Project -A Report

On

"STUDY ON THE PERFORMANCE OF CRUMB RUBBER MODIFIED BITUMEN BY VARYING THE SIZES OF CRUMB RUBBER"

Submitted in partial fulfillment of the requirements

for the degree of

BACHELOR OF ENGINEERING

In

CIVIL ENGINEERING

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Declaration

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

The abundance and increase of waste tyre disposal is a serious problem that leads to environmental pollution. Crumb rubber obtained from shredding of those scrap tires has been proven to enhance the properties of plain bitumen since the 1840s. It can be used as cheap and environmentally friendly modification process to minimize the damage of pavement due to increase in service traffic density ,axle loading and low maintenance services which has deteriorated and subjected road structures to failure more rapidly. Use of crumb rubber leads to excellent pavement life, driving comfort and low maintenance . The rheology of CRMB depends on the internal factors such as crumb rubber quantity, type, particle size, source and pure bitumen composition , and external factors such as the mixing time, temperature, and also the mixing process(dry process or wet process).

The present study aims in investigating the experimental performance of the bitumen modified with 15% by weight of crumb rubber varying its sizes. Four different categories of size of crumb rubber will be used , which are coarse(2.36 mm- 1.6 mm); medium size(1.6 mm- 1.18 mm); fine (1.18 mm- 600 µm); and superfine (600 µm- 300µm). Common laboratory tests will be performed on the modified bitumen using various sizes of crumb rubber and thus analyzed. Marshal stability method is used for mix design. Finally a comparative study is made among the modified bitumen samples using the various sizes of crumb rubber particles and the best size is suggested for the modification to obtain best results.

KEYWORD: Crumb Rubber Modified Bitumen(CRMB), Marshal Stability,

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LIST OF NOMENCLATURES/ ABBREVATIONS

CRMB	Crumb rubber modified bitumen
CRM	Crumb rubber modifier
SBS	Styrene butadine styrene
VG-40	Viscosity grade 40
BC-II	Bituminous concrete II
MoRT & H	Ministry of road transport & highways
OBC	Optimum bitumen content
VFB	Percent voids filled with bitumen
VMA	Percent voids in mineral aggregate
Vv	Percentage air voids
Vb	Volume of bitumen %
Gb	Bulk density of specimen
Gt	Theoretic density of mixes

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1 Chapter: Introduction

The project in the following chapters relates to a study on the performance of crumb rubber modified bitumen by varying the sizes of crumb rubber.

1.1 General

Road construction plays a vital role in the development of a sustainable infrastructure for all economies. Countries without roads and highways will find themselves underdeveloped and will struggle to attain a level of wealth that is generally reached in the developed world. The construction of roads and highways has been a priority in the world since Roman times.

Bitumen has been used in the construction of Flexible pavements for more than a century. The durability properties of the bitumen binder, is the key factor for the binder characterization in Bitumen mixes, and hence pavement performance. Enormous advances have been made in the use of the bitumen as binder in pavement construction and rehabilitation. The bituminous layer itself may display a significant amount of permanent deformation in hot climatic factors such as temperature, moisture and repeated loads.

Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. Traditionally soil, stone aggregate, sand, bitumen, cement etc. are used for road construction. The necessary specifications should be formulated and attempts are to be made to maximize the use of solid wastes in different layers of the road pavement. The practice of disposing waste tyres in landfills and open burning is becoming unacceptable because of rapid depletion of available landfill sites and clear environment respectively. The conventional bituminous mix includes stone aggregate and 3 to 5 percent bitumen by weight of the aggregate. The scrap tyre rubber can be incorporated into bitumen, often abbreviated as modified bitumen and granulated or ground rubber or crumb rubber can be used as a portion of the fine stone aggregate. The use of waste in hot bituminous mixes enhances pavement performance, protect environment and provide low cost and quieter roads.

India has a road network of over 46,89,842 kilometers in 2013, the second largest road network in the world. It has primarily flexible pavement design which constitute more than 98% of the total road network. India being a very vast country has widely varying climates ,terrains ,construction material and mixed traffic condition both in terms of loads and volumes. Increased traffic factors such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavement. So to minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved. There are many modification processes and additives that are currently used in bitumen modifications such as styrene butadiene styrene (SBS), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA) and crumb rubber modifier(CRM).

Crumb rubber is the term usually applied to recycled rubber from automotive and truck scrap tires. During the recycling process steel and fluff is removed leaving tire rubber with a granular consistency. Continued processing with a granulator and or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles. From physical and chemical interaction of crumb rubber with conventional bitumen crumb rubber modified bitumen (CRMB) is made. Its advantages are: lower susceptibilities to daily

and seasonal temperature variations, higher resistance to deformation at elevated pavement temperature, better age resistance properties, higher fatigue life of mixes, better adhesion between aggregate and binder, prevention of cracking and reflective cracking and overall improved performance in extreme climate conditions and under heavy traffic condition.

1.2 Need for present investigation

Presently in India bitumen is modified with various types of modifier such as crumb rubber, natural rubber, reclaimed polyethylene and polymers are being used for construction of bituminous roads. A number of products are also available in market, with which bitumen has been modified with a blend of modifiers. Readily blended type of Polymer modified bitumen, crumb rubber modified bitumen and natural rubber modified bitumen are also available in the market in commercial form. As per IRC: SP: 53-2010 these products shall be evaluated for their suitability in an approved laboratory by conducting various tests to know its properties.

In past number of researchers worked on the various factors that influence the ageing behaviour of neat bituminous mixes. But limited work has been reported on the various factors such as the effect of temperature, mixture stiffness, aggregate type and gradation and method of testing on behaviour of polymer modified bituminous mixes.

In the present study an attempt is made to investigate the influence of mixing temperature on bituminous mixture with different types of bitumen by carrying out experimental investigations such as Marshall mix design test, Indirect Tensile Strength test and Fatigue test were carried out using Paving Grade (VG-40) and Crumb rubber using various sizes(coarse,medium,fine.semi-fine).

1.3 General information on rubber as material:

The Indian rubber industry plays a role of a core sector in the Indian economy. Since Independence, the sector has expanded significantly by increasing the range of products manufactured and number of manufacturing units, increasing exports, and technological sophistication. As per the Rubber Board’s estimates as at the end of FY12, the sector has 4,550 units comprising 51 tyre factories, 501 large and medium scale units, and around 3,998 small scale or tiny sector units manufacturing around 35,000 rubber products and directly employing 500,000 people.

As of 2011, India is the world's fourth largest producer and the second largest consumer of natural rubber. India ranks as the fifth largest consumer in the world in terms of consumption of natural rubber and synthetic rubber taken together. India is also the world's largest manufacturer of reclaim rubber and stands first in productivity of natural rubber. As per the provisional data, the per capita consumption of rubber in India is only 1.14 kg., which is far lower than 9 to 13.5 kg. per capita consumption in Japan, US, Germany, and Canada in 2011. This envisions remarkable growth prospects for the industry in the years to come.

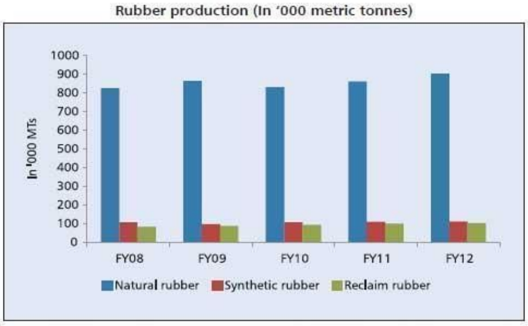
The wide range of rubber products manufactured by the Indian rubber industry comprises all types of heavy duty earth moving tyres, auto tyres, tubes, automobile parts, footwear, beltings, hoses, cycle tyres and tubes, cables and wires, camelback, battery boxes, latex products, pharmaceutical goods, molded, and extruded goods. The industry caters to the sectors like defense, civil, aviation, aeronautics, railways, agriculture, transport, textiles, engineering industries, automobiles, tyres, pharmaceuticals, mines, steel plants, ports, hospitals, and sports amongst others.

India rubber industry is divided into two sectors - tyre and non-tyre. The tyre sector produces all types of auto tyres, conventional as well as radial tyres. The non-tyre sector produces high technology and sophisticated industrial products.

