INFLUENCE OF FILLERS ON PAVING GRADE BITUMEN

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For award of the Degree

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Submitted by

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CERTIFICATE

This is to Certify that the Project report entitled "INFLUENCE OF FILLERS ON PAVING GRADE BITUMEN", Submitted by "Ishfaq mohi ud din" in partial fulfilment of the requirement for the award of Masters Degree in Traffic and Transportation Engineering at Lovely Professional University, Phagwara, Punjab is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this project report has not been submitted to any other University/Institute for the award of any Degree.

Date: 29-04-2015

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Lastly I thank Almighty, my parents, friends and classmates for their constant encouragement without which this assignment would not be possible

Ishfaq Mohi Ud Din

DECLARATION

I hereby declare that the dissertation entitled, INFLUENCE OF FILLERS ON PAVING GRADE BITUMEN Submitted for the Masters Degree is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

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ABSTRACT

This study is about the effect of fillers on paving grade bitumen under various conditions. The basis of the thesis is to find out change in the physical properties of the bitumen by modifying it with different fillers. The types of fillers used in project are Cement, Fly ash and Stone dust. Fillers help in filling the voids and change the physical and chemical properties. Fillers modify the properties, increase the performance of, and provide improved Durability to various construction materials (Such as concrete and asphalt). The effects of fillers are therefore of vital importance. When bitumen is combined with filler, mastic is formed. This mastic can be viewed as the component of the asphalt mixture that binds the aggregates together and also the component of the asphalt that undergoes deformation when the pavement is stressed under traffic loading. The characteristics of the filler can significantly influence the properties of the mastic, and thus the filler properties can have significant effects on asphalt mixture performance. Different percentage of fillers is used to modify the bitumen. Various physical tests were conducted on Virgin and Modified Bitumen to evaluate its physical properties. Marshall Test was conducted on bituminous mix prepared using modified and Virgin Bitumen and the results were analysed and compared.

The study indicated that use of fillers improves the physical properties of Bitumen. Further it also indicated that use of fillers improves Marshall Stability and Flow in the bituminous mix.

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LIST OF ABBREVIATIONS

HMA	HOT MIX ASPHALT
DGBM	DENSE GRADED BITUMINOUS MACADEM
MORT&H	MINSTRY OF ROAD TRANSPORT AND HIGHWAYS
OBC	OPTIMUM BITUMEN CONTENT
VA	AIR VOIDS
VMA	VOIDS IN MINERAL AGGREGATES
VFB	VOIDS FILLED WITH BITUMEN

Chapter 1

INTRODUCTION

1.1 General

Pavement is a durable coating laid in the targeted area to support vehicles or pedestrians. In the past, widespread use of cobblestones and granite was made, but now these surfaces are mostly replaced by asphalt or concrete. Road surfaces are regularly marked to guide vehicular traffic. Fillers modify the properties, accelerate the performance, and offer greater durability to composites, polymers, rubber, adhesives, coatings and building materials (such as concrete and asphalt). Fillers are used to reduce the cost of materials, increase the stiffness and provide special features to a material (such as colour or fireproof). The effects of fillers are therefore crucial

Typical fillers are fine powders having particle size less than 75µm. Fillers can be naturally occurring like calcium carbonate, manufactured or derived from industrial waste such as fly ash from power plant. Other conventional fillers include silica, kaolin, mica, and silica materials. Fillers modify the system in two ways. Firstly, the manner in which shape, particle size and the size distribution of the particles of the filler affect the system by filling the liquid with solid particles. Secondly, the way that the interactions between the solid and liquid phase of the mixture meets the material. Second interactions may vary by strong chemical bonds or physical interactions leading reinforced materials strength. Asphalt is a vital building material. Most of the roads are built or paved with asphalt. In 2003, about 300 million tons of asphalt was produced in Europe and 500 million tons in the United States (EAPA, 2004). The effect of repeated stress manifests itself in two ways, permanent deformation, commonly known as "rutting" and "cracking", due to fatigue of asphalt.

The asphalt is composed of three major components; aggregates, binder and fillers. The relationship between these different components leads to a family of asphalt mixtures with different properties. HMA typically includes a proportion of air, which is often regarded as the fourth component. Minimizing the amount of air through the proper design and a proper compaction is essential to ensure a durable product. Furthermore, very little air, caused by overfilling aggregate structure can lead to rutting. The most commonly used filler in asphalt is limestone (Kavussi and Hicks (1997)), which is derived from microorganisms during the formation of the crust. Limestone is the general term for the rocks in which the form of calcite is predominant mineral. Limestone may also contain a proportion of magnesium carbonate, silica, clays, iron oxides and organic matter. Basically, gaps/voids are measured in the air and do not take into account the interactions between bitumen and filler. Charge interactions in the different types of bitumen can lead to changes in different ways. The filler may cause variations in the viscosity of the liquid phase as a result of the restructuring, changes or other physical effects.

Fillers are used in the design of bituminous mixes as a cost effective proportion in mixture having the following properties

Durability: The mix should provide adequate durability as a paved road, where it must not suffer excessive aging and hardening during production and service period.

Stability: The mix must provide sufficient stability under traffic loading through its service life. The stability of a mixture under traffic load is the amount of resistance to deformation. This is achieved by selecting good quality of aggregates with proper gradation and selecting optimum asphalt content with proper filler.

Fatigue resistance: The mix, as a paved road, must resist cracking effects that may induced due to repeated traffic loading over time. Excessive amount of mineral fillers will tend to increase the stiffness of the mixture, and hence, decreases the resistance to fatigue cracking.

Air voids content: There must be sufficient voids in the total compacted mix to allow for a slight amount of additional compaction under traffic loading and a slight amount of asphalt expansion due to increase in temperature without flushing, bleeding and loss of stability.

Workability: The mix must be capable to provide sufficient workability and hence permit efficient placement and compaction of the mix with reasonable effort without segregation, sacrificing stability and performance

The performance of bituminous surfaced roads is directly affected by the proportion and quality of ingredient materials in the mixture. The mix design has been a major concern where various studies were conducted. These studies revealed that certain modifications in the mixture such as changing the type, size and gradation of aggregates, varying the filler to asphalt ratio, type and amount of filler alter the properties of mixes.

1.2 Different type of fillers:

Figure 1.21 Cement

Figure 1.22 Brick dust

Figure 1.23 Lime

Figure 1.24   Stone dust

1.3 Need of the study:

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well as reliable performance of the in-service highway can be achieved. Two things are of major considerations in this regard pavement design and mix design. This laboratory investigation emphasizes on the mix design considerations. A good design of mix is expected to result in a mix which is adequately strong, durable and resistive to fatigue and permanent deformation and at the same time environment friendly and economical.

An attempt has been made in this investigation to assess the influence of fillers such as fly ash and stone dust in bitumen paving mixes. It has been observed as a result of this project that bituminous mixes with these fillers increases the Marshall properties, thus substantiating the need for its use. The fillers used in this investigation are likely to partly solve the solid waste disposal of the environment.

1.4 Objectives of the study:

The primary objectives of the present study are

To evaluate the properties of bitumen with different types of fillers as admixture.

To compare the performance of HMA mix with varying percentage of different filler content

1.5 Organization of thesis:

The whole thesis is divided into 6 chapters:

Chapter 1: This chapter deals with the introduction of thesis, need and objectives of the study.

Chapter 2: This chapter discusses the summary of literature review.

Chapter 3: This chapter deals about research methodology. It considers the path through which research will be carried out.

Chapter 4: This chapter deals about materials, equipments and experimental setup that are used in the conduction of various experimental works.

Chapter 5: This chapter deals with the results and discussion. The results obtained and their influence will be discussed.

Chapter 6: This chapter discusses about the conclusion drawn from the present investigation. This chapter also covers the future scope.

Chapter 2

REVIEW OF LITERATURE

2.1 General

Asphalt is an essential building material. Most of the roads are built of asphalt. Furthermore, asphalt mixtures are designed to minimize the effects of water in the system, both having relatively dense mixture and impervious to moisture, for example in the case of asphaltic concrete, or by adding sufficient bitumen mixture to provide a thick layer of bitumen on the aggregate (referred to as " bitumen film "). Road surfaces are generally built in layers; with each layer of pavement serve a slightly different function. The layers of the road surface are subjected to the highest stresses in the pavement that are in direct contact with the vehicle's tyres and also the surface is exposed to the elements resulting in the surface of pavement to reach higher temperatures and are subject to higher stresses.

Normally the top layer is made from high quality components and requires excellent resistance to permanent deformation. This top layer of pavement provides the smooth surface for vehicles; therefore, the riding quality and creep resistance are key properties of this layer. Under the top layer is greater structural layer of the road. This layer, referred as the "base" is designed to distribute the load of the vehicle to a level that can be supported from the floor of the platform of the road, which is usually built of aggregates consisting of natural soil conditions. The asphalt mixture is composed of three major components; aggregates, binder and fillers. The air is present in asphalt mixtures in varying degree. Different proportions between these components give rise to family of asphalt mixtures with different properties.

