LABORATORY INVESTIGATIONS OF DENSE BITUMINOUS MACADAM (GRADE 1) MIX USING DIFFERENT TYPES OF ADDITIVES

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IN

CIVIL-INFRASTRUCTURE ENGINEERING

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DECLARATION

The author hereby declares that this thesis entitled **"Laboratory Investigations of Dense Bituminous Macadam (Grade 1) Mix Using Different Types Of Additives"**, in whole or part, has not been used to obtain any degree in this, or any other, institute. Except where references have been given in text, it is entirely the authors own work.

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CERTIFICATE

This is to certify that the thesis entitled **"Laboratory Investigations of Dense Bituminous Macadam (Grade 1) Mix Using Different Types Of Additives"**, being submitted by **Mr. KARAN GUPTA, Roll No 801123003** in partial fulfilment for the award of degree of **Masters of Engineering in Infrastructure Engineering** at **Thapar University, Patiala** is a bonafide work carried out by him under our guidance and supervision and that no part of this thesis has been submitted for the award of any other degree.

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(Karan Gupta)

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ABSTRACT

India has a road network of over 4,236,000 kilometres, the third largest in the world. The road transport carries close to 85% of passenger traffic and 70% of freight transport. The properties of bitumen and bituminous mixes can be improved to meet requirements of any pavement with the incorporation of certain additives or a blend of additives. Bituminous mixes can be prepared and used in a pavement section for a bituminous binder course using different types of additives such as Polymers, Crumb Rubber and waste materials like discarded tube tyres, plastic bottles and rice husk ash. Modified bituminous mixes are expected to give higher life of surfacing depending upon degree of modification and type of additives used.

The consumption of plastics is increasing day by day. Nearly 50 to 60% of the total plastics are consumed for packing. Once used plastic materials are generally thrown out as they do not undergo bio-decomposition. Hence, they are either land filled or incinerated. Both are not eco-friendly processes as they pollute the land and the air. Similarly, waste tyres in India are categorized as solid hazardous waste. It is estimated that about 60% of waste tyres are disposed via unknown routes in the urban as well as rural areas. The hazards of waste tyres include- air pollution associated with open burning of tyres, aesthetic pollution caused by waste tyre stockpiles and illegal waste tyre collecting and other impacts such as alterations in hydrological regimes when gullies and watercourses become waste sites.

The present study aims at developing bituminous mixes for the Dense Bituminous Macadam (DBM) Grade 1 incorporating the plastic wastes, waste tyre tubes and rice husk ash as partial replacement of the bitumen content. Also the study focuses on the DBM Grade 1 mixes with different blends by using Crumb Rubber Modified Bitumen (CRMB) and Polymer Modified Bitumen (PMB). In this study, the Stability-Flow analysis for the various DBM Grade 1 mixtures with modified binders and with different percentage replacement of bitumen with plastic wastes, waste tyre tubes and rice husk ash are reported. It is found that of the three materials used, replacement of OBC by 10% discarded tyre tube has the highest stability value. The optimum content of CRMB and PMB for use in DBM Grade 1 mix is 5%. Also the bituminous mixes of DBM Grade 1 with 5% PMB having 40% stone dust shows the maximum stability value and the bituminous mixes of DBM Grade 1 with 5% CRMB having 44% stone dust shows the maximum stability value.

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CHAPTER -1
INTRODUCTION

1.1 GENERAL

The quality of roads dictates the economy of a country and hence the quality of our life's. Roads are vital for the transport of the goods and passengers. In India, road transport carries approximately 85% of passenger traffic and 70% of freight transport. But the construction of highways involves huge amount of the investment and mainly sixty percent of the highway project cost is associated with the pavement construction. Pavement is a durable surfacing of a road, airstrip, or similar area and the primary function is to transmit loads to the sub-base and underlying soil subgrade. Around ninety percent of the Indian Highways have a covered surface with bituminous layers which are constructed and maintained by using naturally available road aggregates and bitumen, a petroleum product, which being mixed at high temperatures to produce hot mix asphalt. Mix design for the different layers of the pavement can have a major impact on the performance, cost and sustainability of the bituminous surfaces.

1.2 FLEXIBLE PAVEMENT

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out and then passes these loads to the next layer below. Typical flexible pavement structure shown in plate 1.1 consisting of:-

a) Surface course: This is the top layer and the layer that comes in contact with traffic. It may be composed of one or several different HMA sub-layers. HMA is a mixture of coarse and fine aggregates and asphalt binders with or without additives.

b) Base course: This is the layer directly below the HMA layer and generally consists of aggregate (either stabilized or un-stabilized).

c) Sub-base course: This is the layer (or layers) under the base layer. A sub-base is not always needed.

d) Subgrade course: The subgrade is the material upon which the pavement structure is placed. Although there is a tendency to look at pavement performance in terms of pavement crust structure material, mix design and thickness but the sub-grade can often be the overriding factor in the overall pavement performance. The CBR value of the subgrade material is generally used to design the total pavement crust thickness as per IRC: 37-2012 guidelines.

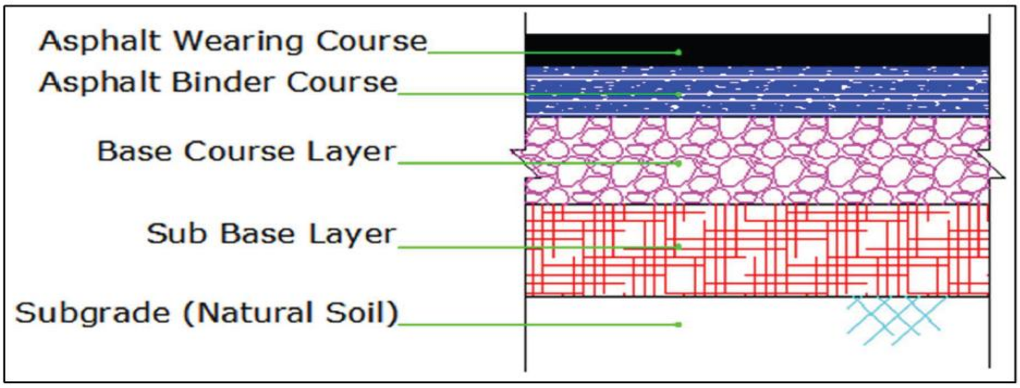

Plate no 1.1: Different layers of the Flexible Pavement Section

A flexible pavement structure is typically composed of several layers (as shown in plate no 1.1) of material with better quality materials on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where the stress intensity is low. Flexible pavements can be analyzed as a multilayer system under loading and are constructed by using different layers such as Bituminous concrete (BC), Dense Bituminous Macadam (DBM), Bituminous Macadam (BM), Wet Mix Macadam (WMM) and Granular Subbase (GSB) as per the MORTH specifications with the designed thickness as per the IRC: 37-2012 have shown in plate no 1.2.