1.3.1 Rubber production and consumption:

The total annual production of rubber (natural rubber and synthetic rubber) between FY08 to FY12 grew at nearly 2% CAGR to 1.01 MMT in FY12. This growth was driven by the growth in the natural rubber production, which grew at a 2.3% CAGR during the same period. In FY12, natural rubber production grew 4.8% to 903,700 MT, whereas synthetic rubber production grew just 0.2% y-o-y to 110,599 MT. Growth in the natural rubber production is attributable to favourable weather conditions and intensive harvesting due to attractive prices. Natural rubber accounts for 89% of the total annual (natural and synthetic) rubber production in the country. The production of reclaim rubber, which is produced from the treatment of ground vulcanised scrap rubber tires, tubes, and waste rubber articles, grew 3.6% y-o-y to 103,565 MT in FY12. The chart below highlights the year-wise production of natural, synthetic, and reclaims rubber.

Rubber production (In '000 metric tonnes)



Source: All India Rubber Industries Association and Rubber Board, Ministry of Commerce and Industry, GoI

The total annual consumption of rubber (natural rubber and synthetic rubber) between FY08 to FY12 grew 5%

1.3.2 Rubber Import & Export:

India imported 550,000 MT of rubber in FY12 compared with the 479,667 MT imported during FY11. The total rubber imported includes 64% of synthetic rubber and the rest being natural rubber. During FY08 and FY12, the total rubber imports has grown at a 18% CAGR, with natural rubber growing at a higher pace of 22% compared with 16% CAGR growth of synthetic rubber.

During FY12, the prices of natural rubber in domestic and international markets were high due to tight supply and currency and future MARKET movements. Taking the advantage of price differential between domestic and international prices during the initial months in FY12, the exporters exported 30,000 MT natural rubber as against the quantity of 29,851 MT shipped during FY11 registering a marginal 0.5% y -o-y growth. The exports however declined at 16% CAGR .

1.3.3 Rubber used in making mix:

Safe disposal of waste rubber is a serious environmental problem. Being a non-biodegradable material it does not decay over the time and even if dumped in landfills, finds its way back in environment through water and air erosion can choke the drains and drainage channels, can be its small pieces eaten by unsuspecting grazing animals causing them illness and death, can contaminate the construction fill etc. The best way of disposal of waste rubber (scrap tires) is its recycling to the maximum extent and many developed countries have recycled waste rubber in construction process of road.

Studies have revealed that waste rubber have great potential for use in rubber modified bitumen road as its addition in small doses about 5-10% by weight of aggregate helps in substantially improving the marshal stability strength, Fatigue life and other desirable properties of bituminous mix leading to improved longevity and pavement performance. The use of waste rubber thus contributes in construction of green road.

1.3.4 Basic Process of Extracting Crumb Rubber

1.SEGREGATION PROCESS

2.CLEANING PROCESS

3.SHREDDING PROCESS

4.COLLECTION PROCESS

1.SEGREGATION PROCESS

Rubber waste collected from various sources must be separated from other waste.


2. CLEANING PROCESS

Rubber waste get cleaned and dried


3.SHREDDING PROCESS

- Will be shredded or cut into small pieces in form of aggregate size.
- Size ranging from 4 mm to 75um.

4. COLLECTION PROCESS

- The rubber pieces were sieved through 22.4mm sieve and retained at 5.6mm sieve and these were added in bituminous mix 10% to 20% by the weight of stone aggregate.

1.4 Objective of the project:

- To study on the performance of Crumb rubber modified bitumen by varying its sizes
- To study the importance of different sizes of Crumb rubber for better performance of bituminous mixes.
- To design the bituminous mixes for Bituminous concrete Grade-II (BC-II) using paving grade (VG-40) and Crumb Rubber by Marshall mix design.
- To determine the various physical properties of materials used in designing Bituminous concrete
- To determine the optimum binder film thickness which gives maximum stability
- To study the durability of the mix by determining the indirect tensile strength carried out at 25 °C on the mix prepared at varying sizes of Crumb rubber .
- To study the performance of the mix prepared with paving grade (VG-40) and Crumb Rubber of varying sizes for bituminous concrete (BC-II).
- To compare the results of Marshall properties for the binders, viz. paving grade (VG-40) and Crumb Rubber at varying Sizes with conventional bitumen results.
- To arrive at a suitable Mixing Sizes for use, by the field engineers to be adhered, to get better performance, durability and film thickness of the bituminous mix.

- ➢ Minimization of Environmental pollution caused by burning of tire and disposing in landfills and thereby protecting it
- ➢ Boost to the technology.

1.5 Scope for present investigations:

This study shows the various engineering properties of paving grade (VG-40) and Crumb rubber modified bitumen. Physical properties such as penetration at 250°C, softening point, and ductility at 270°C, specific gravity and viscosity have been determined for binders.

Aggregate gradation for BC (Bituminous Concrete) grade-2 as per Ministry of Road Transport and Highways (**MoRT&H IV**) was obtained and used with bitumen for preparing specimens.

Marshall Properties have been determined using standard Marshall Method to determine the OBC.

Other primary scopes are:

- Improve skid resistance
- Decrease noise level

- Reduce the maintenance cost
- Improve resistance to cracking in new pavement
- Increase pavement life

2 Chapter: Literature Review

Basically, highway pavements can be categorized into two groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this "flexing". On the other hand, rigid pavements are composed of a PCC surface course. Such pavements are substantially "stiffer" than flexible pavements due to the high modulus of elasticity of the PCC material. Flexible pavements being economical are extensively used as far as possible. A precise engineering design of a flexible pavement may save considerable investment; as well as reliable performance of the in-service highway pavement can be achieved.

In recent years, many countries have experienced an increase in truck tyre pressures, axle loads, and traffic volumes. Tyre pressure and axle load increases mean that the bituminous layer near the pavement surface is exposed to higher stresses. High density of traffic in terms of commercial vehicles, overloading of trucks and significant variations in daily and seasonal temperature of pavements have been responsible for development of distress symptoms like ravelling, undulations, rutting, cracking, bleeding, shoving and potholing of bituminous surfaces. Suitable material combinations and modified bituminous binders have been found to result in longer life for wearing courses depending upon the percentage of filler and type of fillers used.

Modified bitumen

The past years, has seen a continuing, underlying, demand for higher-quality bituminous binders. As a consequence, many modifying additives have been investigated with the aim of improving the properties of the penetration grade bitumen used in road pavements. Some of these modifiers are proprietary products; others are in the public domain. Some have been commercially successful; others have not. Whatever, the fact that there has been such a multiplicity of modifiers can create confusion as to their relative roles and values.

The penetration is a measure of hardness or softness of bitumen binder which shows an effect by adding crumb rubber to bitumen binder; it decreases as rubber content is increased. The penetration shows lower values as rubber content increases at different mix conditions of rubberized bitumen binder, indicating that the binder becomes stiff and more viscous (Mashaan et al, 2011a).

Mahrez (1999) investigated the properties of rubberized bitumen prepared by physical blending of bitumen 80 / 100 penetration grade with different crumb rubber content and various aging phases. The results of penetration values decreased over the aging as well as before aging by increasing the rubber content in the mix. Also, the modified binders have lower penetration values than unmodified binders.

The softening point refers to the temperature at which the bitumen attains a particular degree of softening. The use of crumb rubber in bitumen modification leads to an increase in the softening point and viscosity as rubber crumb content increases (Mahrez, 1999; MAshaan et al , 20011 a). Mahrez and Rehan (2003) claimed that there is a consistent relationship between viscosity and softening point at different aging phases of rubberized bitumen binder.

According to a study conducted by Lee et al. (2008), the higher crumb rubber content produced increased viscosity at 135°C and improved the rutting properties. It was also observed that the increased crumb rubber amount (fine crumb rubber) produced rubberized bitumen with higher viscosity and lower resilience. However, optimum crumb rubber content still needs to be determined for each crumb rubber size and asphalt binder. It is believed that a physicochemical interaction that occurs between the asphalt and the crumb rubber alters the effective size and physical properties of the rubber particle, thus influencing pavement performance (Huang et al, 2007)

Becker et al, (2001) claimed that blend properties will be influenced by the amount of crumb rubber added to the bitumen. Higher amounts indicated significant changes in the blend properties. As rubber content generally increases, it leads to increased viscosity, increased resilience, increased softening point and decreases penetration at 25°C.

The mixture showed improved performance in dynamic stability, 48 h residual stability, flexural strength and strain value. Asphalt containing 0.2 and 0.4 mm size rubber indicated the best laboratory results (DSouza and Weissman , 1994). The particles size disruption of crumb rubber influenced the physical properties of bitumen rubber blend. In general, small difference in the particles size has no significant effects on blend properties. However, the crumb rubber size can certainly make a big difference.

According to a study of Shen et al. (2009), the particle size effects of CRM on high temperature properties of rubberized bitumen binders was an influential factor on visco- elastic properties. The coarser rubber produced a modified binder with high shear modulus and an increased content of the crumb rubber decreased the creep stiffness which in turn showed significant thermal cracking resistance.