An aggregate for use in asphalt must possess several key properties:

• The hardness, toughness

• Abrasion resistance

• Resistance to polishing to provide the resistance to dragging (for aggregates surface)

• Durability compared to salts of freezing and thawing action used in road surfaces

• Good affinity with bitumen

2.2 Effect of fillers on asphalt:

John Francis Mclaughlin and William Harner Goetz (1957) did investigation on use of fly ash as filler for bituminous concrete. They divided the whole study into three stages. In the first part, comparison of fly ash and stone dust fillers was made by means of Marshall Technique. The second and last stage involved the application of ASTM direct compression test. The conclusion that was drawn from the investigation is as under:

Those mixtures having fly ash as a filler are having adequate stability as was concluded through Marshall Test.

Stripping resistance of fly ash mixtures as measured by ASTM D-1075 compared similar as to results obtained from mixtures containing stone dust as filler.

American Coal Ash Association (2003) in their research observed that fly ash can be used as cost effective in paving applications. Fly ash also helps in reducing potential for asphalt stripping due to its hydrophobic nature.

United States Environmental Protection Agency (EPA 2005) suggested that fly ash can be used as additive in pavements. These additives increase the stiffness of asphalt mix, improve rutting resistance of pavements and also improve the durability of the mix.

Other benefits of using fly ash in pavements include:

Reduced potential for asphalt stripping

Reduced cost as compared to other mineral fillers

J. Alam and M. N Akhtar (2011) during their analysis of lime in construction of road observed that lime has good potential in the application of highways. Its low specific gravity, smooth draining nature, ease during compaction, insensitiveness towards change in moisture and better frictional properties can be successfully exploited in construction of roads.

M. Jovanovich, A. Mujkanovic and A. Seper (2011) in their study devolved samples of bituminous aggregate mixtures having fly ash, cement and lime as a filler with varying percentage of bitumen. After preparing various samples, laboratory investigation was done. The following results were observed:

Fly ash as a filler can be used in asphalt mixtures successfully.

With the addition of filler, optimum bitumen content was observed to be lower in mixtures

For flexible pavements, lower proportion of optimum moisture content is considered better. It leads to fewer voids in sub grade. Thus with the usage of pavement, there will be less settlement.

Konstantin Sobolev, Ismael Flores and Justin David Bohler (2013) determined the feasibility of fillers in asphalt concrete was determined. Two different binders were used. These binders were fully blended with filler materials i.e. fly ash, lime and cement .The study result demonstrated that:

Rheological properties of the asphalt were greatly improved with the addition of these fillers.

Fly ash also appears in improving the aging resistance of mastics

With the addition of fillers, compatibility of mixtures was not affected.

RESEARCH METHODOLOGY

This research consists of three stages: characterizing the material, designing mixtures for the three different fillers and suitability of fillers in the bituminous mixtures. In the first step, properties of bitumen, fillers and aggregates were established while in second step, optimum bitumen content for each of these mixtures was determined according to Marshall Mix design method, and in the third level, suitability of Different fillers was evaluated.

3.1 Asphalt binder:

Asphalt used in the study is of penetration grade 60/70, since it is used to a great extent and is good enough to temperature condition. It was purchased from the local distributor. Several tests have been conducted in laboratory to evaluate the physical properties of Asphalt Binder.

Table 3.1: The table shows different standard values as per BIS, IS: 73-2006

Tests	Standard values
Penetration test	60-80 (1/10 mm)
Specific gravity	1.03-1.06
Ductility	Minimum 75 cm

3.2 Fillers:

Three different types of fillers were selected in this study. These are stone dust, cement and fly ash. Cement was bought from the local distributor of the ACC plant, Phagwara. Lime and fly ash was brought from various local sources. The filler material is screened by No. 200 sieve. Specific Gravity of the stone dust, lime and fly ash was calculated and noted down.

3.3 Aggregates:

In combination to the binder, and mineral fillers used in Marshall Technique, crushed stone will be used in the preparation of bituminous mixture samples. Aggregate having desirable properties such as strength, hardness, toughness, specific gravity and shape is selected. The determination of physical properties of aggregates is done by performing various tests. The coarse aggregates and fine aggregates are isolated into different screen sizes. Aggregates are sieved, examined and recombined in laboratory to meet the specific gradation

3.4 Marshall Mix Designs:

Marshall Stability test is performed to determine the optimum bitumen content and the test samples shall be prepared by combining varying percentages of bitumen ranging from 4.5% by the weight of aggregates to 6.5% with an increase of 0.5 % for each type of fillers. The Specimen preparation, compaction and testing will take place according to Marshall Mix Design Method. Marshall Stability and Flow Tests are conducted on each sample. The bulk specific gravity, density, and percent air voids will be determined for each sample.

Chapter 4

MATERIALS, EQUIPMENTS AND EXPERIMENTAL SETUP

4.1 Bitumen:

Conventional bitumen grade VG 30 is used in the present laboratory work. The various specifications of the bitumen as per IRC guidelines are listed below:

Table 4.1: Physical requirements of bitumen for dense graded bituminous macadam (as per IRC: 73-2006)

Test	Specifications
Penetration (25°c / 100gm / 5sec)	60-70
Ductility (cm)	Not less than 75
Specific gravity (at 27°c)	More than 0.99

4.2 Coarse aggregates:

Coarse aggregates comprise of crushed stones, crushed gravel or any other hard material retained by the sieve of 2.36 mm. The aggregates should be clean, hard, and durable so that they will form a good sample. The aggregates must meet the physical requirements specified in Table 4.2.

Table 4.2: Physical requirements for coarse aggregate for dense graded bituminous macadam as per IRC guidelines

PROPERTY	TEST	SPECIFICATION
Measure of strength or quality of material	Specific gravity	2.5-3.2(average 2.70)
Strength	Aggregate impact value test	Max 27%
Resistance to crushing	Aggregate crushing value test	Max 30%
Water absorption	Water absorption test	Max 2%

4.3 Fine aggregates:

Fine aggregates comprise of natural or crushed material or may be combination of the two. The fine aggregate passes the 2.36 mm sieve and is retained on a 75 micron. Aggregates should be free from dust and should possess adequate hardness and durability. Fine aggregate should have a sand equivalent not less than 50 when tested according to the requirement of IS: 2720 (Part 3).

4.4 Filler:

The Filler materials used in the project are stone dust, fly ash and cement. The filler shall be graded within the limits indicated in Table 4.4

Table 4.4: Grading requirements for mineral filler as per IRC guidelines.

IS Sieve (mm)	Cumulative per cent passing by weight of total aggregate
0.6	100
0.3	95-100
0.075	85 – 100

The filler should not contain organic impurities and should possess Plasticity Index not greater than 4. The Plasticity Index criteria will not apply if filler is cement or lime.

4.5 Aggregate Gradation:

4.5.1 Gradation:

For the preparation of bituminous mixes, aggregate gradation is done according to the MORT&H specifications. Gradation should be within the limits as per MORT&H. The sieves are arranged with one another according to the size. About 2.5 to 3kg of aggregates are then sieved through various sizes. The percent passing through each sieve is observed. When tested, the combined grading of coarse and fine aggregates and for the specific mixture shall be within the limits as shown in table 4.5, for dense bituminous macadam as specified.

Table 4.5: Composition of dense graded bituminous macadam as per MORT&H specifications

Nominal aggregate size	20 mm
IS Sieve[1] (mm)	Cumulative % by weight of total
37.5	100
26.5	90-100
19	71 – 95
13.2	56 – 80
9.5	
4.75	38 – 54
2.36	28 – 42
1.18	-
0.6	-
0.3	7 – 21
0.15	-
0.075	2 – 8
Bitumen content %	
Bitumen grade (pen)	65 or 90

The aggregates used in the tests are of sizes 6 mm, 10 mm and 20 mm and fine aggregate as sand. Cement, lime and fly ash will be used as the fillers. Bitumen grade used will be VG-30.

4.6 Physical properties of aggregates:

4.6.1 Aggregate impact test:

Impact test is designed to determine the toughness or the resistance of aggregates under repeated use of impact breakdown. The total impact test apparatus and the procedure is standardized by the Bureau of Indian Standards (BIS) .The device consists of impact test machine , a cylindrical measure, tamping rod , IS test sieves , balance and oven .Survey sample consists of aggregates passing 12.5 mm test sieve and retained on 10 mm. The sample is witnessed to total of 15 blows of the hammer. Crushed aggregate is then sieved on the 2.36 mm.