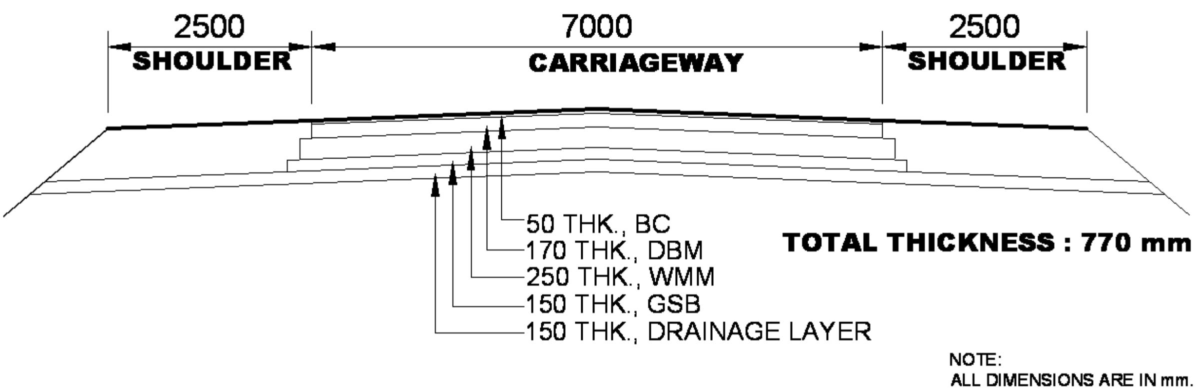

Plate no 1.2: - Section of Flexible Pavement designed as per IRC: 37-2012

1.3 BITUMINOUS MIXES FOR FLEXIBLE PAVEMENT LAYERS

Bituminous mixes are composite materials that consist of a binder mixed with filler/fines (together with bitumen called the mastic) and aggregates .The mixes of asphalt pavements consist of bituminous binder that connect between the filler together and the aggregates.

In India, MORTH Specifications provides different mix specifications for base courses, binder courses and for wearing courses. The major properties in bituminous paving mixtures are stability, flow, durability, flexibility and skid resistance (in the case of wearing surface). Traditional mix design methods are established to determine the optimum a binder content that would perform satisfactorily, particularly with respect to stability and flow values. Selection of the components and their relative proportions are influenced by the pavement section in which the mix is to be incorporated.

Design of bitumen-aggregate mixes for the different layers broadly consists of the following steps:

- Selection of the type and gradation of the mineral aggregates.
- Selection of the type and grade of binder.
- Selection of the amount of binder to satisfy the project specific requirements for mix properties.

The properties of bituminous mixes can be improved, making it more durable, cost effective and much more sustainable by adding polymers, plastics and various other additives. Various forms of modifications of the physical properties of bitumen and stability of bituminous mixes can be evolved using different materials like crumb rubber, waste plastics, rice husk ash, mineral fillers, fly ash and different types of the polymers.

1.4 DENSE BITUMINOUS MACADAM MIX

Dense bituminous macadam is mainly used as binder course for roads having much higher number of heavy commercial vehicles. In DBM mix there is a wide scope of varying the gradation to obtain the good mix without affecting the durability of pavement. Achieving adequate compaction of bituminous mixes is crucial to the performance of flexible pavement. Normally Marshall Mix design method is adopted for mix design of Dense Graded Bituminous Macadam, (DBM). DBM is also intended for use as road base material. The construction work of DBM consists of construction in a single layer of DBM on a previously prepared base or sub-base layer as shown in plate 1.3 and plate 1.4.

1.5 MATERIAL SPECIFICATIONS FOR DBM MIX

1.5.1 Bitumen

The bitumen for the DBM is a paving bitumen of penetration Grade complying with Indian Standard Specifications for "Paving Bitumen" IS: 73, and of the penetration specified by MOSRT&H Specifications for Road and Bridge Works (Fourth Revision) Re-print March 2007 for Dense Bituminous Macadam.

1.5.2 Coarse Aggregates

The coarse aggregates for the DBM mix consists of crushed rock, crushed gravel or other hard material retained on the 2.36 mm sieve. Aggregates should be clean, hard, and durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious substances. Where the Contractor's selected source of aggregates have poor affinity for bitumen, as a condition for the approval of that source, the bitumen shall be treated with an approved anti -stripping agent, as per the manufacturer's recommendations, without additional payment. Before approval of the source, the aggregates should be attested for stripping. The aggregates should satisfy the physical requirements as specified in Table 1.1 (Ref: MOSRT&H Specifications for Road and Bridge Works (Fourth Revision) for Dense Bituminous Macadam.).

1.5.3 Fine Aggregates

Fine aggregates for DBM consists of crushed or naturally occurring mineral material or a combination of the two, passing the 2.36mm sieve and retained on the 75 micron sieve. Aggregates should be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter.

1.5.4 Filler

Filler for the DBM consists of finely divided mineral matter such as rock dust, hydrated lime or cement. The filler should be graded within the limits indicated in Table 1.2

Table 1.1 Physical Requirements of Coarse Aggregate for Dense Bituminous Macadam [MORTH, Clause 507.2.2]

PROPERTY	TEST	SPECIFICATION
CLEANLINESS	GRAIN SIZE ANALYSIS	MAX 50% PASSING 0.075MM SIEVE
PARTICLE SHAPE	FLAKINESS AND ELONGATION INDEX	MAX30%
STRENGTH	LOS ANGELES ABRATION VALUE AGGREGATE IMPACT VALUE	MAX35% MAX27%
DURABILITY	SOUNDNESS SODIUM SULPHATE MAGNESIUM SULPHATE	MAX 12% MAX18%
WATER ABSORPTION	WATER ABSORPTION	MAX 2%
STRIPPING	COATING AND STRIPPING BITUMEN AGGREGATE MIXTURES	MINIMUM RETAINED COATING 95%
WATER SENSTIVITY	RETAINED TENSILE STRENGTH	MIN 80%

Table 1.2 Requirements of Mineral Filler [MORTH, Clause 507.2.4]

IS SIEVE (MM)	CUMULATIVE PERCENT PASSING BY WEIGHT OF AGREEGATE
0.6	100
0.3	95-100
0.075	85-100

1.5.5 Aggregate Grading and Binder Content:

When tested in accordance with IS: 2386 Part 1, the combined grading of the coarse and fine aggregates and added filler for the particular mixture should fall within the limits shown in Table1.3 , for Dense Bituminous Macadam grading 1 or 2. The type and quantity of bitumen, and appropriate thickness, are also indicated for each mixture type.

