, the laboratory setup cannot fully recreate actual manufacturing, construction and performance conditions. For instance, Mix design compaction should create the same general density to which the traffic will finally compact a mix in the field under service conditions. However, despite limitations such as the preceding, Mix design procedures can provide a cost effective and reasonably accurate simulation that is useful in making Mix design decisions (Freddy L. Roberts 1991).

II. LITERATURE SURVEY

(Jitsangiam et al. 2013) The most commonly-used asphalt mix design in Thailand still relies on the Marshall mix design procedure which is empirical in its nature, in the sense that it is based on data produced by experiment and observation rather than reliable "in-field" data. As a result of this, the Marshall mix design procedure has substantial drawbacks with respect to replicating the real or actual behavior of asphalt during construction and in actual in-service conditions. The Strategic Highway Research Program (SHRP) has developed the Superior Performance Asphalt Pavements (Superpave) mix design procedure, which shifts to a large degree away from the empiricism of the Marshall mix design to provide a more reliable and responsive solution to actual pavement conditions.

This study aims to evaluate whether the Superpave mix design procedure can be reliably implemented under Thailand pavement conditions. A map of the Performance Grade (PG) asphalt binders was generated to cover the study area, namely the North part of Thailand, according to the Superpave asphalt classification with the highest and lowest temperature ranges that the asphalt might be subjected to. Using local materials, and considering loading and environmental conditions, a comparative study of the performance of two mixes, designed using Superpave and Marshall Mix design procedures, was carried out. The Superpave mixes proved superior to the Marshall Mixes. However, the asphalt binder commonly used in Thailand is not suitable for Thailand pavement conditions, based on the PG grade asphalt classification system.

III. THEORETICAL ANALYSIS:

Materials selection

Hot mix asphalt (HMA) is the most common material used for paving today. It primarily consists of asphalt cement binder and mineral aggregates. The binder acts as an adhesive agent that binds aggregate particles into cohesive mass. When bound by asphalt cement binder, mineral aggregate acts as a stone framework that provides strength and toughness to the system. The behavior of HMA depends on the properties of the individual components and how they react with each other in the system (Khalid S.A, 2006).

Asphalt Cement Binder

Asphalt binders characteristics

Asphalt binders, sometimes referred to as asphalt cement binders or simply asphalt cement, are an essential component of asphalt concrete where it is the cement that holds the aggregate together. Asphalt binders are a co-product of refining crude petroleum to produce gasoline, diesel fuel, lubricating oils, and many other petroleum products, asphalt binder is produced from the thick, heavy residue that remains after fuels and lubricants are removed from crude oil (NCHRP, 2011).

This heavy residue can be further processed in various ways, such as steam reduction and oxidation, until it meets the desired set of specifications for asphalt binders. For demanding, high-performance applications, small amounts of polymers are sometimes blended into the asphalt binder, producing a polymer-modified binder. Asphalt binders have been mixed with crushed aggregate to form paving materials for over 100 years. They are a very useful and valuable material for constructing flexible pavement worldwide. However, asphalt binders have very unusual engineering properties that must be carefully controlled in order to ensure good performance.

One of the most important characteristics of asphalt binders that must be addressed in test methods and specifications is that their precise properties almost always depend on their temperature. Asphalt binders tend to be very stiff and brittle at low temperatures, thick fluids at high temperatures, and leathery/rubbery semi-solids at intermediate temperatures. Such extreme changes in properties can cause performance problems in pavements. At high temperatures, a pavement with a binder that is too soft will be prone to rutting and shoving. On the other hand, a pavement that contains a binder that is too stiff at low temperatures will be prone to low-temperature cracking.

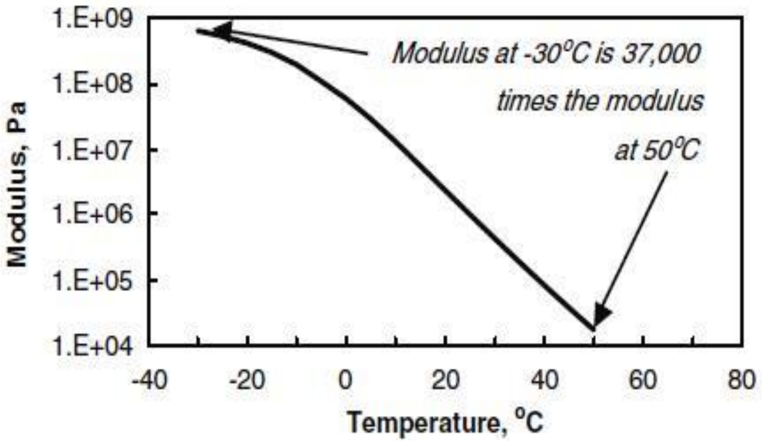

Figure 4.1 Change in dynamic shear modulus with temperature for typical asphalt binder (frequency = 10 rad/s) (NCHRP, 2011).

Figure 3-1 illustrates the extreme change in modulus that occurs in asphalt binders over the range of temperatures likely to occur in pavements; at −30°C (86oF) the modulus of this particular asphalt binder was about 37,000 times greater than its modulus at 50°C (122oF) (NCHRP, 2011). Specifications for asphalt binders must control properties at high, low, and intermediate temperatures. Furthermore, test methods used to specify asphalt binders usually must be conducted with very careful temperature control; otherwise, the results will not be reliable. Asphalt binders are also very sensitive to the time or rate of loading. When tested at a fast loading rate, an asphalt binder will be much stiffer than when tested at a slow loading rate. Therefore, time or rate of loading must also be specified and carefully controlled when testing asphalt binders.

Another characteristic of asphalt binders that complicates specification and testing of these materials is that, for various reasons, such binders tend to change in its rheological properties of with time which is known as Age Hardening. For example, when asphalt binders are heated to high temperatures, as happens when mixing and transporting HMA, the rheological properties of the asphalt cement binder affect the pavement performance.

Age Hardening is the first significant hardening of the asphalt cement takes place in the drum mixer where heated aggregate is mixed with hot asphalt cement. During the short mixing time, the asphalt cement, which is in very thin films, is exposed to air at temperatures which range from 275 to 325°F (60-135oC). Substantial rheological changes such as a decrease in penetration and an increase in viscosity of the asphalt cement take place during this short mixing period from both air oxidation and loss of more volatile components (Freddy L.Roberts 1991).

- Oxidation is the reaction of oxygen with asphalt cement, the rate depending on the character of the asphalt cement and the temperature.
- Volatilization is the evaporation of the lighter constituents from asphalt cement and is primarily a function of temperature. It is usually not a significant factor contributing to long-term aging in the pavement.
- Polymerization is a combining of like molecules to form larger molecules, causing a progressive hardening. There is no scientific evidence that this is a significant factor during the low temperature aging of asphalt in pavements in spite of such speculation in the literature.
- Thixotropy is a progressive hardening due to the formation of a structure within the asphalt cement over a period of time, which can be destroyed to a degree by reheating and working the material. Thyrotrophic

hardening (also called satiric hardening) is generally associated with pavements which have little or no traffic, and its magnitude is a function of asphalt composition.

- Syneresis is an exudation reaction in which the thin oily liquids are exuded to the surface of the asphalt cement film. With the elimination of these oily constituents, the asphalt cement becomes harder.