Aggregate impact value (AIV) = 100W2/W1

Where W1 is the weight of aggregate

W2 is the weight of aggregates passing through 2.36 mm sieve

Figure 4.6.1: Impact testing machine

4.6.2 Aggregate crushing test:

Coarse aggregates used in road construction must be strong enough to withstand crushing during compaction rollers, and because of the heavy vehicle traffic. Samples of dry cleaner aggregates passing through a sieve of 12.5 mm and held on 10 mm sieve are used . Load is applied at a uniform rate of 4.0 tons per minute until the total load is 40 tons and after this, it is released. The crushed aggregates are removed from the cylinder and sieved on the 2.36 mm sieve

Aggregate crushing value = 100W2/W1

Where W1 is the weight of aggregates

W2 is the weight of crushed material passing through 2.36 mm sieve

Figure 4.6.2 : Aggregate crushing test machine

4.6.3 Specific gravity and water absorption test:

The specific gravity of a aggregate is regarded as a measure of the strength or the quality of the material. The specific gravity value of aggregates is used for the calculation of the void content in compacted bituminous mixtures. Water Absorption provides an idea about strength of the rock. With more water absorption, stones are more porous in nature and are not suitable.

specific gravity = dry weight of aggregate/weight of equal volume of water

specific gravity = W4/(W3-WS)

Where W4 is the weight of oven dried aggregates

W3 is the weight of saturated surface dry aggregate in air

WS is the weight of saturated aggregate in water

Water absorption = percent weight of water absorbed in terms dried weight of aggregates

= (W3-W4)/W4

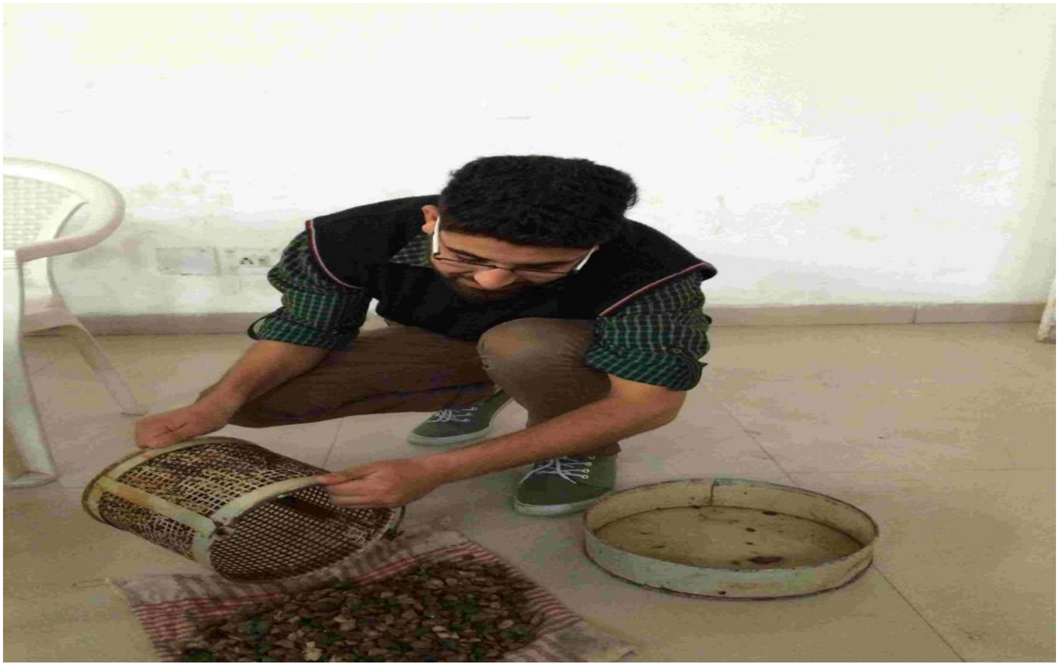

Figure 4.6.3: Wire basket for Specific gravity test

4.7 Physical properties of bitumen:

4.7.1 Penetration Test:

This test is done according to the ASTM D5. The test is mainly used for classifying bitumen into various grades. This provides a measure of consistency or hardness of bitumen. The penetration test consists of a needle with specified dimensions and is allowed to penetrate a specimen of bitumen under a standard load (100 g) for a given time (5 sec) at 25° temperature. The penetration is defined as the vertical depth to which a needle will penetrate under given set of conditions. The lower the penetration value, harder will be the bitumen and vice versa

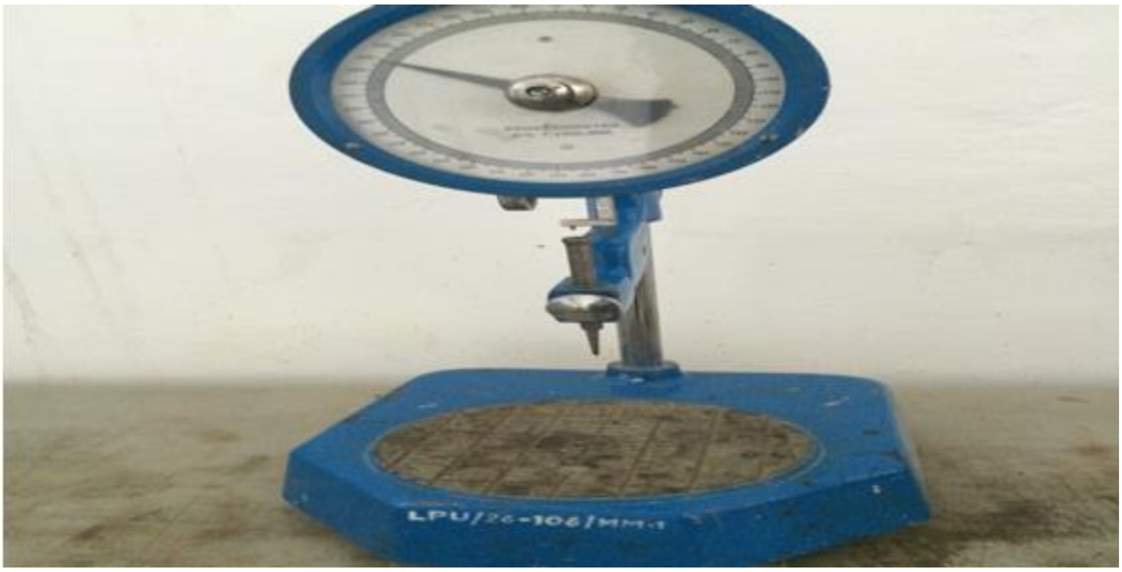

Fig 4.7.1 Penetration Testing Machine

4.7.2 Ductility Test:

This test is done according to IS 1208-1978 specifications. Ductility test is an empirical test which gives measure about the cohesive strength of bitumen. In this test, a standard size of bitumen is pulled at a constant rate at constant temperature. The ductility value is defined as the distance in centimetres to which a standard briquette can be stretched before thread breaks. The test is performed at 27 ± 0.5° with a rate of pull of 50± 2.5 mm per min. Material with higher ductility value is more likely to withstand loading and unloading in better way.

4.8 Test on bituminous mixes:

4.8.1 Determination of optimum bitumen content:

4.8.2 Marshall Test: This test is performed to determine the stability of bituminous mixtures according to ASTM D 1559. In this test, load is applied at the rate of 51mm per minute and resistance to plastic deformation of bituminous mixtures is determined. There are two important features of the Marshall technique namely

Density – void analysis

Stability – flow tests

Marshall Stability of mixture is defined as the maximum load carried by the compacted specimen at a standard temperature of 60°. Flow is defined as the deformation of the specimen under maximum load. The coarse aggregates, fine aggregates and the filler material are proportioned and mixed in such a way that the final gradation of the mixture is within the range specified for the desired type of bituminous mix. The aggregate and filler are mixed together in the desired proportion to fulfil the design requirements. The required quantity of the mineral aggregate mix is weighed and taken so as to produce a compacted bituminous mix specimen of thickness 63.5 mm approximately

Approximately 1200 g of the aggregates and filler mix is taken, weighed correctly and heated to a temperature of 175° to 190°c. The compaction mould assembly and rammer are cleaned and kept pre-heated at a temperature of 195° to 150°c. The bitumen binder is heated to a temperature of 120° to 165°. The mix is placed in the pre-heated mould and is compacted by the rammer at the specified temperature, by applying 75 blows on each side. The specimen is carefully extruded from the mould using specimen extractor.