Table 1.3: Gradation of Dense Bituminous Macadam [MORTH, Clause 507.2.5]

MORTH SPECIFIED GRADATION FOR DENSE BITUMENOUS MACCADAM		
Grading	1	2
Thickness	80-100 mm	50-75 mm
Nominal Aggregate Size	40mm	25 mm
Sieve, mm		
45	100	
37.5	95-100	100
26.5	63-93	90-100
19		71-95
13.2	55-75	56-80
9.5		-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen Content, %	Min.4	Min. 4.5

1.5.6 Mixture Design

Apart from conformity with the grading and quality requirements for individual ingredients as explained above, the mixture should meet the requirements set out in Table 1.4.

Table 1.4 Requirements of DBM Mix [MORTH, Clause 507.3.1]

MINIMUM STABILITY (KN AT 60DEGREE C)	20.25
MINIMUM FLOW(mm)	3
MAXIMUM FLOW(mm)	6
COMPACTION LEVEL (NUMBER OF BLOWS)	112 BLOWS ON EACH OF TWO FACES OF THE SPECIMEN
PERCENT AIR VOIDS	3-6.
PERCENT VOIDS IN MINERAL AGGREGATE(VMA)	As PER TABLE 1.5 BELOW
PERCENT VOIDS FILLED WITH BITUMEN (VFB)	65-75

The requirements for minimum per cent voids in mineral aggregate (VMA) should be as per Table 1.5

Table 1.5 Minimum Percent Voids in Mineral Aggregate [MORTH, Clause 507.3.1]

NOMINAL MAXIMIUM PARTICLE SIZE	MINIMUM VMA PERCENT RELATED TO DESIGN AIR VOID PERCENT		
	3 %	**4%**	**5%**
9.5	14	15	16
12.5	13	14	15
19	12	13	14
25	11	12	13
37.5	10	11	12

1.5.7 Binder Content

The binder content should be optimized to achieve the requirements of the mixture set out in Table 1.3 and as per the traffic conditions. The Marshall method for determining the optimum binder content should be adopted.

Where 40 mm dense bituminous macadam mixture is specified, the modified Marshall method described in Asphalt institute Manual Series (MS-2) should be used. This method requires modified equipment and procedures; particularly the minimum stability values in Table 1.4 shall be multiplied by 2.25 and the minimum flow shall be 3 mm.

1.6 ADDITIVES IN THE BITUMINOUS MIXES

1.6.1 Polymers

A polymer is a large molecule (macromolecule) composed of repeating structural units typically connected by covalent chemical bonds. While polymers, in popular usage, suggest plastic, the term actually refers to a large class of natural and synthetic materials with a variety of properties. Well-known examples of polymers include plastics, proteins and elastomers, which include the natural and synthetic rubbers.

Plate 1.3: Laying of DBM mix at site.

Plate 1.4: Final view of compacted layer of DBM

Rubbers and many resins are natural polymers found in plants. Chemists discovered that polymers were made up of repeating units; hence, they were able to synthesize polymers from small organic molecules .Consequently, synthetic polymers, which are commonly called plastics, are made available for use in science and engineering fields.

a) Classification of Polymer Modified Bitumen

The polymer and rubber modified bitumen's are classified into four types as given below:

a) Type A PMB (P) — Plastomeric Thermoplastics

b) Type B PMB (E) — Elastomeric Thermoplastics

c) Type C NRMB — Natural Rubber and Latex Based.

d) Type D CRMB — Crumb Rubber/ Treated Crumb Rubber.

Type A, Type B and Type C can be further classified into three grades according to their penetration value and Type D can be further classified into three grades according to their softening point values as given below:

GRADES OF PMB (P)

- **PMB (P) 120**: PMB (P) 120 means that Type A PMB (P) with penetration value in between 90 to 150.
- **PMB (P) 70:** PMB (P) 70 means that Type A PMB (P) with penetration value in between 50 to 90.
- **PMB (P) 40:** PMB (P) 40 means that Type A FMB(P) with penetration value in between 30 to 50.

GRADES OF PMB (E)

- **PMB (E) 120:** PMB (E) 120 means that Type B PMB (E) with penetration value in between 90 to 150.
- **PMB (E) 70:** PMB (E) 70 means that Type B PMB (E) with penetration value in between 50 to 90.
- **PMB (E) 40:** PMB (E) 40 means that Type B PMB (E) with penetration value in between 30 to 50.

GRADES OF NRMB

- **NRMB 120**: NRMB 120 means that Type C NRMB with penetration value in between 90 to 150.

- **NRMB70**: NRMB 70means that Type C NRMB with penetration value in between 50 to 90.
- **NRMB 40**: NRMB 40means that Type C NRMB with penetration value in between 30 to 50.

GRADES OF CRMB

- **CRMB 50**: CRMB 50 means Type D CRMB having minimum softening point value of 50.
- **CRMB 55**: CRMB 55 means Type D CRMB having minimum softening point value of 55.
- **CRMB 60**: CRMB 60 means Type D CRMB having minimum softening point value of 60.

1.6.2 Crumbed Rubber Modified Bitumen (CRMB)

Over the years, road structures have deteriorated more rapidly due to increases in service traffic density, axle loading and low maintenance services. To minimise the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved with regards to performance related properties, such as resistance to permanent deformation (rutting) and fatigue cracking. The modification of bituminous binder has been explored over the past years in order to improve road pavement performance properties. 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). The use of commercial polymers, such as SBS and SBR in road and pavement construction will increase the construction cost as they are highly expensive materials. However, with the use of alternative materials, such as CRMB, will definitely be environmentally beneficial, and not only it can improve the bitumen binder properties and durability, but it also has a potential to be cost effective. In recent times, a serious problem that leads to environment pollution is the abundance and the increase of waste tyre disposal. Large amounts of rubbers are used as tyres for cars and trucks. Despite the long run in service, these tyres are not discarded.

In recent years, researches on applications of rubberised bitumen binders have reported many advent-ages. These advantages include improved bitumen resistance to rutting due to high viscosity, high softening point and better resilience, improved bitumen resistance to surface initiated cracks, the reduction of fatigue/ reflection cracking, the reduction of temperature susceptibility, improved durability as well as the reduction in road pavement maintenance costs .