When crumb rubber is blended at high temperatures with bitumen to produce a modified binder (i.e wet process), the two materials interact once bitumen components migrate into the rubber causing it swell (Bahia and Davies, 1994). Initially, the interaction between crumb rubber and bitumen is a non-chemical reaction, where the rubber particles are swollen by the absorption of the aromatic oils of bitumen (Heitzman, 1992).

Modified bitumen using crumb rubber showed an improvement in the performance of pavements over the base binders as a result of the interaction of crumb rubber with base binders. Due to this interaction, there are noticeable changes in the viscosity, physical and rheological properties of the rubberized bitumen binder (Airey et al , 2003; Bahla and Davies, 1995), leading to high resistance of rutting of pavements (Huang et al, 2007).

The rubber particles are considered in their movement into the binder matrix to move about due to the swelling process which limits the free space between the rubber particles. Compared to the coarser particles, the finer particles swelleasily thus, developing higher binder modification (Abedlrahman and Carpenter, 1999).

3 Chapter: Methodology

The present investigation aimed at the laboratory evaluation of Bituminous concrete (BC-II) with different Bitumen type such as Paving Grade Bitumen (VG-40) and Crumb rubber . The aggregate gradation for bituminous concrete (Grading-II) recommended by Ministry of Road Transport and Highways (MoRT&H) is used. Marshall Stability tests and Indirect Tensile Strength (ITS) tests are carried on BC-II mixes.

MATERIALS:

VG-40 bitumen, crumb rubber, Softening point apparatus, Penetration test Apparatus, Bitumen mixing setup, Marshall test apparatus, Air voids apparatus.

3.1 Parameters considered in the present studies of materials:

3.1.1 Aggregate

The coarse aggregate used in this study are collected from KAUSA MUMBRA ,THANE are used. Crusher run stone dust is used as mineral filler. Ordinary Portland cement is used as filler. The necessary required tests on aggregates are conducted in the laboratory and the results are obtained.

Table 3.1.1: Physical Properties of Aggregates

Sl. No	Tests	MoRT&H Requirements
1	Aggregate impact value, (%)	27 maximum

2	Los Angeles Abrasion value, (%)	35 maximum
3	Combined flakiness and Elongation Index, (%)	35 maximum
4	Aggregate specific Gravity 1) Coarse aggregates 2) Fine aggregates 3) Filler (Quarry Dust)	-------

3.1.2 Filler

Filler shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement. The filler shall be free from organic impurities and have plasticity index not greater than 4. The plasticity index requirement shall not apply if filler is cement or hydrated lime. In present study rock dust has been used. The specific gravity test was conducted in the laboratory and results are obtained..

3.1.3 Bitumen and Modifier Used

Bitumen used are

- Paving Bitumen
  - ✓ Paving grade Bitumen (VG-40)
- Modifier
  - ✓ Crumb rubber

Modified bitumen is generally recommended for the roads with heavy traffic and locations of extreme climatic conditions. The selection of modified bitumen will be based on climatic, traffic, performance reports and life cycle cost analysis.

Bitumen sample VG-40 grade from the company **CPT TANK , BITUMEN SUPPLIER, BYCULLA** is used for the study.

Table.3.1.3: Physical properties of paving grade bitumen (VG-40)

Sr. No	**Property**	**Requirement as per IRC: SP: 53-2002 and IS: 73-2000**
1	Penetration at 25^{0}C 0.1mm, 100gm, 5sec	30-50
2	Softening Point (R&B) (^{0}C)	60 minimum
3	Flash Point (^{0}C)	220 minimum
4	Ductility at 27^{0}C, (cm)	+60
5	Specific Gravity	-----

3.2 Laboratory testing for basic properties of materials

3.2.1 Gradation of aggregates

Gradation of an aggregate is the most crucial in any type of road work mix design. The gradation affects almost all the key property of a bituminous hot mix. A proper selected aggregate gradation during the primary stage of mix design, play very significant role in the durability and stability of road surface.

In India Bituminous concrete is used as the wearing course in most of the high volume roads since Bituminous concrete is close graded mix with high strength, durability and low porosity hence Close graded Bituminous concrete grading-II as per the MoRT&H Specification is selected for the present study. The grading of BC aims at providing a fairly dense layer and the nominal maximum size is 19 mm to provide for 30 to 45 mm thick bituminous concrete surface layer. The details are shown in table 3.4.

Table 3.2.1 : Gradation adopted for bituminous concrete mixes as per MORT&H

Grading	2
Nominal aggregate size (mm)	13
layer thickness (mm)	30-45
IS Sieve size (mm)	Cumulative % by weight of total aggregate passing
19	100
13.2	79-100
9.5	70-88
4.75	53-71
2.36	42-58
1.18	34-48
0.6	26-28

0.3	18-28
0.15	12-20
0.075	4-10
Bitumen content	5-7

Marshall properties	**MoRT&H Specification**
Stability	Min 900kg
Indirect Tensile Strength	Min 80%
Flow	2-4mm
VMA	Min 16%
VFB	65-75%

Table 3.2.2: Marshal properties as per MoRT & H Specification

The gradation obtained by job mix formula of aggregates used in this project is as per IRC grading II as given by (MORTH: Specifications for Road and Bridge works 2003):

3.2.2 Test on Aggregates

1. Impact Test
2. Crushing Value Test
3. Water Absorption Test

Table 3.2.3: physical properties of aggregates as per IS CODE and MoRT &H

Requirements

SI.NO	TEST	ISCODE	MoRT&H REQUIREMENT
1	IMPACT TEST	IS 2386	24%MAX
2	CRUSHING VALUE TEST	IS 2386	30%MAX
3	WATER ABSORPTION TEST	IS 2386	2%MAX

1. Impact Test

1. The aggregate impact tester is carried out by a machine known as aggregate impact tester.

2. It consists of a circular base over which two vertical guide bars are mounted.

3. The guide bars are connected at the top by a metal plane through which the adjustable stop for release of hammer and the locking pin operate.

4. The hammer having weight 13.5kg to 14kg slides up and down the vertical guide bars and can be held by the releasing claw fixed to the lifting handle.

5. The height of the fall of the hammer can be adjusted to 380mm

6. The cylindrical steel cup having internal diameter 102mm and depth 50 mm can be fixed firmly to the base.

7. In addition a measure and a tapping rod are used for preparation the test sample.

Equipments: Impact Testing Machine, cup, Circular base,etc.

Procedure:

1. The sample is broken into clips passing 12.5mm sieve and retained on 10mm sieve. The material is heated in an oven at a temperature of 100°c to 110°C for 4hrs then cooled.

2. The sample is placed in cup and the hammer is allowed to fall from heights of 380mm for the total of 15 blows. It should be seen that each blow is delivered at an interval of not less than a sec.

3. The crushed aggregate is then removed from the cup and it is sieved on 2.8mm sieve. The material passing through the sieve is collected and weighted. The aggregate impact value is obtained by the expression.

3.2.3 Test on Bitumen

1. Ductility Test
2. Softening Point Test
3. Penetration Test

1. To Determine Ductility Of Given Bitumen Sample:

In the flexible pavement construction where bitumen binders are used it is of significant importance that the binders from ductile thin films around the aggregate these serve as a stationary binder in improving the physical the interlocking at the aggregate. The binder material which does not passes sufficient ductility would crack and thus provide previous pavement surface. This in turn results in damaging effect to the pavement structure, it has been started by some agencies that the penetration and ductility properties together. But depending upon the chemical composition and the type of crude sources of the bitumen, sometimes it has been observed that the above statement is incorrect. It may hence be mentioned that the bitumen may satisfy the penetration value, but may fail to satisfy the ductility requirement. Bitumen paving engineer would however want that both test requirements are specified in the field jobs penetration or ductility is expressed as the distance in cm to which a standard briquette of bitumen can be attached before the thread break, the test is conducted at 27^0 to 5^0C and at a rate of pull of 50 (+/-) 2.5 mm per minute. The test has been conducted by IS1208.

Apparatus:

Briquette mould : mould is made of brass metal with shape and dimensions as indicated in fig. 10.2 both ends called lips passes circular holes to grip and these fixed and movable ends of testing machine side pieces when placed together from the briquette of following dimensions

Length	75mm
Distance between clips	70mm
Width of mouth of clips	30mm
C/S of minimum width	10mm X 10mm

Ductility Machine : It is equipment that used as for function as a constant temp water both and a pulling device at a pre-calibrated rate the central rod is machine is threaded and through gear system provides a movement to one end where the clips is fixed during initial pavement. The other clip end is hooked at the fixed end of machine. Two clips are thus pulled apart horizontally at uniform speed of 50 (+/-) 2.5 mm per minute.