Absolute Viscosity at 140°F (60oC); Viscosity can simply be defined as resistance to flow of a fluid. Viscosity grading of asphalt cements is based on viscosity measurement at 140° F (60oC). This temperature was selected because it approximates the maximum HMA pavement surface temperature during summer.

A capillary tube viscometer is used to perform the viscosity test at 140° F (60oC). Two viscometers, the Cannon-Manning vacuum viscometer and the Asphalt Institute vacuum viscometer (Figure 3.3), are commonly used. (IS: 1206) (ASTM D2171) test method describes the test procedures.

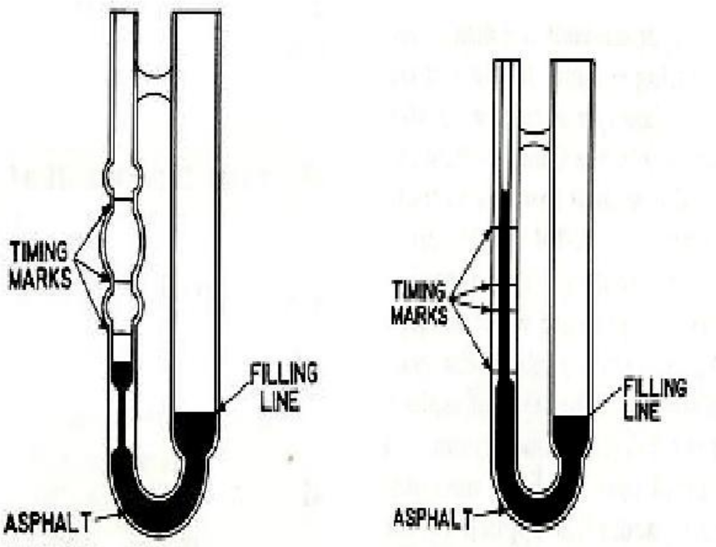

Figure Cannon-Manning vacuum viscometer (left), Asphalt Institute vacuum viscometer (right)

The viscometer is mounted in a thermostatically controlled, constant temperature water or oil bath which is maintained at 140°F (60oC). The viscometer tube is charged with asphalt cement through the large side until the level of asphalt cement reaches the filling line. After the filled viscometer tube is kept in the bath for a prescribed period of time to obtain the equilibrium temperature of 140°F (60oC), a partial vacuum is applied to the small side of the viscometer tube to cause the asphalt cement to flow. Application of partial vacuum is necessary because the asphalt cement is too viscous to flow at this temperature. A vacuum control device and a vacuum pump are needed as part of the testing equipment. After the asphalt cement starts to flow, the time (in seconds) required for it to flow between two timing marks is measured. The measured time (in seconds) is multiplied by the calibration factor for the viscometer tube to obtain the value for viscosity in poises, which is the standard unit for measuring viscosity. Manufacturers calibrate their viscometer tubes with standard oils and furnish the calibration factor with each tube.

Superpave performance grade tests

- **Rolling Thin Film Oven (RTFO)**
- **Pressure Aging Vessel (PAV)**
- **Rotational Viscometer (RV)**
- **Dynamic Shear Rheometer (DSR)**
- **Bending Beam Rheometer (BBR)**
- **Direct Tension Tester (DTT)**

Rolling Thin Film Oven (RTFO); it Simulate the asphalt binder aging during the manufacture and construction of HMA pavement. The (RTFO) was selected because it continually exposes fresh binder to heat and air flow during rolling, modifiers, if used, usually remain dispersed in the asphalt binder due to rolling action, unlike TFO test in which the binder does not move, it does not allow any surface skin in to be formed, which inhibits aging, and it takes only 75 minutes to perform rather than five hours required for the TFO test. (AASHTO T230) and (ASTM D2872) are describing the detailed procedure.

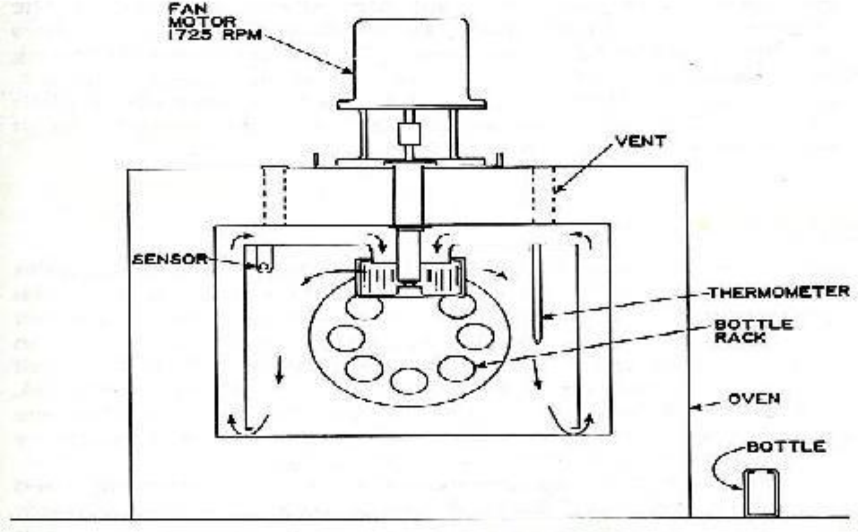

Figure Rolling Thin Film Asphalt (RTFO)

The RTFO test provides an aged asphalt binder for further testing by the dynamic shear rheometer (DSR), and allows the determination of the mass of volatiles lost from the binder during the test. The amount of volatiles lost indicates the amount of aging that may occur during HMA production and construction. Some asphalt binders gain weight, rather than lose weight, during the RTFO aging because of the oxidative products formed during the test.

IV. METHODOLOGY APPROACH

Gradation and Size

Aggregate gradation is the distribution of particle sizes expressed as a percent of the total weight. The gradation as a percent of the total volume is of most importance, but expressing gradation as a percent by weight is much easier and is standard practice. The gradation by volume and weight is approximately the same as long as the specific gravities of the various aggregates being used are approximately equal. If there are large differences in the specific gravity of aggregates being used for a particular mix, then the gradation should be determined as a percent of total volume. Gradation is determined by sieve analysis, that is, by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom, and weighing the material retained on each sieve. The gradation of an aggregate is normally expressed as total percent passing various sieve sizes (Freddy L.Roberts 1991).

Dense or Well-Graded; refers to a gradation that is near the FHWA's 0.45 power curve for maximum density. The most common HMA and PCC mix designs in the U.S. tend to use dense graded aggregate. Typical gradations are near the 0.45 power curve but not right on it. Generally, a true maximum density gradation (exactly on the 0.45 power curve) would result in unacceptably low VMA.

Gap Graded; refers to a gradation that contains only a small percentage of aggregate particles in the mid-size range. The curve is flat in the mid-size range. Some PCC mix designs use gap graded aggregate to provide a more economical mix since less sand can be used for a given workability. HMA gap graded mixes can be prone to segregation during placement.

Open Graded; refers to a gradation that contains only a small percentage of aggregate particles in the small range. This results in more air voids because there are not enough small particles to fill in the voids between the larger particles. The curve is near vertical in the mid-size range and flat and near-zero in the small-size range.

Uniformly Graded; refers to a gradation that contains most of the particles in a very narrow size range. In essence, all the particles are the same size. The curve is steep and only occupies the narrow size range specified.