1.6.3 Plastic Waste

Plastic is everywhere in today's lifestyle. It is used for packaging, protecting, serving, and even disposing of all kinds of consumer goods. With the industrial revolution, mass production of goods started and plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, communication or info tech has been virtually revolutionized by the applications of plastics. Use of this non-biodegradable (according to recent studies, plastics can stay unchanged for as long as 4500 years on earth) product is growing rapidly and the problem is what to do with plastic-waste. Studies have linked the improper disposal of plastic to problems as distant as breast cancer, reproductive problems in humans and animals, genital abnormalities and even a decline in human sperm count and quality. If a ban is put on the use of plastics on emotional grounds, the real cost would be much higher, the inconvenience much more, the chances of damage or contamination much greater. The risks to the family health and safety would increase and, above all the environmental burden would be manifold. Hence the question is not 'plastics vs no plastics' but it is more concerned with the judicious use and re-use of plastic-waste.

Advantages of Using Waste Plastic as a Modifier

- It easily binds the coarse aggregate at normal temperature.
- It doesn't require any change in road laying practice.
- The material is available locally in form of shredded, which is presently treated as waste.

The processes make use of plastic bags in shredded form. The disposal of waste plastics, which is environmental program, is thereby eliminated

1.6.4 Rice Husk Ash

Rice milling generates a by product know as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice, broken rice and bran.

Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash.

Rice husk is an agricultural residue abundantly available in rice producing countries. The annual rice husk produce in India amounts is generally approximately 12 million tons. Rice husk is generally not recommended as cattle feed since its cellulose and other sugar contents are low. Furfural and rice bran oil are extracted from rice husk. Industries use rice husk as fuel in boilers and for power generation. Among the different types of biomass used for gasification, rice husk has a high ash content varying from 18 –20 %. Silica is the major constituent of rice husk ash .Silica is about 80%to 90% of the total mass of rice husk ash .With such large ash content and silica content in the ash it becomes economical to extract silica from the ash, which has wide market and also takes care of ash disposal.

Applications of Rice Husk Ash:-

- Aggregates and fillers for Concrete and Board Production
- Economical Substitute for Micro Silica / Silica Fumes
- Absorbents for Oils and Chemicals
- Soil Ameliorants (An Ameliorant Is Something That Helps Improve Soil Drainage, Slows Drainage, Breaks Up Soil Or Binds Soil, Feeds And Improves Structure Etc.)
- As a Source of Silicon
- As Insulation Powder in Steel Mills
- As Repellents in the Form Of "Vinegar-Tar"
- As a Release Agent in the Ceramics Industry
- As an Insulation Material for Homes and Refrigerants

CHAPTER - 2

LITERATURE REVIEW

2.1 GENERAL

The relevant literature pertaining to the use of various additives in the bituminous mixes carried out in India and abroad has been reviewed and presented in succeeding sections.

2.2 USE OF PLASTIC WASTE IN BITUMINOUS MIXES

Justo et al (2002), at the Centre for Transportation Engineering of Bangalore University on the possible use of the processed plastic bags as an additive in bituminous concrete mixes. The properties of the modified bitumen were compared with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 % by weight. Therefore the life of the pavement surfacing course using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen.

Surendra et al (2008) used waste plastic for modification of bituminous concrete. Marshall Method was adopted to find out optimum binder content. Marshall specimen were prepared for bitumen content 5,5.5,6,6.5 percent by weight of aggregate with 6%,10%,14% and 18% waste plastics by weight of bitumen. The Marshall Stability values increased by 18%, 45%, 18% for the mix with 10%, 14%, 18% waste plastics.

Sheeb et al (2007), concluded that the modified mixture has a higher stability and VMA (Void in Mix Aggregate) percentage compared to the non-modified mixtures. This, in returns, would positively influence the rutting resistance of these mixtures. The air void contents of the modified mixtures are not far from that of the non-modified one. Air void proportion around4% is not enough to provide room for the expansion of asphalt binder to prevent bleeding or flushing that would reduce the skid resistance of the pavement and increase rutting susceptibility. In summary, using the poly-ethylene in asphalt mixtures reduces pavement deformation; increase fatigue resistance and provide better adhesion between the asphalt and the aggregates.

Rokade S (2012) made an attempt to use waste plastic, Low Density Polyethylene (LDPE) and Crumb Rubber, blended using dry process for LDPE and wet process for

CRMB. Marshal method of bituminous mix design was carried out for varying percentages of LDPE and Crumb Rubber to determine the different mix design characteristics. The study on the use of LDPE and CRMB reveals that the Marshal Stability value, which is the strength parameter of SDBC has shown increasing trend.

Tapkın (2010) presents an application of neural networks (NN) for the prediction of Marshall Test results for polypropylene (PP) modified asphalt mixtures. PP fibres are used to modify the bituminous binder in order to improve the physical and mechanical properties of the resulting asphaltic mixture. Marshall Stability and flow tests were carried out on specimens fabricated with different type of PP fibres and also waste PP at optimum bitumen content. It has been shown that the addition of polypropylene fibres results in the improved Marshall Stabilities and Marshall Quotient values.

Shiva Prasad K,(2012) In the present study, the importance was to add the shredded waste plastic bottles to bituminous concrete (BC) mix and to evaluate the various mix properties like Marshall Stability, flow, bulk density, voids in the mix and VFB. Also the effect of soaking conditions of the mix was investigated. Indirect tensile strength investigated for OBC and 8% plastic coated on aggregates which had yielded the highest marshal stability. The optimum plastic content for 60/70 and 80/100 grade bitumen was 8%

Al-Hadidy (2009) Investigates the potential use of low density polyethylene (LDPE) as a modifier for asphalt paving materials. Five different blends including conventional mix were subjected to binder testing such as rheological tests, as well as to some other tests related to the homogeneity of the system. Further, its effect on the moisture sensitivity and low temperature performance of stone matrix asphalt (SMA) mixtures was studied. Research results indicate that modified binders showed higher softening point, keeping the values of ductility at minimum range of specification of (100cm), and caused a reduction in percentage loss of weight due to heat and air (i.e. increase durability of original asphalt)

2.3 USE OF CRMB IN BITUMINOUS MIXES

Shankar et al (2009), crumb rubber modified bitumen (CRMB 55) was blended at specified temperatures. Marshall's mix design was carried out by changing the modified bitumen content at constant optimum rubber content and subsequent tests have been performed to determine the different mix design characteristics and For conventional bitumen (60/70) also. This has resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67%).

Reddy et al. (2006) Marshall's mix design was carried out by changing the CRMB content at and subsequent tests have been performed to determine the different mix design characteristics and concluded that the fatigue life, temperature susceptibility and resistance to moisture damage characteristics of the bituminous mixes can be improved by the use of CRMB as compared to other unmodified bitumen.