Procedure:

1. The bitumen sample is melted to a temperature at 75 to 100^0C above the approximate softening points until it is strained through IS sieve 30 poured in mould assembly and placed on brass plate after a solution in mould assembly and placed in brass plate after a solution of glycerin and deximo is applied at all surfaces of mould exposed to bitumen.
2. After the sample is poured into the mould for 30 to 40 minutes. The plate assembly along with the sample is placed in water both maintained at 27^0C for 30 minutes.
3. The sample and mould assembly are removed from water both and excess bitumen material is cut off by leveling the surface using hot knife after trimming the specimen, the mould assembly containing sample is replaced in water bath maintained at 27^0C for 85 to 95 minutes.
4. The sides at moulds are now removed and the clips are carefully hooked on the machine without causing any initial strains.
5. The pointer is set to read zero. The machine is started and the two clips are thus pulled apart horizontally while the test is in operation.
6. It is checked weather the sample is test is immersed in water at the depth of at least 10 mm.
7. The distance at which the bitumen thread breaks is recorded in cm to report at ductility value.

- **I.R.C. Recommendations:**

The distance travelled up to the point of breaking of thread measured in cm is recorded as ductility value. It is recommended by IS that results should not differ from value by more than followings.

Repeatability Reproducibility= 5%

Reproducibility=10%

2 .SOFTENING POINT TEST

This test is done to determine the softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen as per IS: 1205 – 1978. The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

Equipments:

- Ring and ball apparatus
- Thermometer – Low Range : -2 to 80°C, Graduation 0.2°C – High Range : 30 to 200°C, Graduation 0.5°C

Preparation of sample:

The sample should be just sufficient to fill the ring. The excess sample should be cut off by a knife.

- Heat the material between 75 and 100 o C. Stir it to remove air bubbles and water, and filter it through IS Sieve 30, if necessary.

- Heat the rings and apply glycerine. Fill the material in it and cool it for 30 minutes.

- Remove excess material with the help of a warmed, sharp knife.

Procedure to determine softening point of bitumen:

1. Materials of softening point below 80°C:

2. Assemble the apparatus with the rings, thermometer and ball guides in position.

3. Fill the beaker with boiled distilled water at a temperature 5.0 ± 0.5°C per minute.

4. With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of 5.0 ± 0.5°C per minute.

5. Apply heat until the material softens and allow the ball to pass through the ring.

6. Record the temperature at which the ball touches the bottom, which is nothing but the softening point of that material.

Materials of softening point above 80°C:

The procedure is the same as described above. The only difference is that instead of water, glycerine is used and the starting temperature of the test is 35°C.

3.3 Mixing of crumb rubber and aggregate with plain bitumen:

1. DRY PROCESS

2. WET PROCESS

Since we are varying the sizes of crumb rubber we are adopting the dry process as well wet process.In preparing the modified binders, about 500 g of the bitumen was heated to fluid condition in a 1.5 litre capacity metal container. The aggregates and the bitumen were mixed as per the dry processes. For each mixture sample 15% [3] of crumb rubber by weight of four different sizes is used, which are coarse (2.36 mm - 1.6 mm); medium size (1.6 mm - 1.18mm); fine (1.18 mm-600 µm); and superfine (600 µm - 300 µm). The Mixture is mixed manually for about 3-4 minutes. The mixture is then heated to 160 °C . Care is taken to maintain the temperature between 160 °C to 170 °C. The modified bitumen is cooled to room temperature and suitably stored for testing. The bitumen is than added with the mixture of crumb rubber and aggregate and the mixture is allowed to cool for the test procedure.

Table 3.3: MIXING PARAMETERS USED BY SEVERAL TRANSPORTATION AGENCIES

AGENCY	MIXING TEMP.	MIXING TIME (MIN)	CRUMB RUBBER SIZE	CRUMB RUBBER(%)

ONTARIO,CANADA	180 deg. Cel.	45	0.5mm-1.00mm	18-20%
CALIFORNIA	190-226 deg. Cel.(adding CR)190-218 deg.cel.(blending)	45 (minimum)	2.36mm-75 microns	20+_2%
ARIZONA	180-205 deg.cel.(adding CR)165-190 deg.cel.(blending)	60(minimum)	2.36mm-1.18 mm	Minimum 20%
FLORIDA	168-190 deg.cel	30(minimum)	1.18mm-300 microns	Minimum 20%

3.4 Design of Bituminous Mix

The main objective of the mix design is to produce a bituminous mix by proportioning various components so as to have:

- Sufficient bitumen to ensure a durable pavement.
- Sufficient strength to resist shear deformation under traffic at higher temperature.
- Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic.
- Sufficient workability to permit easy placement without segregation.
- Sufficient flexibility to avoid premature cracking due to repeated bending by traffic.

- Not very high stiffness at low temperature to prevent shrinkage cracks.

The bituminous mix was designed by using Marshall Method of mix design. The Marshall test was used to obtain the optimum bitumen content based on ASTM D-1559-96.

Marshall Mix Design

Marshall Mix design method is the recommended method for characterization of bituminous mixes in India. The impact compaction due to the absence of Kneading and Shearing action used in standard Marshall Method does not simulate mix densification as it occurs in a real pavement during field compaction by road rollers and by traffic. Because of this standard Marshall Compaction is gradually being replaced by gyratory compaction in many countries, as it is possible to obtain similar degree of reorientation of aggregate particles caused by the shearing action imparted to the bituminous mix in the field. A low cost option to gyratory compaction was first reported in South Africa. This consists of modification for the face of the Marshall Hammer by providing indents on the compaction face. In the present investigation, instead of Modified Marshall Hammer only standard Marshall Hammer is used.

The compaction level chosen is 75 blows on either side of the Marshall specimens for Bituminous concrete (BC-II) with different sizes of binders. Marshall Tests were conducted according to ASTM-D1559-96. Optimum binder content will be calculated as the average of binder content corresponding to maximum stability, maximum unit weight, and % air voids.

3.4.1 Marshall Mix Design Method

The concept of the Marshall method of mix design was originally conceived by Mr. Bruce Marshall, formerly a bituminous engineer with the Mississippi State Highway Department. The Marshall method was later further improved by the U.S. Corps of Engineers who added certain features and developed the mix design criteria. The Marshall mix design method and criteria were originally developed for airfield pavements, but were later also adopted for use in highway pavements. Due to its simplicity, the Marshall method of mix design was the most commonly used mix design method in the U.S. before the introduction of the Superpave design system, and it is still the most commonly-used mix design methods in the rest of the world.

3.4.2 Test procedure for Preparing Marshall Specimens

The Marshall mix design procedure as recommended by the Asphalt Institute is described in detail in the Manual "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types" by the Asphalt Institute [1997]. The Marshall mix design procedure consists of the following main elements:

1. Selection of aggregates — the aggregates must meet all the requirements as specified by the local highway agency. These requirements typically include limits on L.A. abrasion loss, soundness loss, sand equivalent, percent of deleterious substance, percent of natural sand, percent of particles with crushed faces, and percent of flat or elongated particles. The gradation of the aggregate blend to be used must meet the gradation requirements for dense-grade HMA mixture as set by the local highway agency.
2. Selection of asphalt binder — the asphalt must meet the specification requirements as set by the local highway agency.
3. Preparation of asphalt mixture samples — Samples of asphalt mixtures at five different asphalt contents, with three replicates per asphalt content are prepared. The asphalt contents are selected at 0.5% increments with at least two asphalt contents above the estimated optimum and at least two below it. The aggregate and asphalt are mixed at a temperature at which the asphalt kinematic viscosity is 170 ± 20 centistokes.

4. Compaction of the asphalt mixtures — The asphalt mixture is compacted in a 101.6 mm (4-in.) diameter cylindrical mould by a Marshall compaction hammer, which is 6.5 kg (10 lb) in weight and dropped from a height of 457 mm (18 in.) for a specified number of blows per side of the specimen. The number of blows to be applied per side is 35, 50 or 75 for light, medium or heavy designed traffic, respectively. Light traffic is defined as having less than 104 ESALs. Medium traffic has between 104 and 106 ESALs, while heavy traffic has more than 106 ESALs. Compaction of the mixtures is done at a temperature at which the asphalt kinematic viscosity is 280 ± 20 centistokes. The compacted specimen is 101.6 mm (4 inches) in diameter and approximately 63.5 mm (2.5 in.) in height.
5. Testing of the compacted Marshall specimens — The tests to be run on the Marshall specimens include (1) determination of bulk specific gravity in accordance with AASHTO T166 [AASHTO,1997] or ASTM D2726 [ASTM, 2001] and (2) Marshall stability test, which measures the Marshall stability and Marshall flow, in accordance with ASTM D1559

[ASTM, 2001].