Fine Gradation; a gradation that, when plotted on the 0.45 power gradation graph, falls mostly above the 0.45 power maximum density line. The term generally applies to dense graded aggregate.

Coarse Gradation; a gradation that, when plotted on the 0.45 power gradation graph, falls mostly below the 0.45 power maximum density line. The term generally applies to dense graded aggregate

Restricted Zone; the restricted zone refers to a particular area of the FHWA's 0.45 power gradation graph associated with Superpave mix designs. It was originally observed that mixes closely following the 0.45 power maximum density line in the finer gradations sometimes had unacceptably low VMA. Therefore, in an attempt to minimize this problem, Superpave included a restricted zone through which a typical gradation should not pass as a recommended guideline.

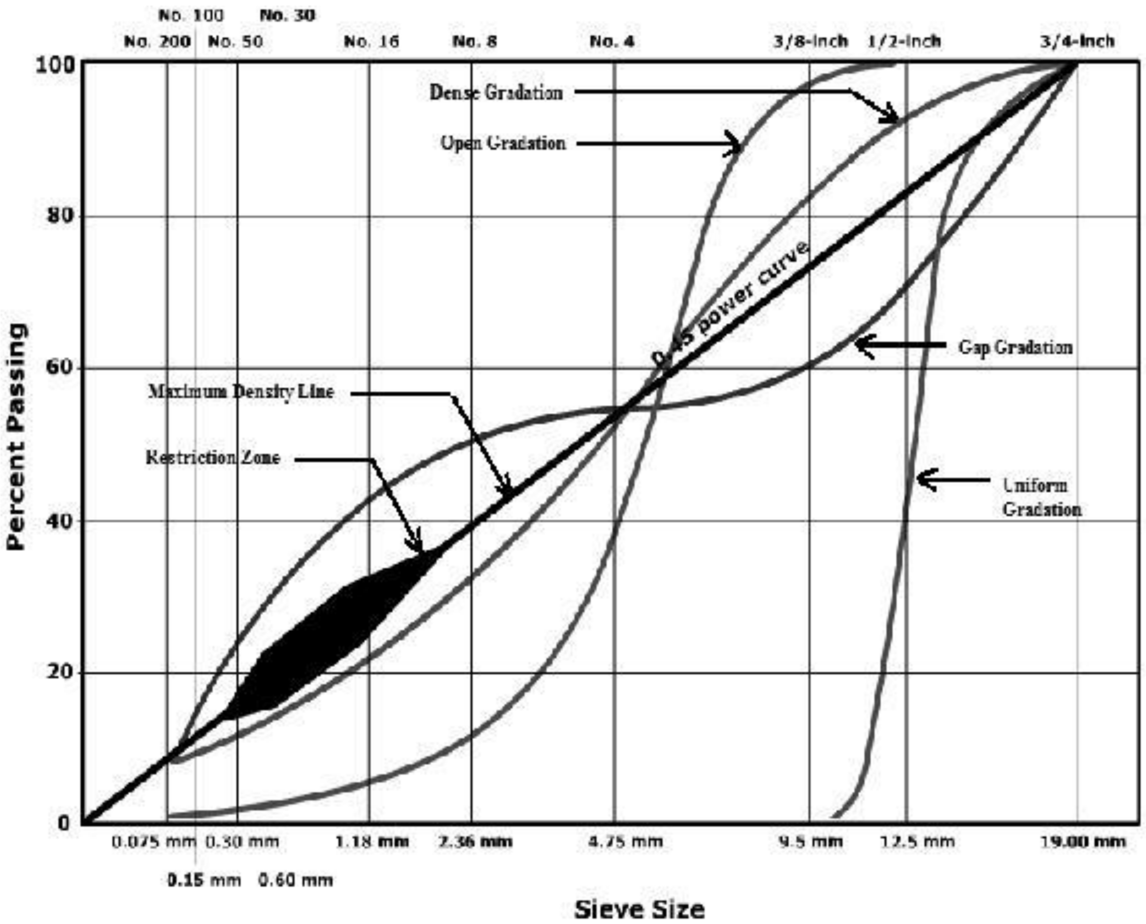

Figure 3.20 FHWA gradation graph showing representative gradations

From a construction standpoint, the maximum aggregate size is normally limited to about one-half of the lift thickness. In recent years, there has been an increase in the use of large stone mixes to minimize rutting potential of HMA. The introduction of larger stone sizes increases the volume concentration of the aggregate. This factor contributes to a reduction of both design asphalt content and cost of the mix. These large stone mixtures are more resistant to rutting than the smaller aggregate size mixtures. However, the use of a maximum aggregate size greater than 1 inch often results in harsh mixes that tend to segregate during placement. Therefore, special attention must be given to mix design, mat thickness, material handling, mixing, and paving procedures when these larger maximum aggregate size mixtures are used.

Sieve Analysis; the gradation of an aggregate is determined by a sieve analysis. Standard procedures for a dry sieve analysis are given in (ASTM Cl36), and for a washed-sieve analysis for determining the amount of material passing the No. 200 sieve, the procedures are in (ASTM Cl 17). The washed sieve analysis is a more accurate measure of the true gradation, but the dry method is faster and is often used to estimate the actual gradation. When the dry method is used, the measured amount of material passing the No. 200 sieve is most likely significantly lower than the actual amount in the aggregate mixture. For clean aggregate, a dry sieve analysis may be accurate enough since the amo unt of material passing the No. 200 sieve is low.

Aggregate Blending to Meet Specifications; for various reasons, mostly associated with achieving maximum density and desired void properties, certain desirable gradation limits are usually required of aggregates for HMA. Because it is unlikely that a single natural or quarried material will meet these specifications, two or more aggregates of different gradations are typically blended to meet specifications limits. Aggregates are also separa ted into sizes to improve handling characteristics. Mixing of coarse and fine aggregate in one stockpile results in segregation; hence, aggregates should be separated into sizes prior to hauling and stockpiling.

Another reason for blending aggregates is that it is often more economical to combine naturally occurring and processed materials to meet specifications than to use all processed materials. The nature of particle size distribution can be examined by graphically representing the gradation by

- A cumulative percent passing on a semi log scale, or
- The cumulative percent passing versus the sieve sizes raised to the 0.45 power.

Both methods are commonly used by engineers to help select the best aggregate blend. If the specifications are expressed in terms of the total percent passing each sieve, they can be plotted as bands or envelopes. A method of transforming a passing-retained specification to an approximate equivalent total percent passing specification. The transformation enables the passing-retained specification to be plotted on the total percent passing chart, making visual examinations and comparisons of different specifications possible.