Chiu and Lu (2007) investigated the feasibility of using Asphalt Rubber (AR) as a binder for SMA. They produced this AR by blending ground tire rubber (GTR) with AC-20 asphalt. They termed it as AR-SMA. The performance of AR-SMA was evaluated in terms of moisture susceptibility. It was found that the AR-SMA mixtures were not significantly different from the conventional SMA mixtures in terms of moisture susceptibility. It was also observed that no fibre was needed to prevent drain down when this AR is used in the mix.

Ahmet (2005) The Taguchi method was used to determine optimum conditions for tire rubber in asphalt concrete with Marshall Test. The tire rubber in asphalt concrete was explored under different experimental parameters including tire rubber gradation,
Mixing temperature, aggregate gradation, tire rubber ratio (0–10% by weight of asphalt), binder ratio (4–7% by weight of asphalt), compaction temperature (110–1351C), and mixing time (5–30min). The optimum conditions were obtained for tire rubber gradation (sieve #40), mixing temperature (1551C), aggregate gradation (grad. 1), tire rubber ratio (10%), binder ratio (5.5%), compaction temperature (1351C), mixing time (15min).

Kumar (2010) Investigates to improve the mechanical properties of asphalt mixes, additives are added to the base asphalt binder. These binders are called modified asphalt binders. The objectives of the present study are to compare the performance of asphalt mixes with different binders by two different mix design methods and to optimize the asphalt binder type to achieve the desired performance. Two methods of mix design namely, Marshall and Super pave mix design methods are considered. The performances of asphalt mixes viz., tensile strength, moisture damage, densification and rutting resistance were compared. The results indicated a statistically significant difference in the optimum asphalt binder content from the two mix design methods.

The Marshall method of asphalt mix design is found to yield lower optimal asphalt binder content when compared to the Super pave method of mix design. The moisture susceptibility and construction densification index of asphalt mixes designed using Super pave method were found to be significantly lower than that of the mixes designed by Marshall method. Optimization using a Mixed Integer Linear Program (MILP) indicated that the polymer modified asphalt binder outperforms the requirements of engineering properties when compared to other commercial binders used in the study.

2.4 USE OF PMB IN BITUMINOUS MIXES

Awwad et al (2007), polyethylene as one sort of polymers is used to investigate the potential prospects to enhance asphalt mixture properties. The objectives also include determining the best type of polyethylene to be used and its proportion. Two types of polyethylene were added to coat the aggregate High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE). The results indicated that grinded HDPE polyethylene modifier provides better engineering properties. The recommended proportion of the modifier is 12% by the weight of bitumen content. It is found to increase the stability, reduce the density and slightly increase the air voids and the voids of mineral aggregate.

Putman et al. (2004) used a performance grade binder PG 76-22 to study the SMA properties. Marshall's mix design was carried out by changing the bitumen content at constant and subsequent tests have been performed to determine the different mix design characteristics .They observed that polymer modified bitumen gives better performance (in terms of deformation) than unmodified bitumen.

2.5 USE OF OTHER ADDITIVES IN BITUMINOUS MIXES

Stuart (1996) studied the effect of mineral fillers on properties of SMA mixtures. They chose eight mineral fillers on the basis of their performance, gradation etc. They evaluated the properties of SMA mixtures in terms of drain down of the mastic, rutting, low temperature cracking, workability, and moisture susceptibility.

Hassan et al (2010) studied effect of using waste glass power as mineral filler on Marshall property of SMA by comparing with SMA where lime stone, ordinary Portland cement was taken as filler with varying content (4-7%). Marshall's mix design was carried out by changing the lime stone, ordinary Portland cement content at and subsequent tests have been performed to determine the different mix design characteristics

Mallick (1994) used viscosity grade binder AC-20 for their research on SMA properties related to mixture design. Marshall's mix design was carried out by changing the Binder Content and subsequent tests have been performed to determine the different mix design characteristics.

CHAPTER-3

MIX DESIGN PROCEDURE & INGREDIENT TESTING FOR DBM 1

3.1 MODIFIED MARSHALL TEST FOR DBM GRADE I

Marshall Mix design is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. In India, it is a very popular method of characterization of bituminous mixes. In this study also, the Marshall method was used to determine the Optimum Binder Content (OBC) for the different mixes and to study other Marshall Characteristics such as Marshall Stability, flow value, unit weight, air voids in a mixture. The Marshall properties such as stability, flow value, unit weight and air voids were calculated to determine the optimum binder contents (OBC). The volumetric analysis of the Marshall Mix samples was carried out by using the procedure reported by Das and Chakroborty (2003).

3.2 APPARATUS DETAILS

a) A mechanical compaction hammer having a flat, circular tamping face with a nominal diameter of 149.4 mm and a10.21±0.01 kg sliding weight with a free fall of 457.2±2.5mm.

b) The compaction pedestal shall consist of a 203.2mm by 203.2mm by 457.2mm wooden post capped with a 304.8mmby304.8mmby25.4mm steel plate. The steel caps should be firmly fastened to the post. The wooden post shall have a dry weight of 673to 769kg/m3 was rests squarely on a solid concrete slab.

c) Oven for heating bituminous mixtures and specimen mould assemblies at required temperature.

d) Hot plate for heating compaction hammer, spoon, and spatula.

e) A flat spatula with blade approximately 25 mm wide and at least 150mm long, stiff enough to penetrate the entire bituminous mixture.

f) Thermometer for determining temperatures of bituminous mixtures. Armoured glass thermometers or dial-type with metals tem with arrange of10to 200°C are recommended. Thermometers shall have increments of not greater than 2.8°C.

g) A balance or scale capable of measuring the maximum weight to be determined, except there sensitivity of any balance or scale utilized shall be at least one gram.

h) Large spoon for placing mixtures in specimen moulds.

i) Marshall stability and flow was determined by using the following apparatus:

- Breaking head consisting of upper and lower cylindrical segment shortest heads. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion the guide rods. When a 152.4 ± 3.1 mm diameter by 100mm thick metal block is placed between the two segments.
- Water bath of sufficient depth to provide for the complete immersion of specimens and thermostatically controlled so as to maintain the bath at 60±1°C.. The tank should have a perforated false bottom or be equipped with a shelf for supporting specimens 50.8 mm above the bottom of the bath.
- Marshall Stability and flow testing apparatus is capable of applying a load with a constant rate of travel of50.8±2.5 mm per minute.
- Height gauge capable of measuring the height of specimens to the nearest 0.1 mm.