The Marshall stability is the maximum load the specimen can withstand before failure when tested in the Marshall Stability test. The configuration of the Marshall Stability test is close to that of the indirect tensile strength test, except for the confinement of the Marshall specimen imposed by the Marshall testing head. Thus, the Marshall stability is related to the tensile strength of the asphalt mixture.

The Marshall flow is the total vertical deformation of the specimen, in units of 0.01 in., when it is loaded to the maximum load in the Marshall Stability test. The Marshall flow can provide some indication of the resistance of an asphalt mixture to plastic deformation. Mixtures with low flow numbers are stiff and may be difficult to compact. However, these mixtures are more resistant to rutting than those with high flow numbers. Mixtures with flow numbers above the normal range may be “tender mixes,” which are susceptible to permanent deformation.

1. Computation of volumetric properties of the specimens — Using the bulk specific gravity of the specimen, the maximum specific gravity of the mixture and the bulk specific gravity of the aggregate, the percent air voids and VMA of the specimen are determined. Percent air voids of the specimen can be computed from the bulk specific gravity of the specimen and the maximum specific gravity of the mixture. VMA can be computed from the bulk specific gravity of the mixture, the bulk specific gravity of the aggregate and the aggregate percent by weight of the mix.

2. Marshall mix design criteria — The Marshall mix design method as recommended by the Asphalt Institute uses five mix design criteria. They are (1) a minimum Marshall stability, (2) a range of acceptable Marshall flow, (3) a range of acceptable air voids, (4) percent voids filled with asphalt (VFA), and (5) a minimum amount of VMA.

A mix design to be adopted must satisfy all these five criteria.

3. Determination of design asphalt content — To facilitate the selection of optimum asphalt content,

The following six plots are made:

a. Average unit weight versus binder content

b. Average air voids versus binder content

c. Average Marshall stability versus binder content

d. Average Marshall flow versus binder content

e. Average VMA versus binder content

f. Average VFA versus binder content

From the plot of air voids versus asphalt content, determine the asphalt content at air voids content of 4%. Using plots, determine the Marshall stability, Marshall flow, VMA and VFA at this asphalt content, and compare them with the Marshall mix design criteria. If all the mix criteria are met, this asphalt content is the preliminary design asphalt content. The preliminary design asphalt content can then be adjusted within the range where all the mix criteria are met according to the special need of the project to arrive at the final design asphalt content. If one or more of the mix criteria cannot be met, adjustments in aggregate type, aggregate gradation and/or asphalt type will need to be made and the mix design procedure will need to be re-conducted.

For the present study Bituminous concrete mix gradation was used following specifications stated by MORT & H table 500-19.

Three specimens of Marshall moulds and one loose mix (uncompacted) are prepared for each size of crumb rubber. Aggregates are oven dried and sieved according to BC gradation and separated. The amount of each size of fraction required to produce a mixed aggregate of 1200gm as per gradation is weighed. The required height of specimen is 63.5(+/-1). Aggregate and crumb rubber are mixed as the per the dry process. Then bitumen is poured in aggregate as per requirement. Then the mixture is mixed till a uniform coating is obtained on aggregate while the mixture is being heated together maintained at around 170 °C. The specimens mould and compaction hammer are cleaned thoroughly and mould assembly is heated in hot air oven to a temperature about 150 °C. A little grease is applied to the mould before the mix is placed. The mould is assembled and the mix is transferred and tampered using spatula. Then 75 blows are applied on either sides of the mould manually. Then the specimen is extracted after 24 hours.

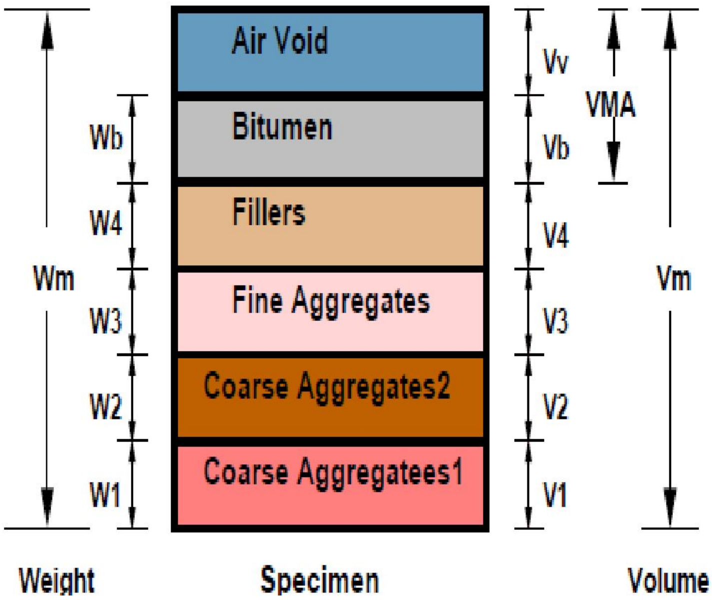
3.4.3 Determination of Optimum Bitumen Content (OBC)

For the determination of OBC, graphs are plotted with bitumen content on the X-axis and following values on the Y-axis

- Marshall Stability values
- Flow values
- Unit weight or Bulk Density (G_b)
- Percent air voids in total mix (V_V)
- Percent voids filled with bitumen (VFB)

The OBC for the mix design is found by taking the average value of the following three bitumen contents found from the graphs of the test results

- Bitumen content corresponding to maximum stability
- Bitumen content corresponding to maximum unit weight
- Bitumen content corresponding to the median of the design limits of percent air voids in total mix (4%).



3.4.4 Volumetric analysis

The specimens are compacted at 50 blows compactive effort on both sides is used for volumetric analysis. Using the following set of equations, the maximum theoretical specific gravity and bulk specific gravity of the mixes, the volumetric properties of the bituminous mixes are evaluated.

$Vv = ((G_t - G_b)/G_t)*100$ ……………. (3.1)

$G_t = 100/ \{(W_1/G_1)+(W_2/G_2)+(W_3/G_3)+(W_4/G_4)+(W_5/G_5)\}$ ……………. (3.2)

$VMA = V_v + V_b$ .... (3.3)

$VFB = (V_b/VMA)*100$ .... (3.4)

$V_b = (W_5/G_5)*G_b$ .... (3.5)

Where,

G_t = Theoretical Density of mixes.

G_b = Bulk Density of Specimen.

W_1 = Percent by weight of coarse Aggregate.

W_2 = Percent by weight of Fine Aggregate.

W_3 = Percent by weight of mineral Filler.

W_4 = Percent by weight of Cement filler.

W_5 = Percent by weight of Bitumen.

G_1 = Apparent Specific Gravity of Coarse Aggregate.

G_2 = Apparent Specific Gravity of Fine Aggregate.

G_3 = Apparent Specific Gravity of Filler.

G_4 = Apparent Specific Gravity of Cement filler.

G_5 = Apparent Specific Gravity of Bitumen.

VMA = Percent Voids in Mineral Aggregate.

V_v = Percent of air voids.

V_b = Volume of Bitumen, %

VFB = Percent voids filled by Bitumen.

3.4.5 Effective specific gravity (G_{se}) of blended aggregate

$$G_{se} = G_{sb} + 0.8 * (G_{sa} - G_{sb}) \qquad \text{............................ (3.6)}$$

Where,

G_{se} = Blended effective Specific Gravity

G_{sb} = Blended bulk specific gravity of aggregate

"$G_{sb} = 100/ \{(W_1/G_1)+(W_2/G_2)+(W_3/G_3)+(W_4/G_4)\}$"

G_{sa} = Blended apparent specific gravity of aggregate

“$G_{sa} = 100/ \{(W_1/G_{b1})+(W_2/G_{b2})+(W_3/G_3)+(W_4/G_4)\}$”

“G_{sb} = bulk Specific Gravity of Coarse Aggregate.”

G_{b1} = Bulk Specific Gravity of Coarse Aggregate.

CHAPTER 4

ANALYSIS OF TEST RESULTS

This chapter describes the various tests carried out on bituminous concrete-II mixes prepared using crumb rubber modified bitumen (VG-40). The optimum bitumen content was determined by Marshall Method of mix design. The aggregate and bitumen was tested for their gradation. The study aims at the property variations at different sizes of the crumb rubber modified bitumen. The mix prepared with OBC at mixing temperatures and was tested for stability and flow.The modified crumb rubber bitumen was also compared with the conventional bitumen and the best suited mixing process- dry or wet was found out. The results, thus obtained were analyzed as follows and the causes for the obtained trend were investigated.