V. ANALYSIS

Mixture Design

Objective of mix design

HMA mix design should be developed with the following objectives (FreddyL.Roberts 1991):

- **Resistance to Permanent Deformation:** The mix should not distort or displace when subjected to traffic. The resistance to permanent deformation (or rutting) becomes critical at elevated temperatures during hot summer months when the viscosity of the asphalt cement binder is low and the traffic load is primarily carried by the mineral aggregate structure. Mix “stability” as measured in Hveem and Marshall methods is not a very reliable measure of resistance to permanent deformation. Resistance to permanent deformation is controlled by selecting quality aggregates with proper gradation and selecting the asphalt content so that adequate voids exist in the mix.
- **Fatigue Resistance:** The mix should not crack when subjected to repeated loads over a period of time. Neither Marshall nor Hveem methods directly measure any resistance to fatigue. Complex repeated load (either constant stress or constant strain controlled) tests need to be run to estimate the number of cycles to cause failure (cracking) in the specimen.
- **Resistance to Low Temperature Cracking:** This mix property is important in cold regions which experience low ambient temperatures. Low temperature cracking of HMA pavement is primarily influenced by the low temperature properties of the asphalt cement binder. Therefore, a proper selection of binder minimizes this problem.
- **Durability:** The mix must contain sufficient asphalt cement to ensure an adequate film thickness around the aggregate particles, thus minimizing asphalt cement hardening or aging during production and in service. The compacted mix should not have very high air voids (increased permeability) which accelerate the aging process.

- **Workability:** The mix must be capable of being placed and compacted with reasonable effort. No test method is currently available to quantify workability during the laboratory mix design phase. Workability problems are most frequently discovered during the paving operations. However, suitable adjustments to the mix design can be made quickly to overcome the workability problems.
- **Skid Resistance:** This requirement is only applicable to surface mixes which must be designed to provide sufficient resistance to skidding to permit normal turning and braking movements to occur. Aggregate characteristics such as texture, shape, size, and resistance to polish are primarily responsible for skid resistance. However, the mix should also not contain too much asphalt cement binder to cause the HMA mix to flush and create a slippery surface.

Marshall Mix Design

The earliest version of the Marshall mix design method was developed at the Mississippi Highway Department by Bruce Marshall around 1939. The Corps of Engineers Waterways Experiment Station (WES) began a study in 1943 to develop a simple portable apparatus for designing asphalt mixtures for airfield pavements. This was primarily prompted by the increase in aircraft wheel loads during World War II. Tire pressures and, therefore, contact pressures also increased, warranting a suitable mix design method to cope with increased tire pressures. The Corps began experimenting with Bruce Marshall's apparatus and embarked on a series of laboratory and field experiments.

Details of Marshall Mix design procedure is going to be presented in fourth chapter- The Experimental Analysis.

The criteria used by the various agencies that design mixes using the Marshall method vary considerably. However, in order to include all the criteria in this literature. Generally most states include measurement of the following properties in a Marshall mixture design:

- A minimum amount of voids in the mineral aggregates (VMA)
- A range of acceptable voids in the total mix (VTM)
- The percent of voids filled with asphalt (VFA)
- A minimum stability
- A range or minimum flow value

VI. EXPERMENTAL INVESTIGATION

Introduction

This research compares the aggregate gradation of the Superpave and the one which is used by MORTH following Marshall mix design procedure. This chapter presents the laboratory experiments conducted in the highway material laboratory,

Materials

The aggregate used in this research work is obtained from Medchal quarry, Hyderabad, AP. Three types of aggregates (course aggregate, fine aggregate and dust) were used to develop aggregate blends in order to meet the gradation requirements. The asphalt used in preparing Marshall specimens is PG 64-22 obtained from HPCL vizak, Hyderabad, AP.

Table Asphalt Cement Physical Properties

Test	Specifications	Result	Specifications limit
Penetration, mm	IS-1203-1978	63	60-70
Ductility, mm	IS-1208-1978	41	40-50
Softening point	IS-1205-1978	48	47-50
Specific Gravity	IS-1202-1978	0.97	0.97-1.02
Viscosity at 60oC, Poise (min)	IS-1206-1978	2200	1600-2400

Viscosity at 135oC, cSt (min)	IS-1206-1978	365	350-400
Dynamic Shear @ 64°C, G*/sin d, kPa	AASHTO T 315	65.3	64

Aggregate

Aggregate Selection

The gradations of aggregate used is of three sizes, coarse aggregate ,fine aggregate, and dust, were used to prepare the aggregate blends to meet the aggregate gradation specifications. The physical properties of the aggregate used in this research are given below in table 4.2.

Aggregate Gradation

The main objective of this thesis is to compare between the aggregate gradation specified by MORTH and the one specified by the Super pave, and conclude its effect on the asphalt mix properties. The aggregate gradation for the Bituminous Concrete pavement specified by MORTH of 19 mm and 13.2 mm is given in table 4.3,(MORTH 2010-5th Revision, Section 500). Table 4.4 - 4.8 shows the Super pave aggregate gradation of 9.5 mm to 37.5 mm. (Freddy L. Roberts 1996.

Table Composition of Bituminous Concrete Pavement Layers as specified by MORTH (MORTH 2010-5th Revision)

Grading	**1**	**2**
Nominal aggregate size	**19mm**	**13.2mm**
Layer thickness	**50 mm**	**25/40 mm**
IS Sieve (mm)	**Cumulative % by weight of total aggregate passing**	
26.5	**100**	**-**
19	**79-100**	**100**
13.2	**59-79**	**79-100**
9.5	**52-72**	**70-88**
4.75	**35-55**	**53-71**
2.36	**28-44**	**42-58**
1.18	**20-34**	**34-48**
0.6	**15-27**	**26-38**
0.3	**10-20**	**18-28**
0.15	**5-13**	**12-20**
0.075	**2-8**	**4-10**
Bitumen content % by mass of total mix	**5-6**	**5-7**

Table Super pave 37.5 mm Nominal size (Freddy L. Roberts 1996)

Sieve size mm	Control Points		Restriction Zone Boundary	
	Lower	Upper	Lower	Upper
50	100.0	100.0	-	-
37.5	90.0	100.0	-	-
25	-	90.0	-	-
19	-	-	-	-
12.5	-	-	-	-
9.5	-	-	-	-
4.75	-	-	34.7	34.7
2.36	15.0	41.0	23.3	27.3
1.18	-	-	15.5	21.5
0.60	-	-	11.7	15.7
0.30	-	-	10	10
0.15	-	-	-	-
0.075	0.0	6.0	-	-

Table 4.5 Super pave 25 mm Nominal size

Sieve size mm	Control Points			Restriction Zone Boundary
	Lower	Upper	Lower	Upper
37.5	100.0	100.0	-	-
25	90.0	100.0	-	-
19	-	90.0	-	-
12.5	-	-	-	-
9.5	-	-	-	-
4.75	-	-	39.5	39.5
2.36	19.0	45.0	26.8	30.8
1.18	-	-	18.1	24.1
0.60	-	-	13.6	17.6
0.30	-	-	11.4	11.4
0.15	-	-	-	-
0.075	1.0	7.0	-	-

The aggregate gradation followed by Superpave mix design specifications differ with respect to the layer type and needs, whereas in the MORTH specifications, a separate different gradation is provided based on the thickness of the layer needed. The comparison is going to be presented by deploying aggregate of 19 mm nominal size for both MORTH and Super pave.

Mixture Design Deploying MORTH 19 mm Aggregate Gradation

The major steps involved in performing a mixture design begin with source acceptance tests in Steps I and II, specimen preparation in Step III; density and voids analysis in Step IV; stability and flow tests in Step V; tabulating and plotting of test results in Step VI, and determining asphalt content in step VII.

Aggregate Evaluation

The aggregate gone through the physical properties tests and results in positive results as shown in section 4.1.1 table 4.2. HMA should include aggregate of good quality in order to sustain the traffic loads and adverse environmental conditions.