Fig 4.8.2 Marshall Testing Machine

4.8.3 Requirement for the mixture:

Apart from conformity with the grading and quality requirements for individual ingredients, the mixture will meet the requirements set out in Table 4.6

Table 4.6: Requirements for dense graded bituminous macadam as per MORT&H

Stability (kN)	9.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (number of blows)	75 blows on each of the two faces
Percent air voids	3-6
Percent voids filled with bitumen	65-75

Fig 4.8.3 Marshall Samples

Chapter 5

RESULTS AND DISCUSSION

5.1 TESTS ON MATERIALS USED: This chapter describes the experimental works carried out.

5.1.1 GRADATION: For preparation of bituminous mixes, aggregate gradation is done according to the Morth specifications. The combined gradation should be within the limits as per Morth. The various sieves are put along one another according to the size. About 2.5 to 3kg of aggregates is taken and sieved through the various sizes. The percentage passing through each sieve is shown in Table 5.1

Table 5.1: percentage passing through each sieve

Is sieve (mm)	Size of aggregates (mm) (individual gradation)					Blending (Hit and trial method)					combined Gradation	Desired limits
	20	10	6	sand	filler	20	10	6	sand	filler		
						20%	22%	30%	25%	3%	100%	
26.5	80	100	100	100	100	16	22	30	25	3	96	90-100
19	38	100	100	100	100	7.6	22	30	25	3	87.6	71-95
13.2	12	80	92	100	100	2.4	17.6	27.6	25	3	75.6	56-80

9.5	5	30	82	100	100	1	6.6	24.6	25	3	60.2	40-65
4.75	0.8	10	40	100	100	0.16	2.2	12	25	3	42.36	38-54
2.36	0.2	3	25	80	100	0.04	0.66	7.5	20	3	31.2	28-42
0.3	-	0.7	10	38	100	-	0.154	3	9.5	3	15.654	7-21
0.075	-	0.54	0.3	12	26	-	0.1188	0.09	3	0.78	3.988	2-8

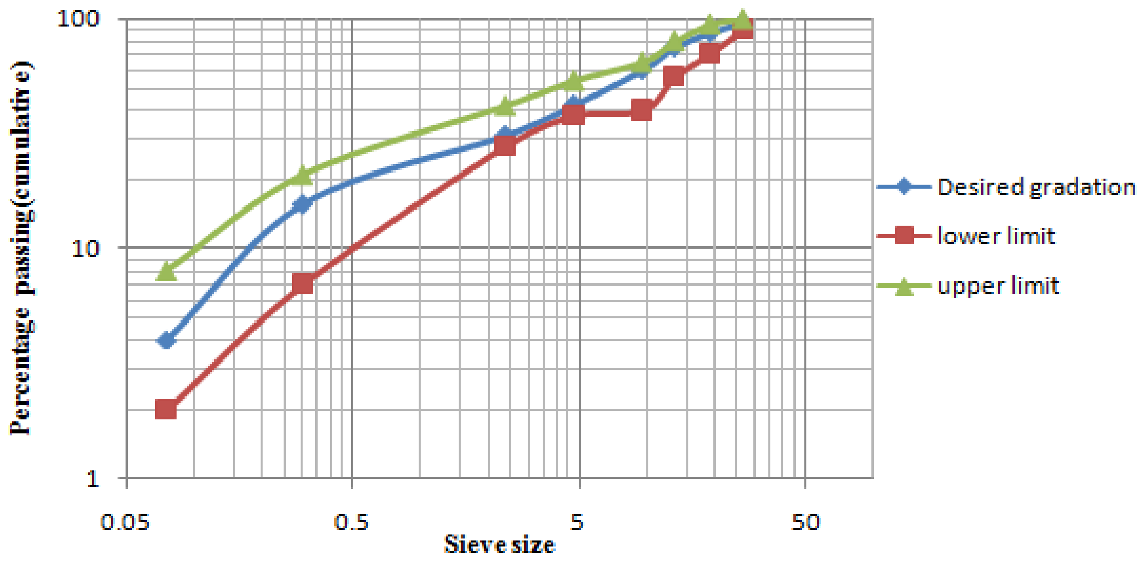

Figure 5.1,1: Gradation curves of aggregates

The figure shows the three types of curves each. The figure shows curves between sieve size and cumulative percentage passing through each sieve. Thus from the figure, it is clearly visible that the aggregates are well within the desired limits

5.1.2 Aggregate Tests:

Table 5.2: Different test results of aggregates and their limits

Aggregate Properties	Test results	Specified limits
Aggregate impact test (According to BIS)	11	< 30%
Aggregate crushing test (According to BIS)	21	< 30%
Water absorption test (According to MORT&H)	1.8	< 2%
Specific gravity test (According to MORT&H)	2.64	2.5-3.2

Thus the results obtained from tests carried out on aggregates are well within the specified range. The aggregates are strong/tough and have good crushing strength. The aggregates have low pores and thus are suitable for pavements

5.2 Tests on bitumen:

The bitumen was modified by adding optimum amount of fillers to the weight of bitumen used. The fillers was pre-heated by oven storage at 170° for 24 hrs to remove any moisture present.VG 30 grade of bitumen was heated to temperature of 150° before the filler is added and then each type of filler was blended for 15 min at constant temperature of 150° separately. The results of the tests are shown in Table 5.3

Table 5.3: Physical properties of VG 30 grade bitumen

Tests	Modified bitumen	Virgin bitumen
Penetration	45.2 mm	63.5 mm
Ductility	48 cm	78 cm
Specific gravity	1.08	1.04

The specific gravity of stone dust, lime and cement came out to be 2.12, 2.23, and 2.38 respectively.

5.3 Observations evaluated from Marshall Test without any filler:

Table 5.4: Marshall Characteristics of a mix using virgin bitumen

Bitumen Content (%)	Unit wt. (g/cc)	Air voids (%) (Va)	Voids filled with bitumen (VFB)%	Stability (kN)	Flow (mm)
4.5	2.361	5.58	65.38	9.21	2.13
5	2.38	4.46	72.31	10.4	2.25
5.5	2.391	4.12	75.04	10.8	2.52
6	2.364	3.3	78.03	11.3	2.78
6.5	2.352	2.83	82.42	9.82	3.03

5.3.1 Flow Value:

It is observed that flow value increases with increases in binder content. For Dense Bituminous Macadam (DBM), flow value should be within 2 to 4 mm. Variation of flow value at different binder content without any filler is shown in Figure 5.3.1

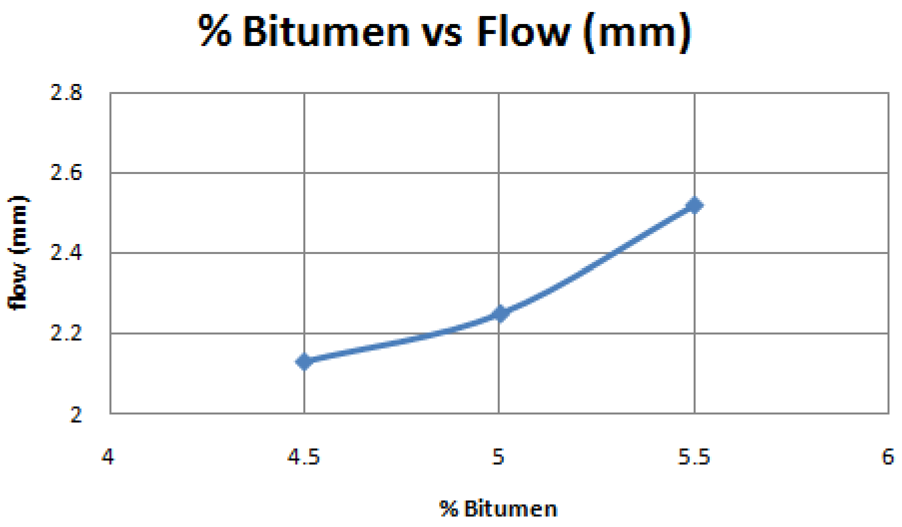

Figure 5.3.1: Marshall Flow with virgin bitumen

5.3.2 Air voids:

It is observed that with increase in binder content, air voids decreases. Variation of voids at different binder content without any filler is shown in Figure 5.3.2

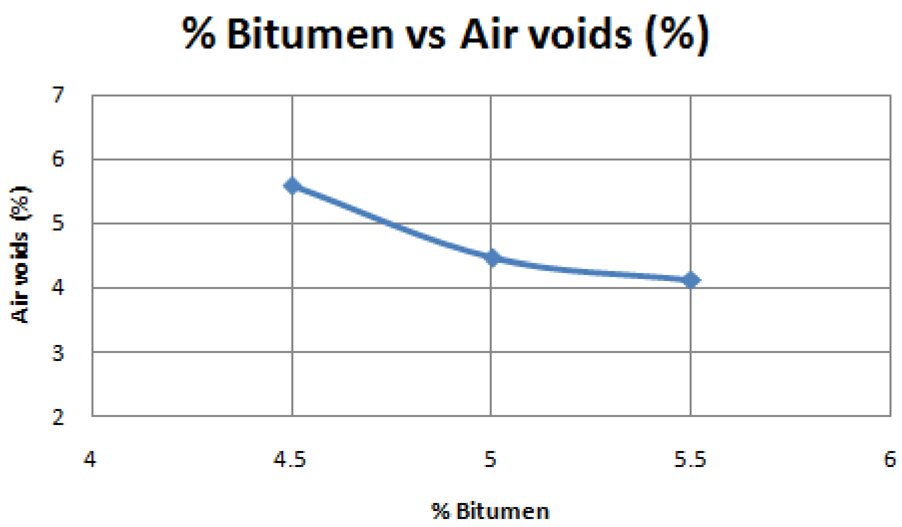

Figure 5.3.2: Percent Air voids in bituminous mix without filler

5.3.3 Unit weight:

It is observed that unit weight increases with increase in binder content upto certain binder content and after that it decreases. The optimum bitumen content is 5 (%). Variation of unit weight at different binder content without any filler is shown in Figure 5.3.3