4.1 AGGREGATES TEST RESULT- (12.5mm to 10mm)

The coarse aggregate used in this study are collected from KAUSA MUMBRA ,THANE . Crushed stone dust is used as mineral filler. The necessary required physical test on aggregates (impact test, crushing test,water absorption test) are conducted in the laboratory and the results are obtained.

4.1.1 IMPACT TEST

Table.4.1.1: Result on impact test of Aggregates

Weight of aggregate g (W1) gms	Weight of aggregate passing through 2.36mm IS sieve after 15 blows (W2) gms	Impact value of aggregate =(W2/W1)*100
340	55	16.17%
340	60	17.64%
340	50	14.70%

4.1.2 CRUSHING TEST

Table.4.1.2: Result on crushing test of Aggregates

Weight of aggregate (W1) gms	Weight of aggregate passing through 2.36mm IS-sieve (W2) gms	Crushing value of aggregate =(W2/W1)*100
2560	590	23.04%
2560	600	23.43%
2560	590	23.04%

4.1.3 WATER ABSORPTION TEST

Table.4.1.3: Result on water absorption of Aggregates

Weight of aggregate (W1) gms	Weight of water absorbed by the aggregate after 24 hours (W2) gms	Absorption value =(W2/W1)*100
2000	37	1.86%
2000	35	1.75%
2000	39	1.95%

CONCLUSION OF PHYSICAL TEST ON AGGREGATE:

From the above physical test (impact test, crushing test, water absorption test) it was found out that:

IMPACT VALUE OF AGGREGATE= **16.19%**

CRUSHING VALUE OF AGGREGATE= **23.17%**

WATER ABSORPTION OF AGGREGATE= **1.85%**

All the values obtained are within the limits given by the MoRT & H requirements.

4.2 TEST RESULTS ON BITUMEN- VG 40

Bitumen sample VG-40 grade from the company **CPT TANK ,BITUMEN SUPPLIER ,BYCULLA** is used for the study.The laboratory test was conducted on both conventional bitumen-VG 40 and crumb rubber modified bitumen. The properties of bitumen found in the laboratory test are presented in Table.

4.2.1 (A) PENETRATION VALUE OF CONVENTIONAL BITUMEN

Table.4.2.1: Penetration value of paving grade bitumen (VG-40)

Test property	Trial 1	Trial 2	Trial 3	Trial 4
Penetration (mm)	48.23	43.96	47.38	45.04

(B) PENETRATION VALUE OF CRUMB RUBBER MODIFIED BITUMEN

<table>
<tr><td>Sample no.1:</td><td>(2.36mm-1.6mm) crumb rubber</td><td rowspan="4">Addition of crumb rubber in the sample 15 %</td></tr>
<tr><td>Sample no.2:</td><td>(1.6mm-1.18mm) crumb rubber</td></tr>
<tr><td>Sample no.3:</td><td>(1.18mm-0.6mm) crumb rubber</td></tr>
<tr><td>Sample no.4:</td><td>(0.6mm-0.3mm) crumb rubber</td></tr>
</table>

Table.4.2.2: Penetration value of CRMB (VG-40)

Test property	Sample 1	Sample 2	Sample 3	Sample 4
Penetration (mm)	39.36	33.82	37.56	40.17

4.2.2 (A) SOFTENING POINT OF CONVENTIONAL BITUMEN

Table.4.2.3: Softening value of paving grade bitumen (VG-40)

Test property	Trial 1	Trial 2	Trial 3	Trial 4
Mean softening point	83^0 C	85^0 C	84^0 C	82^0 C

4.2.2 (B) SOFTENING POINT OF CRUMB RUBBER MODIFIED BITUMEN

<table>
<tr><td>Sample no.1:</td><td>(2.36mm-1.6mm) crumb rubber</td><td rowspan="4">Addition of crumb rubber in the sample
15 %</td></tr>
<tr><td>Sample no.2:</td><td>(1.6mm-1.18mm) crumb rubber</td></tr>
<tr><td>Sample no.3:</td><td>(1.18mm-0.6mm) crumb rubber</td></tr>
<tr><td>Sample no.4:</td><td>(0.6mm-0.3mm) crumb rubber</td></tr>
</table>

Table.4.2.4: Softening value of CRMB

Test property	sample 1	sample 2	sample 3	sample 4
Mean softening point	91^{0}C	95.4^{0}C	99^{0}C	90^{0}C

CONCLUSION OF PHYSICAL TEST ON THE CONVENTIONAL BITUMEN AND CRUMB RUBBER MODIFIED BITUMEN:

From the physical test (softening test ,penetration test, ductility test) it was found out:

PENETRATION VALUE OF CONVENTIONAL BITUMEN= **48.92mm**

PENETRATION VALUE OF CRUMB RUBBER MODIFIED BITUMEN= **36.07mm**

SOFTENING VALUE OF CONVENTIONAL BITUMEN= **85^{0}C**
SOFTENING VALUE OF CRUMB RUBBER MODIFIED BITUMEN= **95.5^{0}C**

By studying the test results of the conventional bitumen and the crumb rubber modified bitumen it is concluded that the penetration value and the softening value of the conventional bitumen can be improved significantly by modifying it with addition of the crumb rubber which is a major environment pollutant.

4.3 Studies on Marshall Properties of bitumen mixes and calculation of OBC.

The values of percentage air voids(Vv), voids in mineral aggregates (VMA) and the voids filled with bitumen(VFB) are calculated for each test specimen and the mean of these for specimens prepared using different binder contents are tabulated.

Marshall stability test is conducted on each specimen and the mean of Marshall stability value(after applying the correction factor if any, for thickness values other than 63.5mm) and the flow value for specimens prepared using different binder contents are tabulated. Graphs are plotted with bitumen content on the X-axis and i) density ii) Marshall Stability iii) flow value iv) air voids v) VFB on the y-axis. Individual values of optimum bitumen contents are obtained considering i) maximum density ii) maximum stability iii) mid range of recommended flow value iv) mid range of recommended voids content. Considering the different values of OBC determined as above, suitable design bitumen content is selected within the range of optimum values of Marshall Stability, flow and air voids in the mix are noted from the graphs and are checked to find if they fulfill the specified mix design criteria.

Table.4.3: Calculation of Volumetric properties for determining the optimum Binder Content for Bituminous Concrete - II mix using VG – 40

Trial No	% bitumen	Avg. Height (cm)	Avg Dia (cm)	Volume (cc)	Wt in Air (gm)	Wt in Water (gm)	Gb (g/cc)	G_t (g/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Flow (mm)	Marshall Stability (Kg)
1	4.5	6.8	10	534.14	1240	712	2.348	2.51	6.37	10.06	16.43	61.25	2.4	2304
2	4.5	6.8	10	534.14	1228	698	2.317	2.51	7.62	9.93	17.55	56.57	2.6	1395.2
3	4.5	6.8	10	534.14	1238	711	2.349	2.51	6.34	10.07	16.41	61.35	2.9	1536
1	5.0	6.9	10	541.99	1247	718	2.357	2.49	5.33	11.23	16.56	67.78	2.8	2304
2	5.0	6.9	10	541.99	1235	709	2.348	2.49	5.71	11.18	16.89	66.19	3.1	2080
3	5.0	6.8	10	534.14	1257	728	2.376	2.49	4.58	11.32	15.89	71.21	2.9	1971.2
1	5.5	6.8	10	534.14	1245	710	2.327	2.47	5.87	12.19	18.06	67.49	3.8	1504
2	5.5	6.8	10	534.14	1256	726	2.370	2.47	4.14	12.41	16.56	74.97	3.5	1792
3	5.5	6.8	10	534.14	1257	728	2.376	2.47	3.89	12.45	16.33	76.20	3.2	2080

1	6.0	6.7	10	526.28	1267	732	2.368	2.45	3.52	13.53	17.05	79.35	4.9	2336
2	6.0	6.7	10	526.28	1254	728	2.384	2.45	2.88	13.62	16.50	82.56	4.65	1504
3	6.0	6.7	10	525.28	1252	696	2.252	2.45	8.27	12.87	21.13	60.89	4.4	1939.2
1	6.5	6.7	10	526.28	1243	706	2.315	2.44	5.03	14.33	19.36	74.01	5.8	1472
2	6.5	6.6	10	518.43	1257	718	2.332	2.44	4.32	14.44	18.75	76.98	4.25	1600
3	6.5	6.6	10	518.43	1254	720	2.348	2.44	3.65	14.54	18.19	79.92	4.5	1536