The blending of coarse aggregate, fine aggregate and dust have been done to obtain a gradation size fall in between the MORTH specification. MORTH aggregate upper and lower specifications limits is shown in the table below. In addition to their graphical representation in figure 4.1

Table 4.9 MORTH 19 mm aggregate upper and lower specifications

Sieves,mm	26.50	19.00	13.20	9.50	4.75	2.36	1.18	0.60	0.30	0.15	0.075
Upper limit specification	100	100	79	72	55	44	34	27	20	13	8
Lower limit specification	100	79	59	52	35	28	20	15	10	5	2

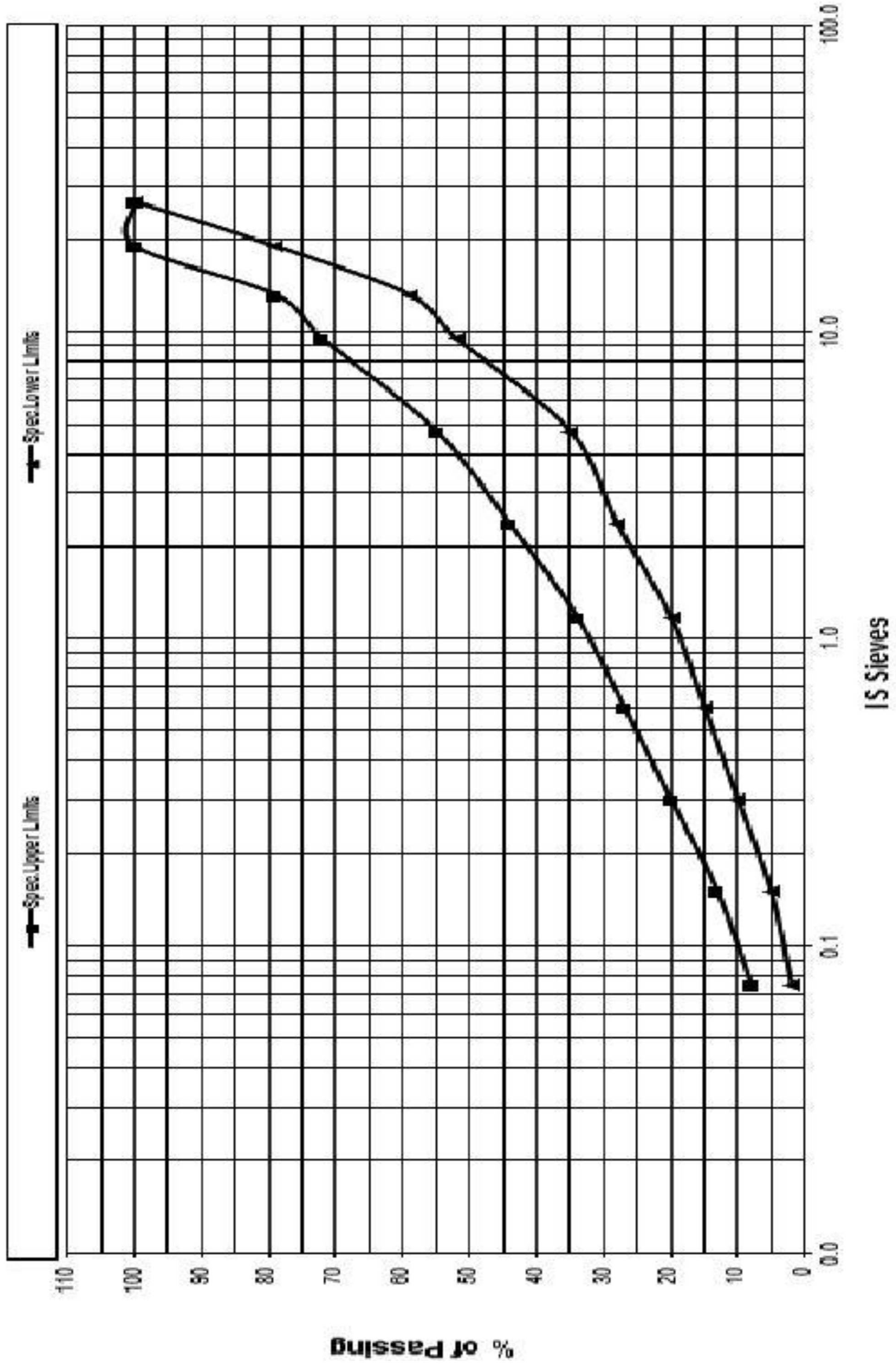

Figure4.1MORTH 19 mm aggregate gradations

The blending of aggregate is carried out to produce three aggregate gradations goes within the MORTH upper and lower specifications limits shown in figure 4.1. The first gradation trial goes near to the upper limit, the second gradation trial goes as a middle gradation between upper and lower limits, and third gradation trial goes near to the lower limits as all shown in table 4.10 and its graphical representation shown in figure 4.2, 4.3, and 4.4 respectfully.

Table 4.10 MORTH specification limits and gradation trials

Sieves, mm	Upper limit specifications	Lower limit specifications	Upper gradation trail	Upper gradation trail	upper gradation rail
26.50	100.00	100.00	100.00	100.00	100.00
19.00	100.00	79.00	96.00	89.50	82.00
13.20	79.00	59.00	75.00	69.00	65.00
9.50	72.00	52.00	68.00	65.50	55.00
4.75	55.00	35.00	51.00	45.00	38.00
2.36	44.00	28.00	40.00	36.00	30.00
1.18	34.00	20.00	30.00	27.00	22.00
0.60	27.00	15.00	23.00	21.00	16.00
0.30	20.00	10.00	16.00	15.00	12.00
0.15	13.00	5.00	11.00	9.00	7.00
0.075	8.00	2.00	6.00	5.00	3.00

Super pave and MORTH data comparison

The comparison between Super pave and MORTH aggregate gradation is going to be presented on the basic Marshall criterion that is obtained from the tests carried on MORTH and Super pave specimens as shown in the previous sections.

Stability

It is clearly to observe that the Superpave aggregate gradation is superior to MORTH gradation. As shown in table 5.1, that the minimum stability accepted by the MORTH specification is 900 kg. The MORTH gradation trails has introduced a bituminous mix with a stability of 16% higher than the mentioned specification, whereas the Superpave stability is 42%.

It can be seen that the stability obtained from the Superpave gradation tails is 26% higher than the one offered by MORTH gradation.