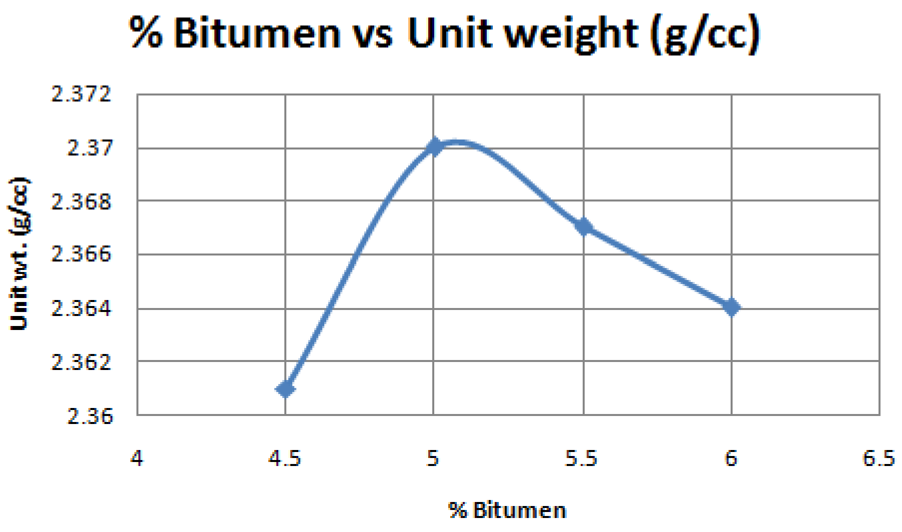

Figure 5.3.3: Unit weight of bituminous mix without filler

5.3.4 Stability:

It is observed that stability value increases with increase in binder content upto certain binder content and after that it starts decreasing. Variation of Marshall Stability at different binder content without any filler is shown in Figure 5.3.4

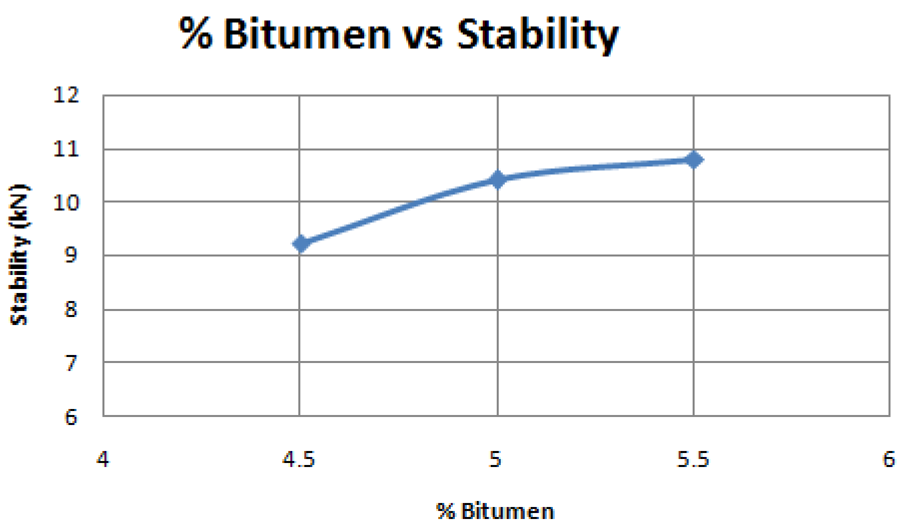

Figure 5.3.4: Marshall Stability value without filler

5.3.5 Voids filled with bitumen (VFB):

VFB increases with increase in binder content. Variation of binder content at different binder content without any filler is shown in Figure 5.3.5

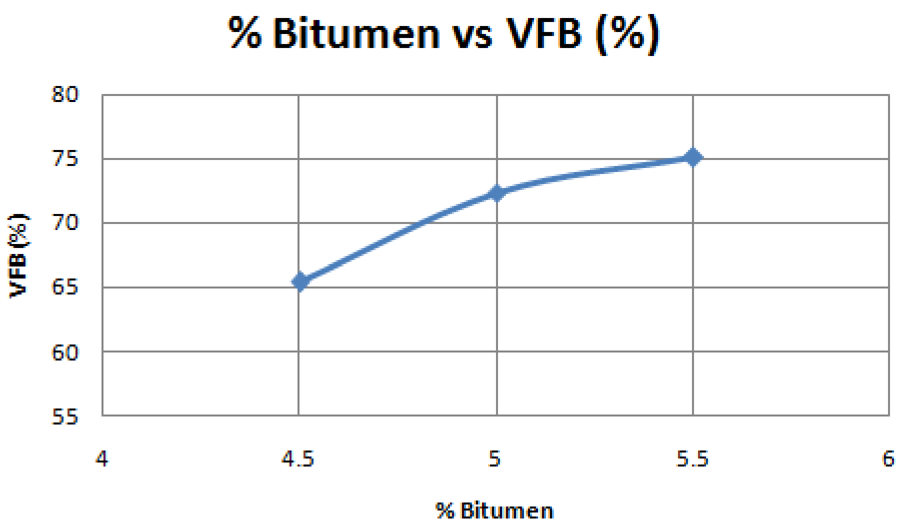

Figure 5.3.5: Percent voids filled with bitumen without filler

5.4 Observations evaluated from Marshall Test with cement as filler:

Table 5.5: Marshall Characteristics of a mix with cement as filler:

Bitumen content (%)	Unit wt. (g/cc)	Air void (%) (Vv)	Voids filled with bitumen(VFB) (%)	Stability (kN)	Flow (mm)
4.5	2.53	5.76	65.3	13.35	2.15
5	2.55	4.23	74	14.8	2.32
5.5	2.539	4	78	13.01	2.61
6	2.52	3.87	79.6	12.03	3.01
6.5	2.49	3.8	83.3	11.32	3.24

5.4.1 Flow value:

It is observed that flow value increases with increases in binder content. For Dense Bituminous Macadam (DBM), flow value should be within 2 to 4 mm. Variation of flow value with different fillers at different binder content is shown in Figure 5.4.1

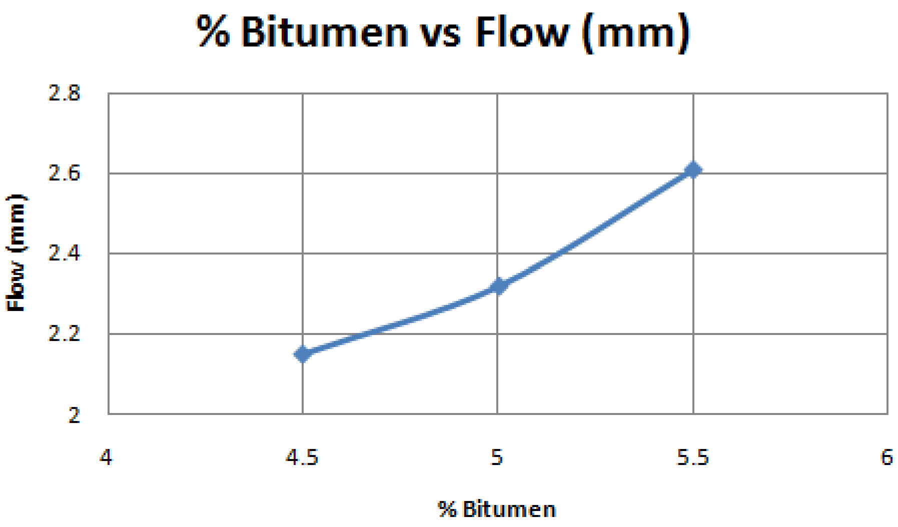

Figure 5.4.1: Marshall Flow value with cement as filler

5.4.2 Air voids:

It is observed that with increase in binder content, air voids decreases. Variation of voids with different fillers at different binder content is shown in Figure 5.4.2