3.3 PROCEDURE OF SAMPLE PREPERATION

a) Approximately 4050g of the ingredients were taken to prepare each mould of the DBM mix. The weight of the mix was taken in such a manner that compacted specimens of DBM should have height in between 88.9 to 101.6mm.

b) Before placing in the mould, the mixture and a mould assembly (base plate, mould and collar) was approximately143°C. The face of the compaction hammer was thoroughly cleaned and heated on a hot plate set at approximately143°C. The temperature of the laboratory during compaction of the specimens was between 20and30°C.

c) Place a 152.4mm diameter paper disc in the bottom of the mould before the mixture is introduced. Place approximately one-half of the batching the mould with a heated spoon. Spade the mixture vigorously, penetrating the entire mixture, with the heated spatula 15 times around perimeter and 10 times over the interior. Place the second half of the batching in the mould and repeat the spading procedure. Smooth the surface of the mix to a slightly rounded shape.

d) If necessary, the mixture and mould shall be returned to an oven at the required temperature for the minimum time necessary to achieve the required Compaction temperature.

e) Place a152.4mm(six inch) paper disc on top of material ,place the mould assembly on the compaction pedestal in the mould holder, and apply the calibrated number of blows (approximately 112) with the mechanical compaction hammer. Compaction was performed at a minimum rate of 40 blows per minute. The compaction hammer shall apply only one blow with each fall, that is, there shall not be a rebound impact. Remove the base plate and collar, and reverse and reassemble the mould. Apply the calibrated number of compaction blows to the face of the reversed specimen.

f) Remove collar, base plate, discs, and allow specimen to cool as shown in plate3.1. Cooling may be accomplished at room temperature, in a25°C air bath, or if more rapid cooling is desired the mould and specimen may be placed in front of a fan until cool.

Plate-3.1 prepared specimens in a standard mould

(g) Extrude the specimen from the mould as shown in Plate3.2. Care was taken in extruding the specimen from the mould, so as not to develop tensile stresses in the specimen or tear the sides of the specimen. The extruded specimens is shown in Plate 3.3

Plate 3.2 Sample Extraction from Extractor

3.4 SPECIMEN TESTING

Specimens prepared as above were tested by the following procedures: -

a) Measure height of specimens to the nearest of 0.1 mm. Prior to measurement to height, excess material was brushed from the edges of the specimens. Compacted specimens should be in-between 88.9 to 101.6mm in height.
b) Determine the specific gravity of the specimens.
c) Determine the bulk density of each of the specimens, by multiplying the respective specificgravityby998kg/m. Record the individual bulk densities to the nearest 1kg/m. The densities of the three specimens shall not differ by more

than 48 kg/m. If this density requirement is not met, the entire set of specimens shall be discarded and a new set of specimens prepared.

Plate 3.3-Samlpes Extracted from Marshalls Mould

d) Determine the average specific gravity of the specimens and record to the nearest 0.001. Calculate the average bulk density of the specimens, by multiplying the average specific gravity by 998kg/m. Record the average bulk density to the nearest 1kg/m.

e) Bring the specimens to 60±1°C by immersing in the water bath 45to 60minutes.Prior to testing, it shall be assured that the inside of the test heads are clean, and that the guide rods are clean and lubricated so that the upper test head slides freely over them.

f) The breaking head temperature was maintained between21 to 38°C, using a water bath when required. Remove the specimen from the water bath, quickly towel dry specimen and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing machine.

g) Apply the load to the specimen with a constant rate of 50.8±2.5mm per minute until the maximum load is reached and the load decreases. The maximum load is defined as the last point in the load/time curve before the load decreases. The elapsed time for the test from removal of the test specimen from water bath to maximum load determination shall not exceed 30 seconds. Plate 3.5 shows the specimen testing.

h) Record the stability of each specimen to the nearest 50newtons, and the flow to the nearest0.1 mm.

i) Correct the stability obtained for each specimen, for the height of the specimen. Record the corrected stability to the nearest 50newtons.

j) Determine and record the average corrected stability to the nearest 50newtons, and the average flow to the nearest0.1 mm.

Plate 3.4-Specimen Testing

3.5 VOLUMETRIC ANALYSIS

In the Marshall method each compacted sample was subjected to the following analysis:

- Bulk Specific Gravity of Sample.
- Voids in the Mineral Aggregate (VMA)
- Voids Filled with Binder (VFB)
- Void in Total Mix (VTM).

Plate 3.5 shows the phase diagram of bituminous mix.

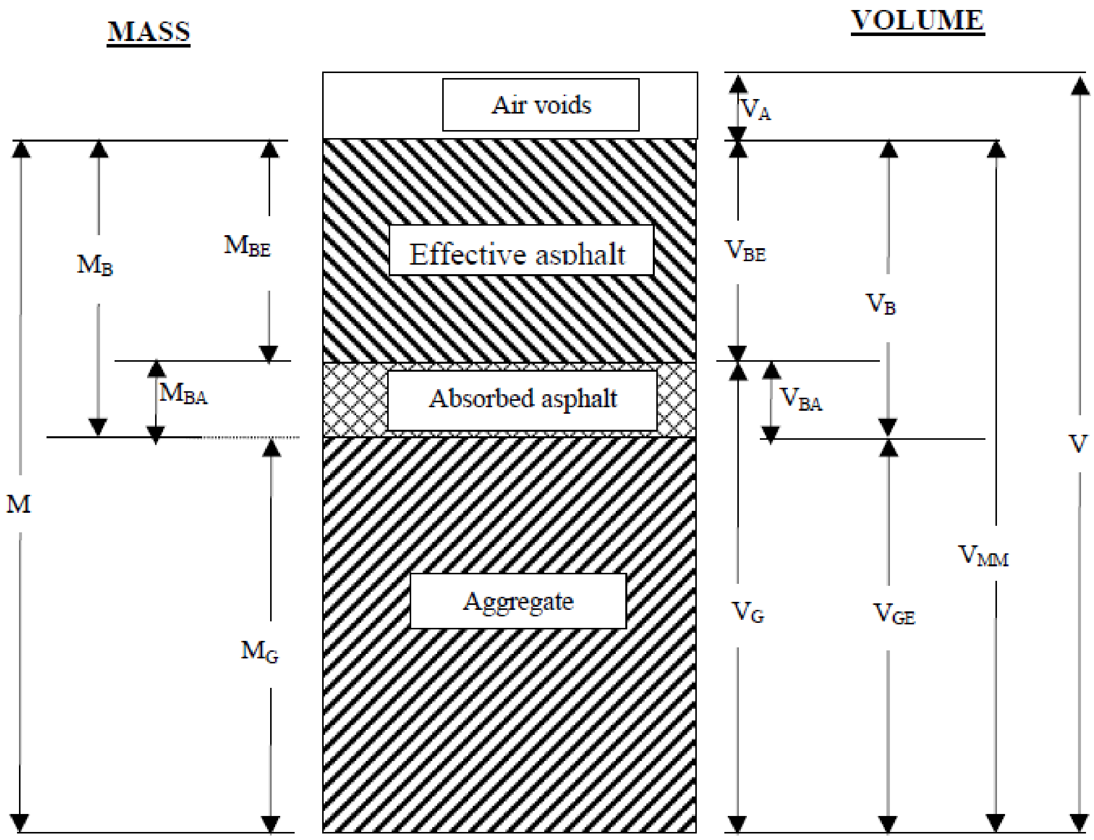

Plate 3.5 Phase Diagram of Bituminous Mix

3.5.1 Bulk Specific Gravity Analysis

The Marshall sample was removed from the mould and cooled at room temperature. Bulk specific gravity was determined using the following equation:

Specific Gravity=A/ (B-C)

where,

A = Weight of dry sample in air (gram)

B = Weight of saturated surface dry sample (gram)

C = Weight sample in water (gram)

3.5.2 Voids in the Mineral Aggregate (VMA)

VMA is the volume of inter granular void space between the aggregate particles of a compacted paving mixture. It includes the air voids and the volume of the asphalt not absorbed into the aggregate .VMA describes the portion of space in a compacted asphalt pavement or specimen which is not occupied by the aggregate. VMA is expressed as a percentage of the total volume of the mix Voids Filled with Binder (VFB).

$VMA=100-((Ps*Gsb)/Gmb))$

where,

Ps = Aggregate content, %

Gsb = Bulk specific gravity of total aggregate

Gmb = Bulk specific gravity of compacted aggregate

3.5.3 Voids Filled with Binder (VFB)

Voids Filled with binder (VFB) is voids in the mineral aggregate that are filled with binder (excluding absorbed binder), expressed as a percent of the volume of the voids in the mineral aggregate.

$VFB= (1-(Gmm*PA/Gmb))*100$

where,

Gmm = theoretical maximum density

PA = Aggregate percentage

Gmb = Aggregate bulk specific gravity.

3.5.4 Voids in Total Mix (VTM) Analysis

Voids in Total Mix (VTM) for hot mix asphalt mixture are defined as void volume between the aggregates coated by bitumen. The equation in determining the VTM is as follows:

$$VTM= (1-(Gsb-Gmb))*100$$

where,

Gsb = Bulk specific gravity of total aggregate

Gmb = Bulk specific gravity of compacted aggregate.

3.5.5 Theoretical maximum Density Analysis

The theoretical maximum density (TMD) is to determine the void in total mix (VTM) for the sample. There are two methods to determine the theoretical maximum density either using calculation or from theoretical maximum density test (AASHTO, 2000). In this study, the calculation method was used to obtain the theoretical maximum density. The equation is

$$TMD=100/ ((A/B) + (C/D))$$

where,

A = Aggregate percentage

B = Bulk specific gravity for blended aggregate

C = Bitumen percentage

D = Specific gravity of bitumen.

3.6 TESTS ON BITUMEN

There are a number of tests to assess the properties of bituminous materials. The following tests were conducted to evaluate different properties of binder to be used. Table 3.1 shows IS code reference of various tests on bitumen sample.

3.6.1 Penetration Test

It measures the hardness or softness of bitumen by measuring the depth in tenths of a mille meter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position as shown in plate 3.6. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25^0C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred.

Plate 3.6-Penetration test apparatus

3.6.2 Ductility Test

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27⁰C temperature. The excess bitumen is cut and the surface is levelled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS. Plate 3.7 shows ductility moulds to be filled with bitumen.

Plate 3.7 Ductility test

3.6.3 Softening point test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerine at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5^0C per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

3.6.4 Specific Gravity Test

In paving jobs, to classify a binder, density property is of great use. In most cases bitumen is weighed, but when used with aggregates, the bitumen is converted to volume using density values. The density of bitumen is greatly influenced by its chemical composition. Increase in aromatic type mineral impurities cause an increase in specific gravity .The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known content to the mass of equal volume of water at 27oC. The specific gravity can be measured using either pycnometer or preparing a cube specimen of bitumen in semi solid or solid state. The specific gravity of bitumen varies from 0.97 to 1.02.

3.6.5 Viscosity Test

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting paving mixes. Low or high viscosity during compaction or mixing has been observed to result in lower stability values. At high viscosity, it resists the comp active effort and thereby resulting mix is heterogeneous, hence low stability values. And at low viscosity instead of providing a uniform film over aggregates, it will lubricate the aggregate particles.

Plate3.8 - Rotational viscometer

A rotational viscometer gathers data on a material's viscosity behavior under different conditions. The rotational viscometer basically consists of two parts –a head unit with a motor and a spindle that is driven by the motor. The viscosity is determined by measuring the resistance of a spindle rotating in the sample. Rotational viscometers can be used for the accurate measurement of viscosity for both Newtonian and non-Newtonian fluids. Newtonian fluids are those that are affected by temperature, such as water, kerosene, mineral oils etc. Non-Newtonian fluids are those that change viscosity when stirred, shaken or otherwise agitated. These include paint, gels, inks, milk, ketchup etc. The apparatus of rotational viscometer is shown in plate 3.8.

3.6.6 Flash and Fire Point Test

At high temperatures depending upon the grades of bitumen materials leave out volatiles. And these volatiles catch fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade. BIS defined the ash point as the temperature at which the vapour of bitumen momentarily catches fire in the form of ash under specified test conditions. The fire point is defined as the lowest temperature under specified test conditions at which the bituminous material gets ignited and burns.

3.7 AGGREGATE TESTING

Aggregates are a principal material in pavement. Additionally, they are often used in either stabilized or un-stabilized base/sub-base courses.

They comprise the majority of pavement volume but only account for a minority of total pavement material costs. Therefore, knowledge of aggregate properties is crucial to design a high quality pavement.

Aggregate were tested for the following parameters:

- Aggregate Crushing Value (ACV) Test
- Abrasion test
- Impact test
- Blending to achieve required gradation for DBM GRADE 1

Table 3.1 IS Codes Reference for Various Tests on Bitumen

Type of test	**Test Method**
Penetration Test	IS: 1203-1978
Ductility test	IS: 1208-1978
Softening Point test	IS: 1205-1978
Specific gravity test	IS: 1202-1978
Viscosity test	IS: 1206-1978
Flash and Fire Point test	IS: 1209-1978
Float Test	IS: 1210-1978
Determination of water content	IS: 1211-1978
Determination of Loss on heating	IS:1212-1978

CHAPTER-4

TEST RESULTS AND DISCUSSION

4.1 GENERAL

This chapter includes the test results obtained after the laboratory testing of the DBM mixes with modified Marshall Method by using various additives in certain percentages as the replacement of binder. All the prepared Marshall samples were subjected to compaction for 112 blows per face to obtain the required density. The results were obtained to determine the Optimum Binder Content (OBC) by performing the Stability-Flow analysis and Volumetric analysis for the prepared samples.