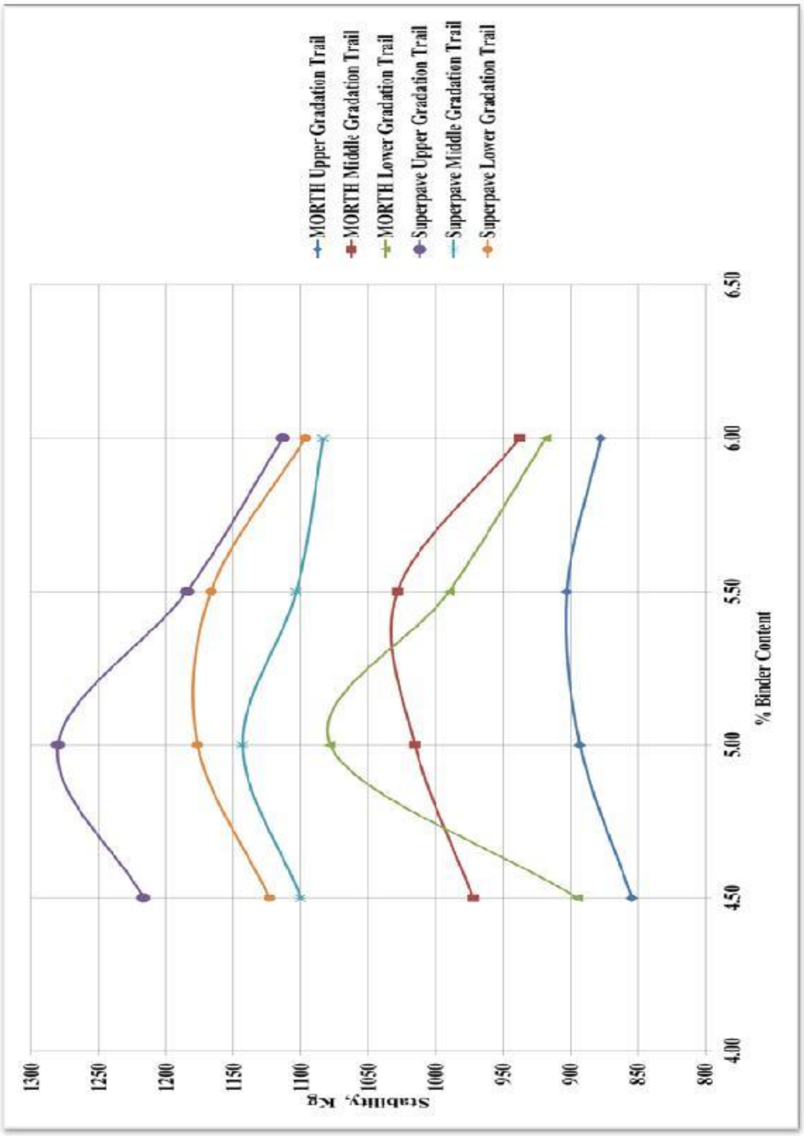

Figure Stability comparison of MORTH and Super pave Gradation

Flow

Super pave gradation trails as shown in figure 5.14 gave an ideal flow values that of (2-4) mm which is the optimum value that specified by MORTH and Asphalt Institute. Whereas the MORTH gradation trails has violated the specification by introducing some values above and below the specifications.

High flow values generally indicates plastic mix that will experience permanent deformation under traffic, whereas low flow values may indicate a mix with higher than normal voids and insufficient asphalt for durability and one that may experience premature cracking due to mixture brittleness during the life of the pavement.

Air Voids

Superpave upper gradation trail and MORTH lower gradation trail gave an ideal air voids values compared to the other gradation trials as shown in figure 5.15. It is important to consider that high air voids value will fasten the aging of the asphalt mix and reduce its durability. The air voids values offered by both gradation trails considered safe and provide a flexible durable mix.

Voids in the Mineral Aggregate – VMA

It has been observed that all the gradation trails produced a VMA values is higher than the specifications because the aggregate used is obtained from 3 stage crusher which uses the Vertical Shaft Impacter (VSI) technique that produce cubical aggregate shape with good surface texture. The Superpave upper gradation trail was closing near to the specified values which can be taken as the best curve that can be used for the bituminous mixture as shown in figure 5.16.