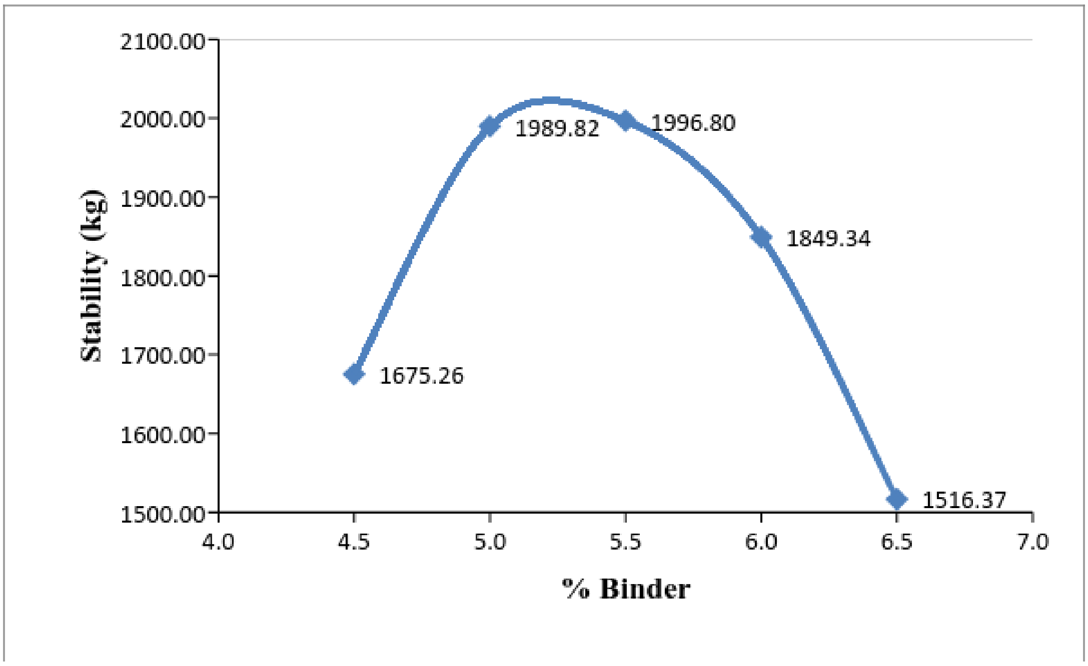


Figure 4.1: Binder content(%) Vs Stability (kg) VG – 40

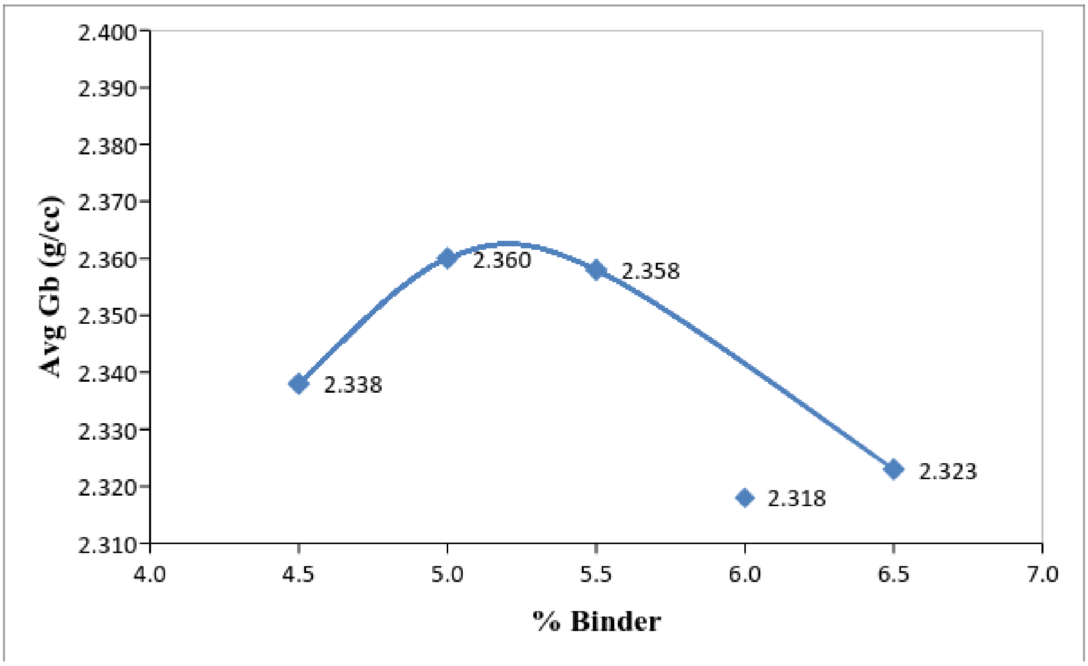


Figure 4.2: Binder content(%) Vs Gb (g/cc) VG – 40

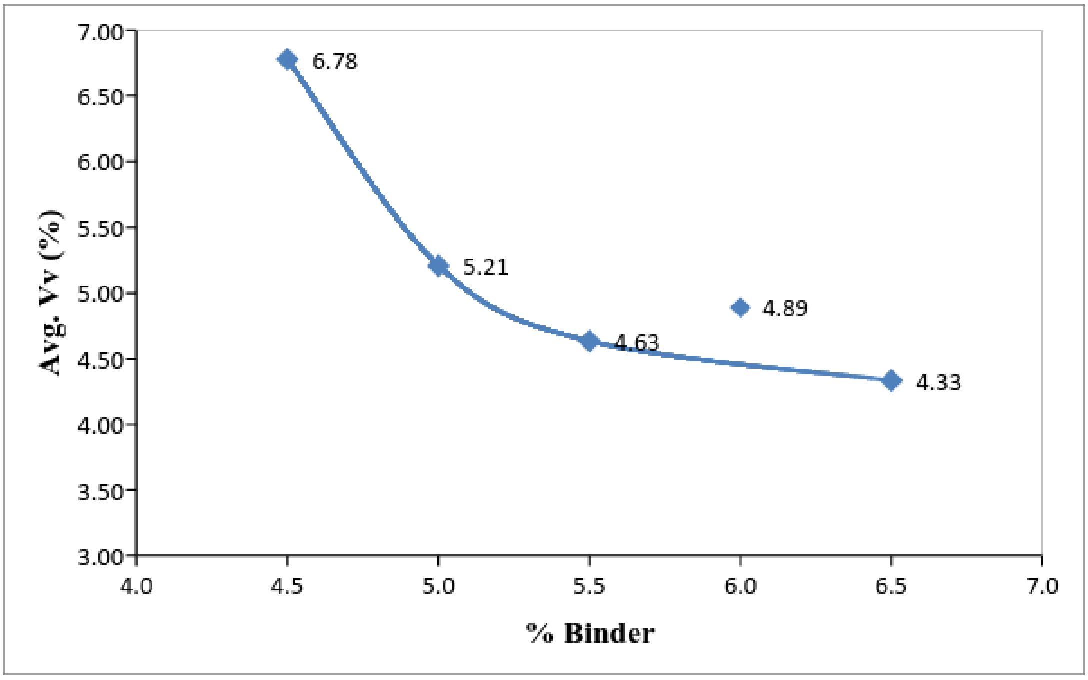


Figure 4.3: Binder content(%) Vs Avg. Vv (%)VG – 40

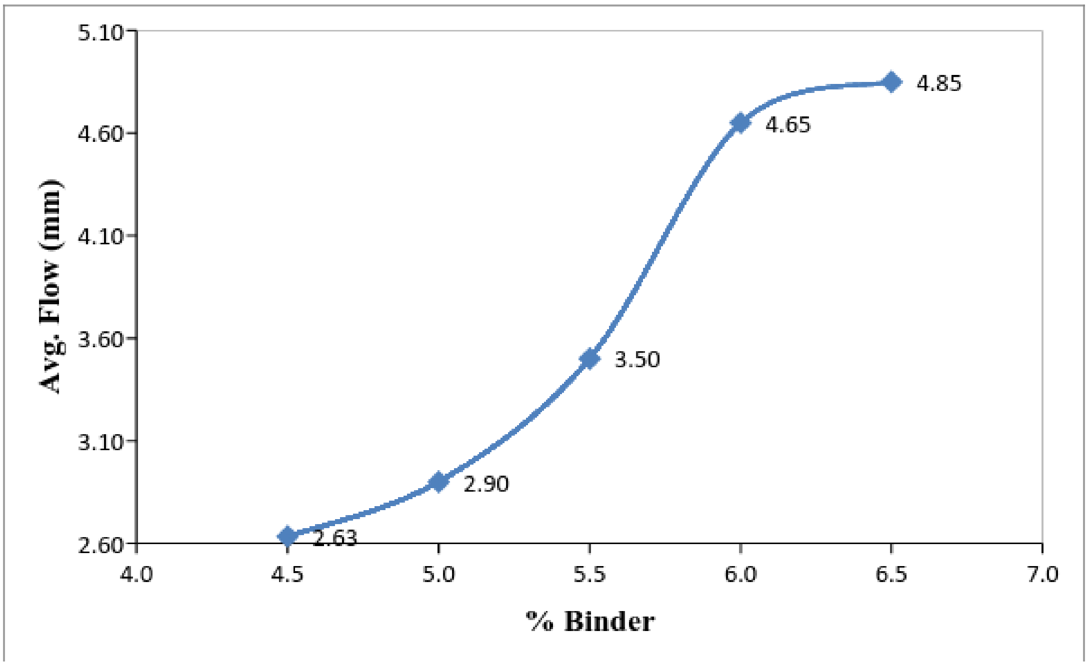


Figure 4.4: Binder content(%) Vs Avg.Flow (mm) VG – 40

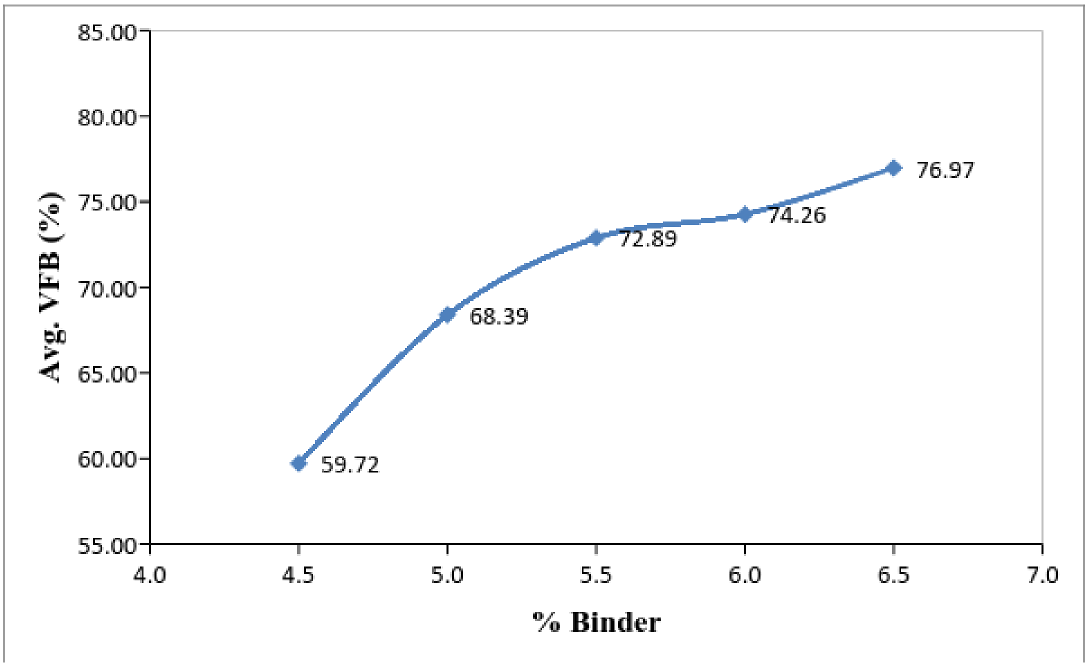


Figure 4.5: Binder content(%) Vs Avg. VFB (%)VG – 40

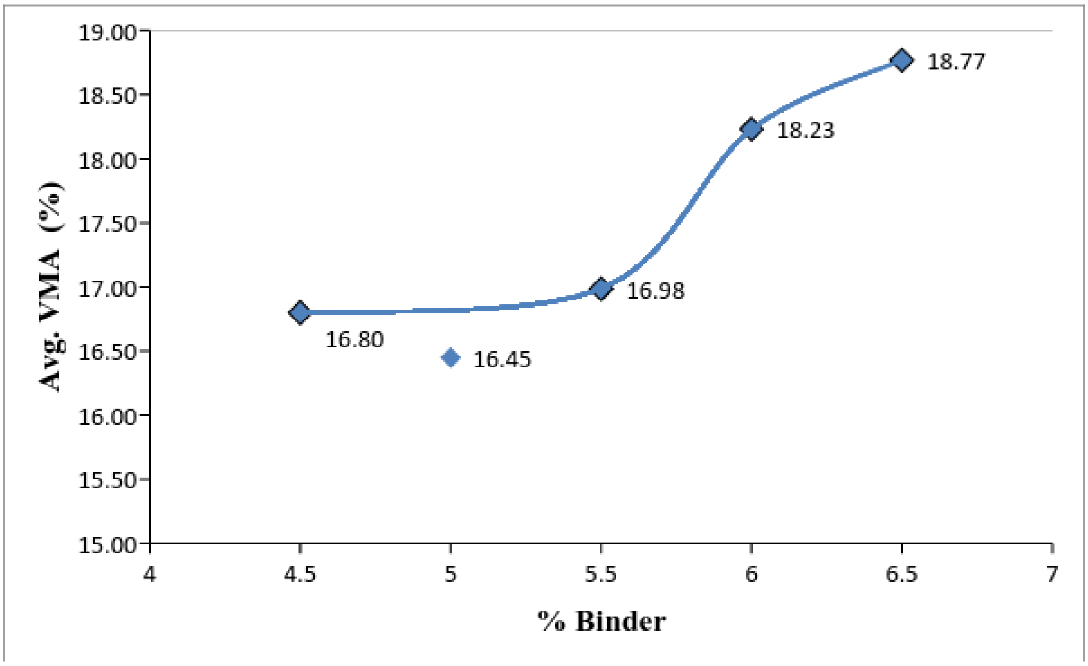


Figure 4.6: Binder content(%) Vs Avg. VMA (%)VG – 40

4.4 MARSHALL STABILITY VALUES OF CRUMB RUBBER MODIFIED BITUMEN

The present study was undertaken to determine the effect of different sizes of crumb rubber on the physical properties of bituminous mixes. Improper sizes of mix may affect its performance. Thus this study was envisaged to bring about awareness in the field engineers about the lapse in following temperature timelines and its effect on deterioration in stability and other physical properties. Accordingly crumb rubber sizes was varied at predetermined OBC i.e Marshall Specimens were prepared at 170°C for the types of binders and tested for Marshall Stability.

The results of the same are tabulated in the following table.

Table 4.4: calculation of volumetric properties and average stability for CRMB

Trial no	Rubber size(mm)	Bitumen (%)	Unit weight	Stability (kg)	Flow (mm)	Air voids(%)	VMA(%)	VFB(%)	Avg. stability
1		5.5	2.32	1422.18	3.37	4.62	18.82	81.05	
2	2.36 - 1.6	5.5	2.3105	1527.14	3.365	4.612	18.831	82.01	1455.08
3		5.5	2.331	1425.94	3.3812	4.595	18.8	82.32	