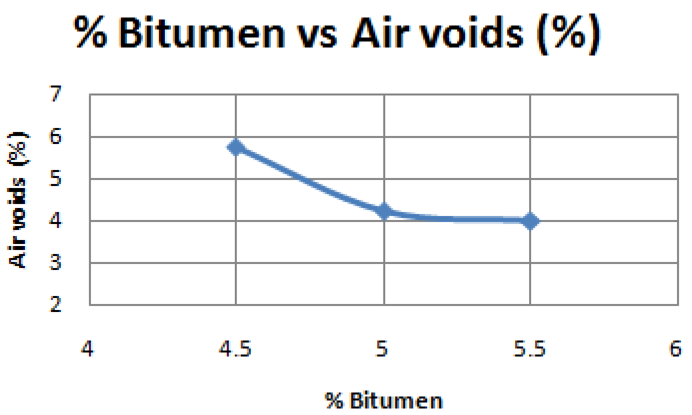

Figure 5.4.2: Percentage Air voids in Bituminous mix with cement as filler

5.4.3 Unit weight :

It is observed that unit weight increases with increase in binder content upto certain binder content and after that it decreases. The optimum bitumen content is 5 (%). Variation of unit weight with different fillers at different binder content is shown in Figure 5.4.3

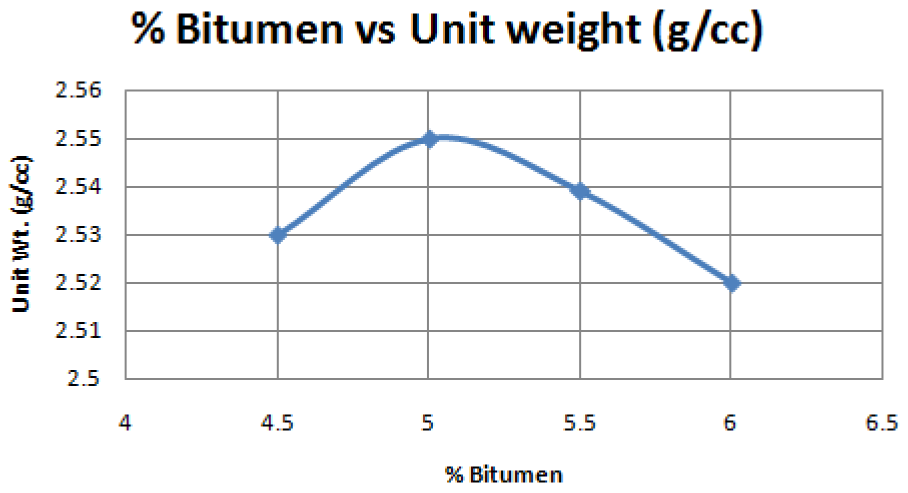

Figure 5.4.3: Unit weight of Bituminous mix with cement as filler

5.4.4 Marshall Stability:

It is observed that stability value increases with increase in binder content upto certain binder content and after that it starts decreasing. The optimum bitumen content is 5 (%). Variation of Marshall Stability with different fillers at different binder content is shown in Figure 5.4.4

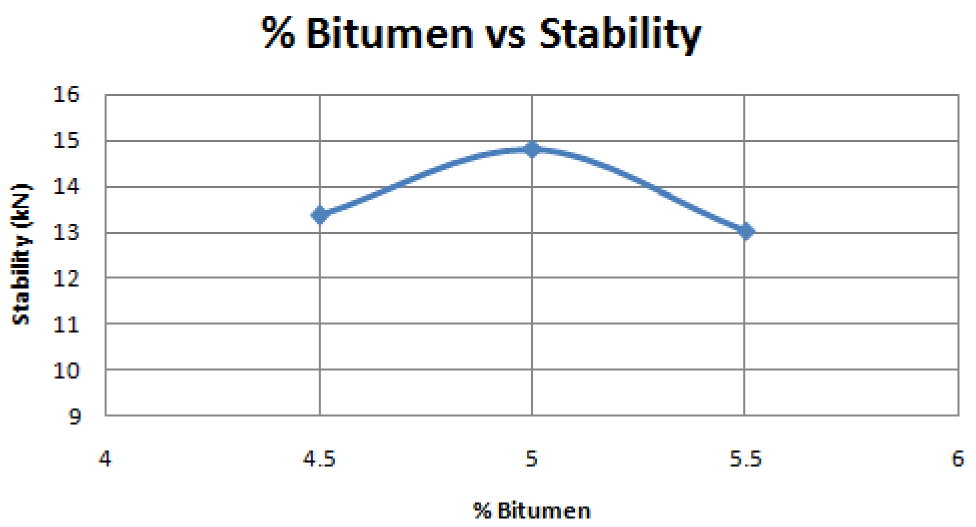

Figure 5.4.4: Marshall Stability value with cement as filler

5.4.5 Voids filled with bitumen (VFB):

VFB increases with increase in binder content. Variation of binder content with different fillers at different binder content is shown in Figure 5.4.5

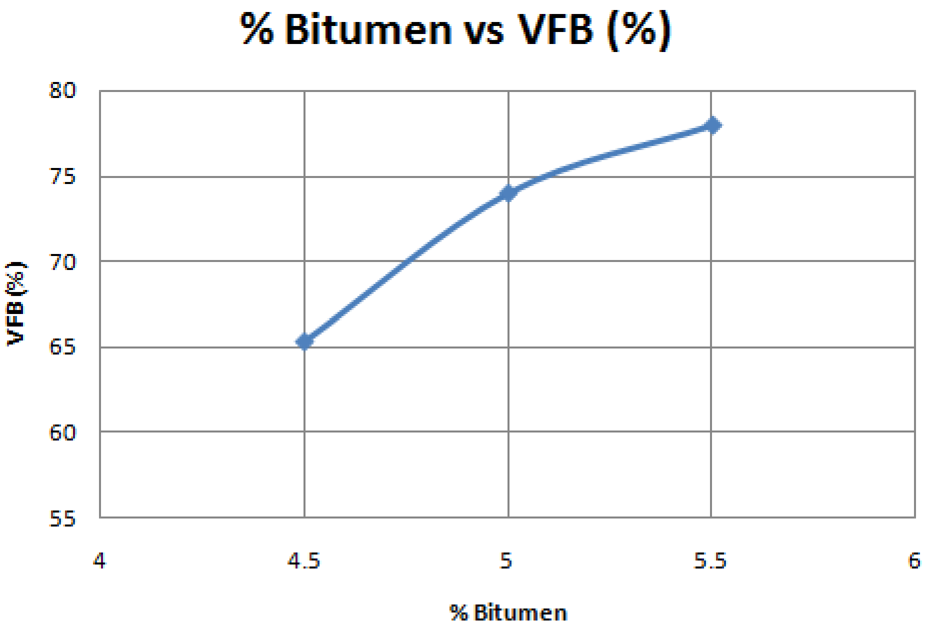

Figure 5.4.5: Percent Voids filled with Bitumen in mix with cement as filler

5.5 Observations evaluated from Marshall Test with fly ash as filler:

Table 5.6: Marshall Characteristics of mix with fly ash as filler:

Bitumen content (%)	Unit wt. (g/cc)	Air void (%) (Vv)	Voids filled with bitumen (VFB) (%)	Stability (kN)	Flow (mm)
4.5	2.48	4.62	72.02	13.03	3.23
5	2.495	3.21	79.6	14.31	3.36
5.5	2.471	3.06	82.06	12.62	3.58
6	2.468	2.6	85.07	11.59	3.76
6.5	2.461	2.45	87.03	10.32	3.88