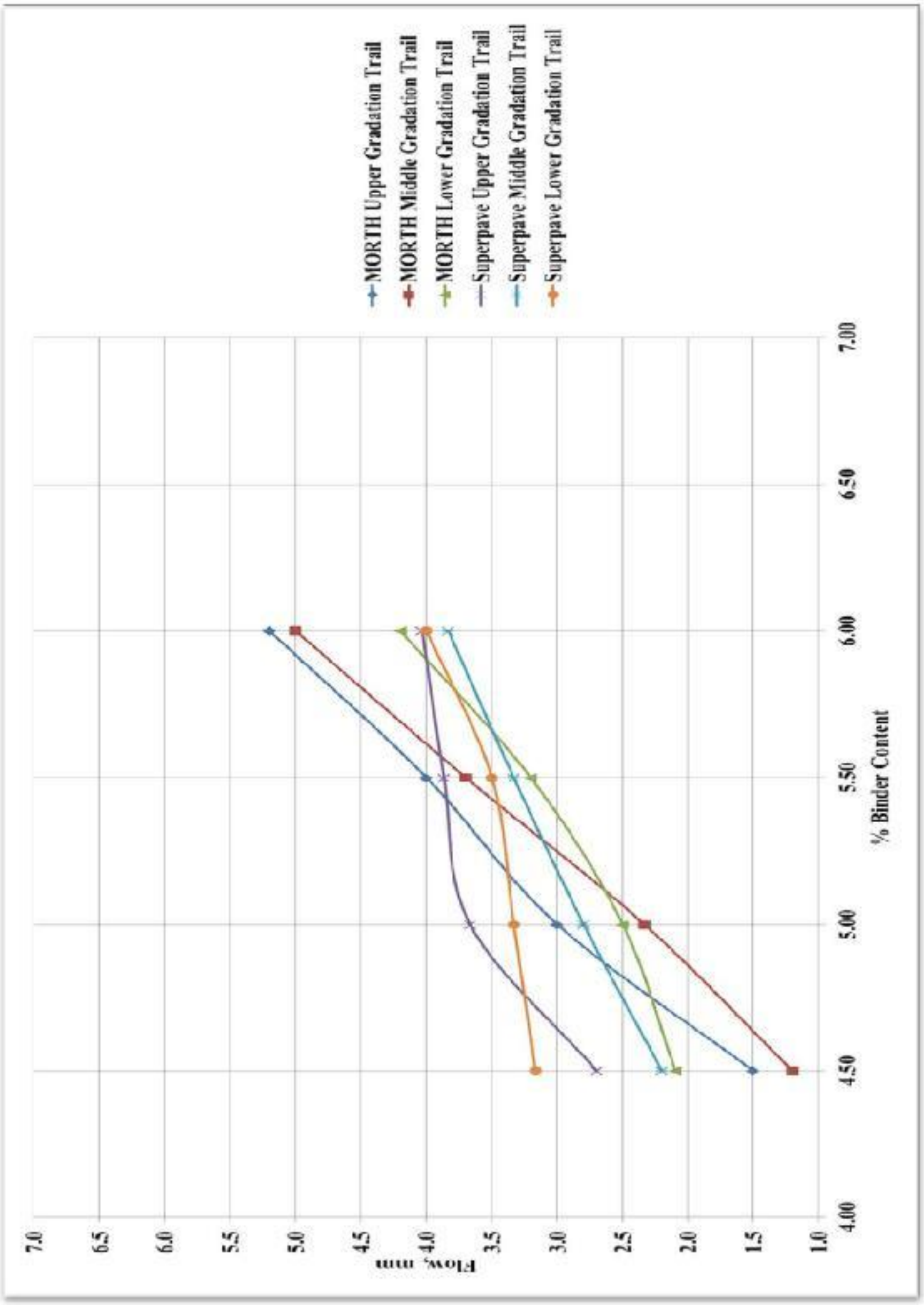

Figure Flow Comparison of MORTH and Super pave Gradation

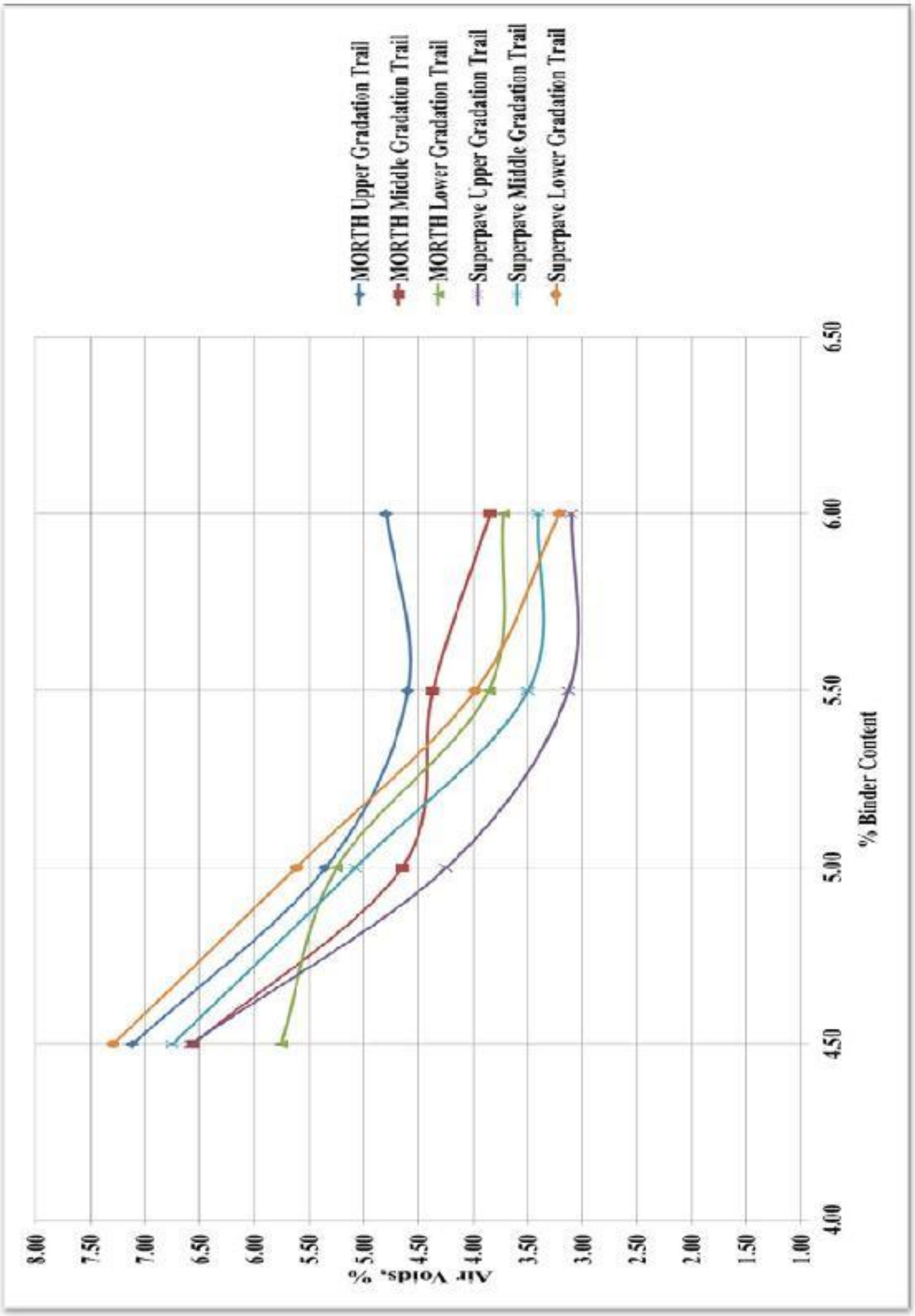

Figure Air Voids comparison of Super pave and MORTH Gradation

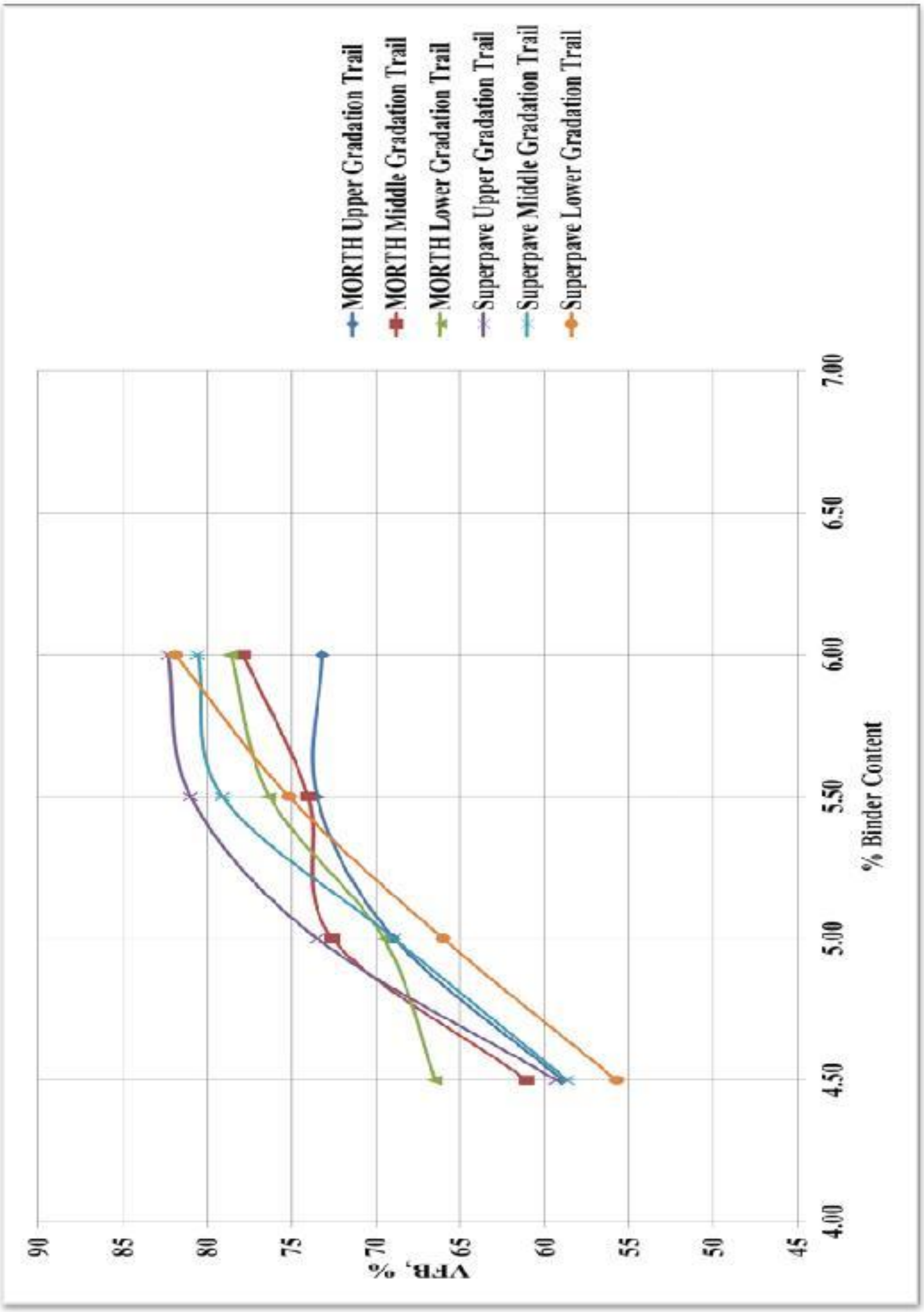

Fig VFA comparison of Super pave and MORTH Gradation

Voids filled with Asphalt – VFA

By considering both specifications of MORTH and Asphalt Institute, both gradation trails shown reasonable values that provide durability to the asphalt mixture and keep the aggregate particles covered with asphalt film that reduce oxidation and prevent water to penetrate and adversely effect on the tensile strength of the mix. Figure 5.17 present MORTH and Superpave VFA comparison.