1		5.5	2.315	1772.58	3.98	4.215	18.93	81.29	
2	1.6 - 1.18	5.5	2.398	1668.29	3.947	4.189	18.981	81.46	1701.75
3		5.5	2.314	1674.38	3.962	4.265	18.942	82.024	
1		5.5	2.29	1658.04	4.18	3.99	19.21	79.213	
2	1.18 - 0.6	5.5	2.3015	1768.96	4.145	4.02	19.103	79.25	1794.71
3		5.5	2.295	1549.14	4.172	4.16	19.414	80.143	
1		5.5	2.28	1912.85	4.27	3.96	19.81	76.58	
2	0.6 - 0.3	5.5	2.27	2015.92	7.265	3.95	19.83	76.9	2015.96
3		5.5	2.265	2120.03	4.275	3.9702	20.14	77.04	

CONCLUSIONS

1. All the values obtained from the physical test on aggregates (impact test, crushing test, water absorption test) are within the limits given by the MoRT & H requirements.

2. The values obtained from the physical test on bitumen VG-40 (penetration test, softening point test, ductility test) are within the limits specified by IRC SP:53-2002 and IS: 73-2000.

3. By studying the test results of the conventional bitumen and the crumb rubber modified bitumen it is concluded that the penetration value and the softening value of the conventional bitumen can be improved significantly by modifying it with addition of the crumb rubber which is a major environment pollutant.

4. It can be observed that the sample prepared using crumb rubber size (600µm-300µm) gives the highest stability value , minimum air voids ,minimum flow value, maximum unit weight and minimum VMA and VFB % values. So the best size to be used for

crumb rubber modifications can be suggested as (600µm- 300µm) size for commercial production of crumb rubber.

4 CHAPTER : REFERENCES

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