5.5.1 Flow value:

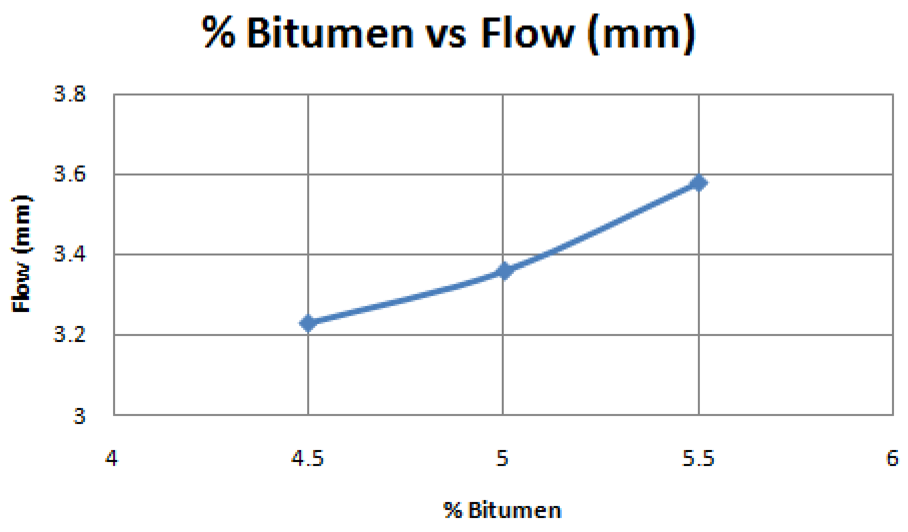

Figure 5.5.1: Marshall Flow value with Fly ash as filler

5.5.2 Air voids:

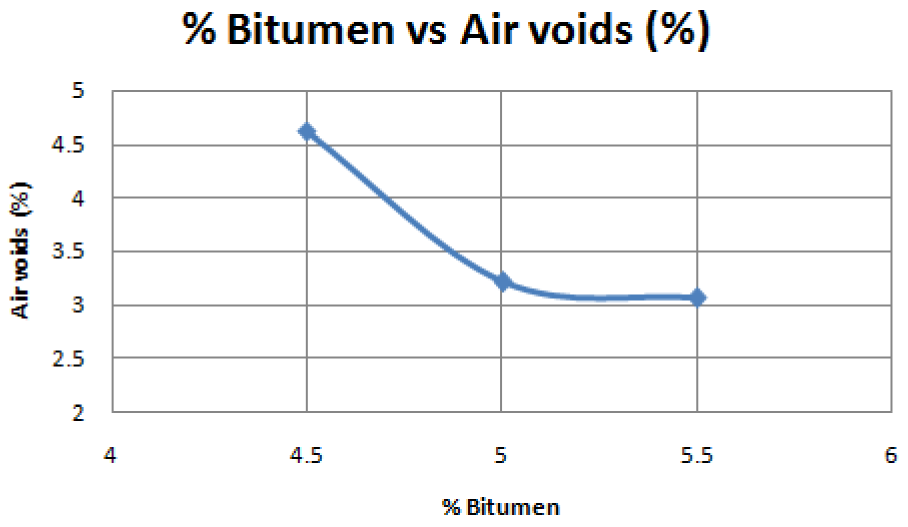

Figure 5.5.2: Percentage Air voids in Bituminous mix with Fly ash as filler

5.5.3 Unit weight:

The optimum bitumen content comes to be 5 (%), as maximun density is attained at this content.

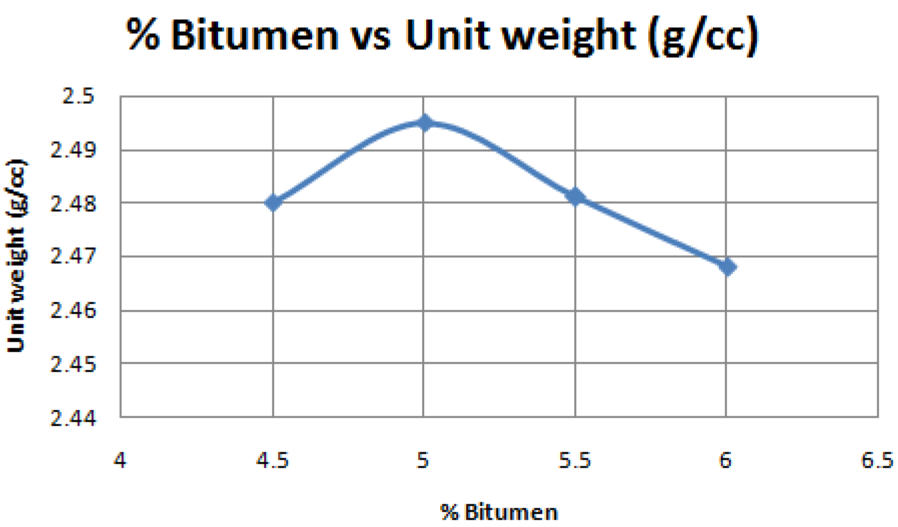

Figure 5.5.3: Unit weight of Bituminous mix with Fly ash as filler

5.5.4 Stability:

The maximum stability comes out at 5 (%) bitumen content. Thus optimum bitumen content is 5 (%).

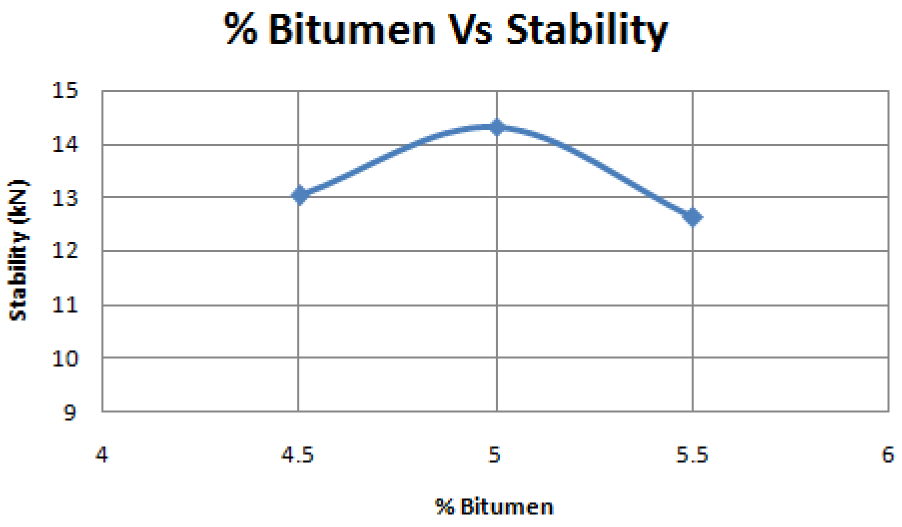

Figure 5.5.4: Marshall Stability value with Fly ash as filler

5.5.5 Voids filled with bitumen (VFB):

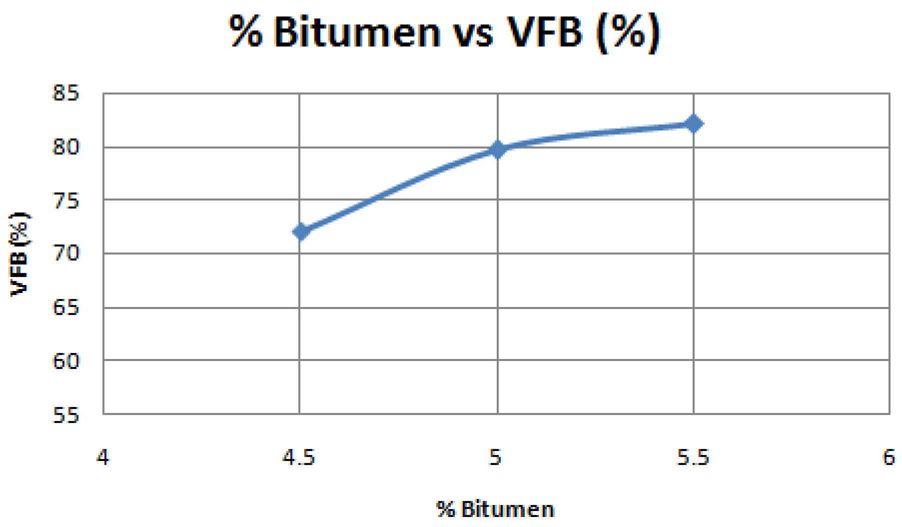

Figure 5.5.5: Percent Voids filled with Bitumen in mix with Fly ash as filler

5.6 Observations evaluated from Marshall Test with stone dust as filler:

Table 5.7: Marshall Characteristics of mix with stone dust as filler:

Bitumen content (%)	Unit wt. (g/cc)	Air voids (%) (Vv)	Voids filled with bitumen (VFB) (%)	Stability (kN)	Flow (mm)
4.5	2.518	5.33	67.60	13.15	2.61
5	2.527	4.3	73.83	14.35	2.76
5.5	2.524	3.74	78.42	12.81	3.01
6	2.496	3.88	78.01	11.72	3.43
6.5	2.48	3.42	82.64	10.41	3.51