Optimum Binder Content – OBC

Super pave showed its superiority to the MORTH gradation trials by offering better results with less binder content consumption. It can be observed from the figure below that the Super pave upper gradation trial is using the least binder content of approximately 7% which can be taken as an economical advantage that is considered superior to other

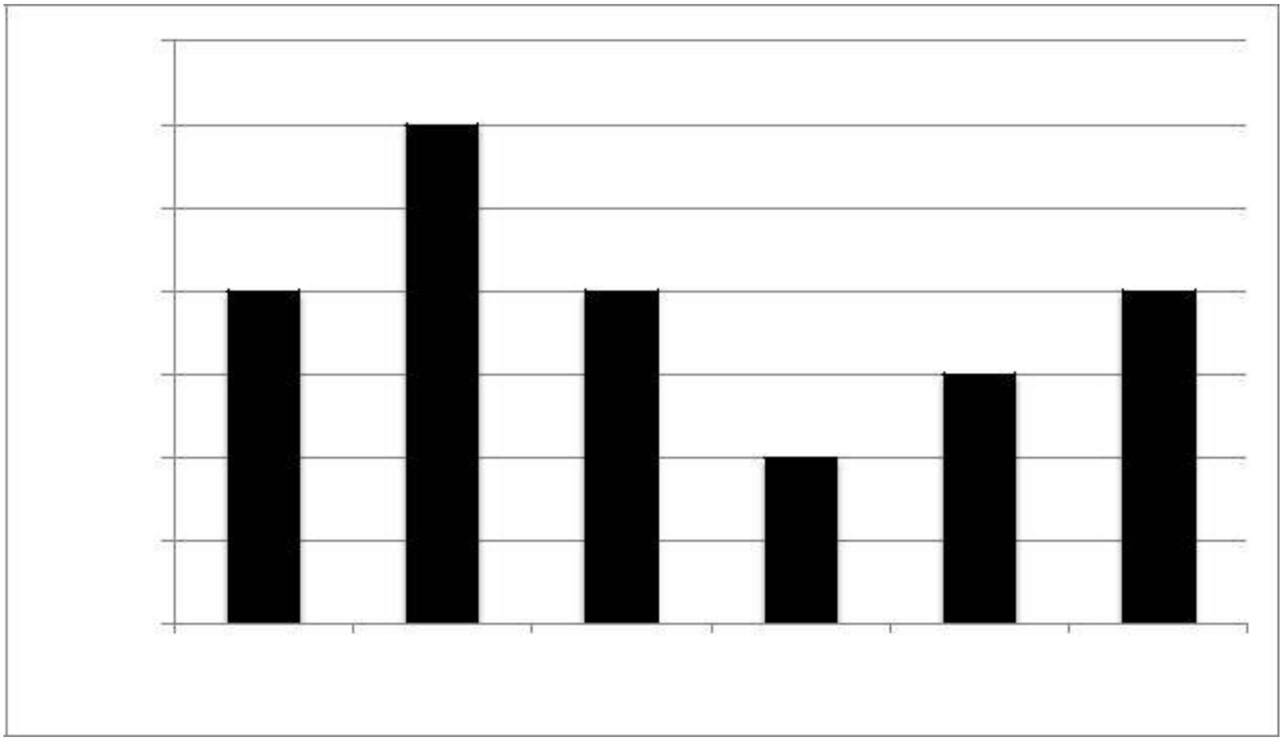

Figure optimum binder content comparison of super pave and MORTH gradation

VII. CONCLUSION

Based on the laboratory effort and experimental analysis of MORTH and superpave gradation data, the following conclusions were made:

- The Super pave aggregate gradation found superior to the MORTH aggregate gradation in all the aspects, such as Stability, Air voids, Density, VMA, VFB, Flow, and optimum binder content.
- MORTH lower gradation trial present the best results compared to the upper and middle gradations trials.
- The Super pave Upper Gradation trial is the golden gradation for which it shows the best results in all the Marshall criteria.
- The Super pave gradation can be considered as more economical than the MORTH gradation for many reasons like, resistance to heavy traffic loads and hence less maintenance cost, less binder content consumption, obedience for specifications, and offering better performance with long life roads.
- The VMA value found high in all the aggregate gradations because the it were obtained from 3 stage crusher which uses the Vertical Shaft Imparter (VSI) technique that produce cubical aggregate shape with good surface texture
- The area of asphalt mixture design is a versatile research platform that is evolving as traffic levels and vehicle design is constantly changing. Super pave design method and aggregate gradation is recommended for roads of high traffic volumes for its positive results shown by many researches including this thesis.

REFERENCES

1. *The Asphalt Institute. (2007). The Asphalt Handbook: MS-4, 7th Ed., The Asphalt Institute, Lexington, KY.*
2. *Federal Highway Administration. (1978–1983). Demonstration Project 39—Asphalt Recycling, Federal Highway Administration, Washington, DC. Obtained from: accessed January 6, 2011.*
3. *National Cooperative Highway Research Program. (1978). NCHRP Program Synthesis of Highway Practice No. 54: Recycling Materials for Highways, Transportation Research Board, Washington, DC.*
4. *Epps, J.A., Little, D.N., Holmgreen, R.J., and Terrel, R.L. (1980). Guidelines for Recycling Pavement Materials, NCHRP Report No. 224, Transportation Research Board, Washington, DC.*
5. *Sullivan, J. (1996). Pavement Recycling Executive Summary and Report, Report No. FHWA-SA-95-060, Federal Highway Administration, Washington, DC.*
6. *Kandhal, P. and Mallick, R.B. (1997). Pavement Recycling Guidelines for State and Local Governments—Participant's Reference Book, Report No. FHWA-SA-98-042, Federal Highway Administration, Washington, DC.*
7. *American Association of State Highway and Transportation Officials. (2010). "AASHTO T 319: Quantitative Extraction and Recovery of Asphalt Binder from Asphalt Mixtures," Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 30th Ed., AASHTO, Washington, DC.*
8. *American Association of State Highway and Transportation Officials. (2010). "AASHTO T 30: Mechanical Analysis of Extracted Aggregate," Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 30th Ed., AASHTO, Washington, DC.*
9. *American Society for Testing and Materials. (2006). "Standard D5821: Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate," ASTM International Book of Standards, ASTM International, West Conshohocken, PA.*
10. *American Association of State Highway and Transportation Officials. (2010). "AASHTO T 304: Uncompacted Void Content of Fine Aggregate," Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 30th Ed., AASHTO, Washington, DC*