5.6.1 Marshall Flow:

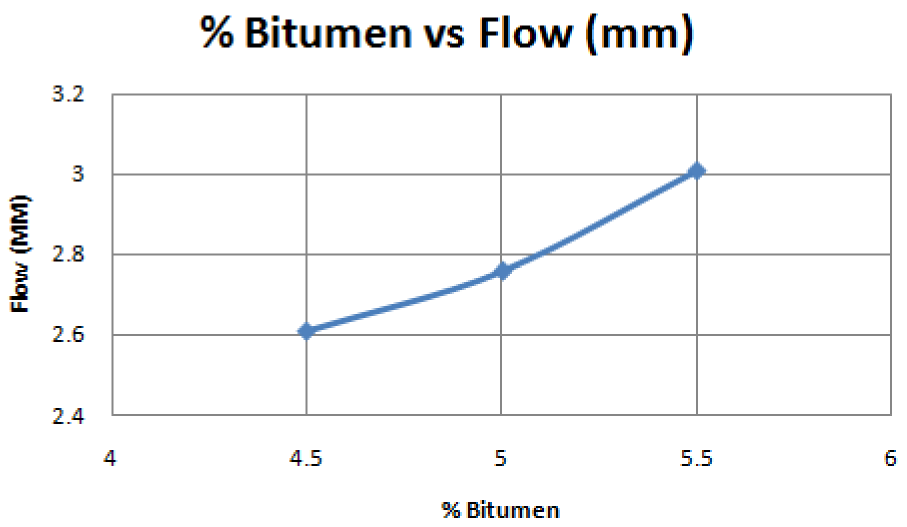

Figure 5.6.1: Marshall Flow value with Stone dust as filler

5.6.2 Air voids:

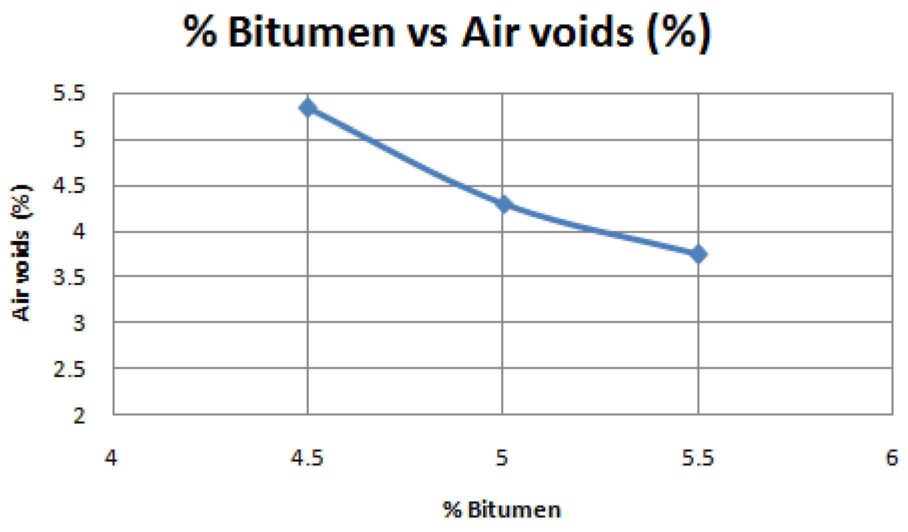

Figure 5.6.2: Percentage Air voids in Bituminous mix with Stone dust as filler

5.6.3 Unit weight:

The maximum density is acheived at 5 (%) of bitumen . Thus optimum bitumen content is acheived with respect to maximun density.

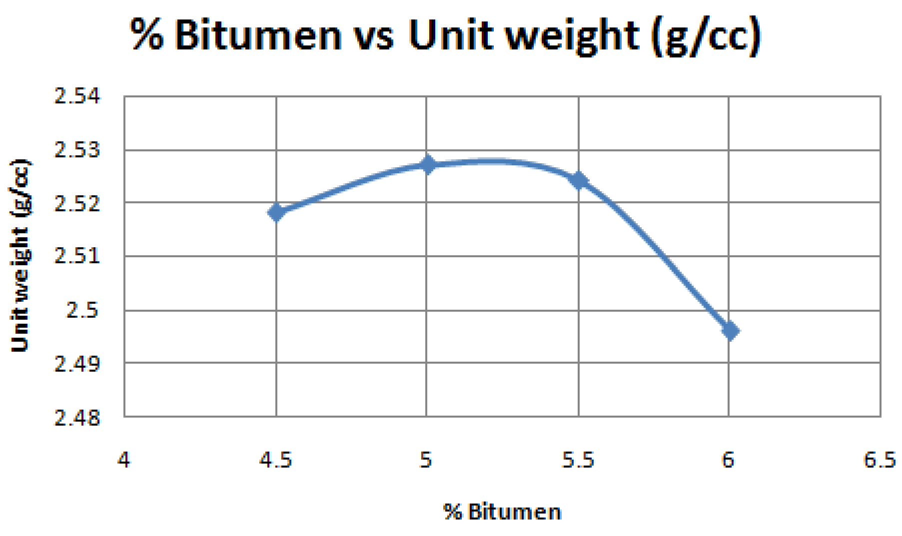

Figure 5.6.3: Unit weight of Bituminous mix with Stone dust as filler

5.6.4 Stability:

The maximum stability is obtained at 5 (%) of bitumen content and is thus optimum bitumen content.

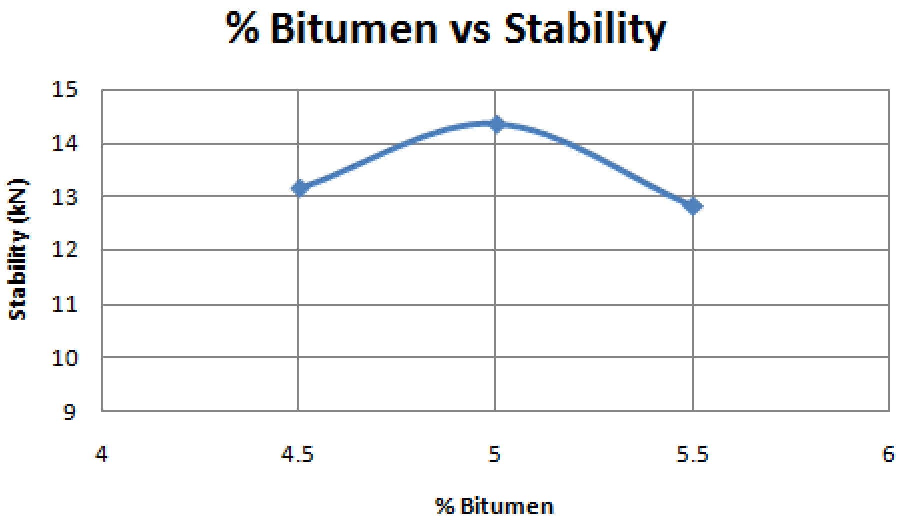

Figure 5.6.4: Marshall Stability value with Stone dust as filler

5.6.5 Voids filled with bitumen (VFB):

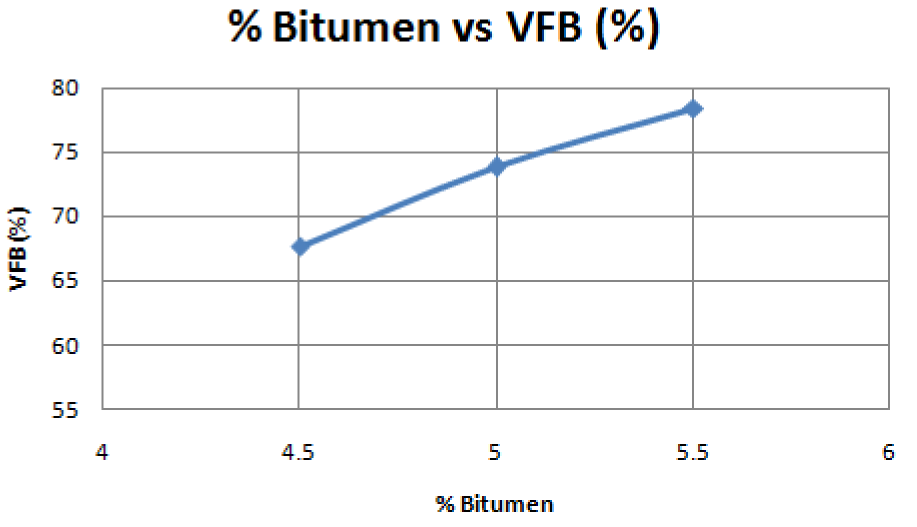

Figure 5.6.5: Percent Voids filled with Bitumen in mix with stone dust as fille

DISCUSSION

- The Marshall Flow increased with the addition of fillers as compared to virgin bitumen

- With the addition of fillers, air voids decreased more abruptly as compared to virgin bitumen. The minimum air voids were obtained with addition of fly ash as filler

- The density and Marshall Stability also increased with the addition of fillers as compared to virgin bitumen. The maximum stability and density was achieved with addition of cement as filler at optimum bitumen content 5 (%).

Chapter 6

CONCLUSION AND FUTURE SCOPE

Based on the results of the experimental investigations conducted on normal and modified bitumen using fillers, the following summaries have been drawn:

- Modified bitumen by using different fillers show less penetration value, thus low grade bitumen can be modified to withstand higher loads.
- The ductility value decreased with the use of fillers as these fillers cause the bitumen to become stiffer.
- From Marshall Stability test, the stability values were found to be increased with the use of fillers. With the use of cement as filler, maximum stability was found followed by fillers fly ash and stone dust. These fillers tend to fill more voids between aggregate grains. Thus mix will continue to gain strength, leading to increased stability of bituminous mix
- The Marshall Flow value also increases with the use of fillers being maximum with the use of fly ash followed by stone dust and cement respectively. This indicates improvements in the resistance to permanent deformation of bituminous mixes with addition of these fillers.
- The density of bituminous mixes prepared with using modified binder increases up to certain limits and then decreases.

From the above results, it is observed that fly ash being a waste product can be effectively used as a filler to improve the properties of bituminous mix. Fly ash also being cost effective as compared to cement and lime.

FUTURE SCOPE

- Evaluation of indirect tensile strength of mixes prepared from modified binder with different fillers.

- Evaluation of fatigue performance of bituminous mixes prepared with modified bitumen.

- Find out the relative rutting characteristics of different bituminous mixes by using Static indentation test at 60°c.

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