4.2 SIEVE ANALYSIS

Sieve analysis test was used to determine the aggregate sizes from a sample taken quarry. Through this sieve test, the proportion of coarse aggregates, fines aggregate and filler was determined and ensuring the aggregate were well blended within the gradation limit as specified in MORTH for DBM Grade 1. The sieve analysis test results are presented in Table 4.1. The Morths gradations of dense bituminous macadam are shown in table 4.2. The blending selected for the gradation of dense bituminous macadam DBM-Grade 1 is shown in table 4.3. The combined gradation of the sample taken is shown in table 4.4.

Table 4.1 Sieve analysis results

Sieve size	**Percentage passing 40mm**	**Percentage passing 20mm**	**Percentage passing 10mm**	**Percentage passing stone dust**
45	100	100	100	100
37.5	95.6	100	100	100
26.5	70.5	100	100	100
13.2	2.14	2.8	57.87	100
4.75	0	0	2	98
2.36	0	0	0.14	88.8
0.300	0	0	0.01	10
0.075	0	0	0	0

4.3 AGGREGATE TESTING

Aggregates were tested for the various specified properties and the obtained test results were compared with the allowable values as per the MORTH specifications as shown in Table 4.5.

Table 4.2 Gradations for Dense Bituminous Macadam

EXISTING MORTHS GRADATION FOR DENSE BITUMENOUS MACCADAM		
Grading	1	2
Thickness	80-100 mm	50-75 mm
Nominal Aggregate Size	40mm	25 mm
Sieve, mm		
45	100	
37.5	95-100	100
26.5	63-93	90-100
19		71-95
13.2	55-75	56-80
9.5		-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen Content, %	Min.4	Min. 4.5

Table 4.3 Percentage of aggregate size taken

Calculated Blending for DBM grading no-1				
40 mm	**20 mm**	**10mm**	**Stones dust**	**Total**
16	16	29	39	100

Table 4.4 combined gradation of the sample taken

Required sieve	**Percentage passing 40mm**	**Percentage passing 20mm**	**Percentage passing 10mm**	**Percentage passing stone dust**	**Combined gradation**	**LIMIT AS PER MORTH**	
45	16	16	29	39	100	100	100
37.5	15.296	16	29	39	99.296	95	100
26.5	9.28	16	29	39	91.28	63	93
13.2	0.3424	0.448	16.7823	39	56.5727	55	75
4.75	0	0	0.58	38.22	38.8	38	54
2.36	0	0	0.0406	34.632	34.6726	28	42
0.300	0	0	0.0029	7.9	7.9029	7	21
0.075	0	0	0	0	0	2	8

Table 4.5 Test results of the ingredient aggregates.

Property	Results	Specifications
Aggregate Impact Value, %	19	Maximum 27
Abrasion value%	27	Maximum 35
Flakiness and Elongation Indices, %, (Combined)	29	Maximum 30
Water Absorption, %	1.5	Maximum 2
Specific Gravity	2.665	

4.4 BITUMEN TESTING

Sample of bitumen were tested for penetration test, viscosity test and softening point test. The penetration and viscosity test was to obtain consistency of bitumen at some specified temperature and designate grade of asphalt while softening point test is to obtain temperature for bitumen melt. The test results of different bitumen tests are shown in table 4.6.

*Table 4.6 Test results of ingredient bitumen sample***.**

TEST RESULTS FOR INGREDIENT BITUMEN		
Property	**Test Results**	**Specified Limits as per BIS : 73-1992**
Penetration at 25ºC/100 gm /5 sec, mm	**65**	60-70
Softening Point, ºC	**51.7**	40-55
Ductility, cm	**75**	> 75
Specific Gravity, at 27ºC	**1.01**	>0.99
Viscosity at 60ºC, Poise	**1032**	1000±200
135ºC, cSt	**265**	>150

4.5 RESULTS OF DBM GRADE 1 MIX DESIGN WITHOUT ANY ADDITIVE

To determine the optimum binder content (OBC), Marshall Samples were prepared by varying percentage of 60/70 binder without any addition of any modifier. Stability-Flow analysis and Volumetric analysis was carried out for the prepared Marshall Core samples with varying bitumen content from 3.5% to 5.5%. The test values obtained are plotted graphically. From the graphs plotted from Fig 5.1 to 5.6, the optimum binder content was found to be 4.5 percent by wt. of aggregates using stability flow values. The outputs of stability and flow values are as in table no 4.7 and fig 5.1 to 5.6:-

Table 4.7 Corrected stability of different sample prepared with different percentage of bitumen

Test	**Bitumen Content By Wt of Mix (%)**	**Bulk Density (gm/cc)**	**Air Voids (%)VTA**	**Voids in Mineral aggregate (%)VMA**	**Voids Filled With Bitumen (%)VFB**	**STABILITY(kN)**		**Flow (mm)**
						Correlation ratio	Corrected Stability (kN)	
1	0.035	2.3	12.02	16.6	26.3	0.97	23.9	1.4
2		2.276	13.7	18.4	25.6	1.00	25.2	1.2
3		2.252	11.42	16.03	29.64	1.00	24.8	1.3
Average		2.276	12.38	17.01	27.18	0.90	24.7	1.3
1	0.04	2.383	7.656	13.54	44.5	0.97	28.7	3.1
2		2.31	7.4	12.9	43.8	1.00	30.2	3.5
3		2.45	7.6	14.3	44.9	0.97	28.4	3.3
Average		2.381	7.552	13.58	44.4	0.97	29.1	3.3
1	0.045	2.34	4.56	11.13	63.4	0.98	34.9	4.30
2		3.45	4.32	12.6	59.1	0.97	36.7	4.60
3		1.524	4.773	12.12	63.26	1.00	35.4	4.90
Average		2.438	4.551	11.95	61.92	1.00	35.7	4.6
1	0.05	2.41	4.01	12.3	66.4	0.98	36.1	6.4
2		2.44	4.12	12.8	67.9	0.96	33.9	6.6
3		2.437	4.146	12.94	68.92	0.97	34.2	6.8
Average		2.429	4.092	12.68	67.74	1.00	34.7	6.6
1	0.055	2.46	3.5	13.8	71.9	1.00	29.6	11.2
2		2.42	3.7	13.5	71.7	0.97	31.4	10.8
3		2.368	4.284	13.44	71.86	0.98	31.5	11
Average		2.416	3.828	13.58	71.82	0.97	30.8	11

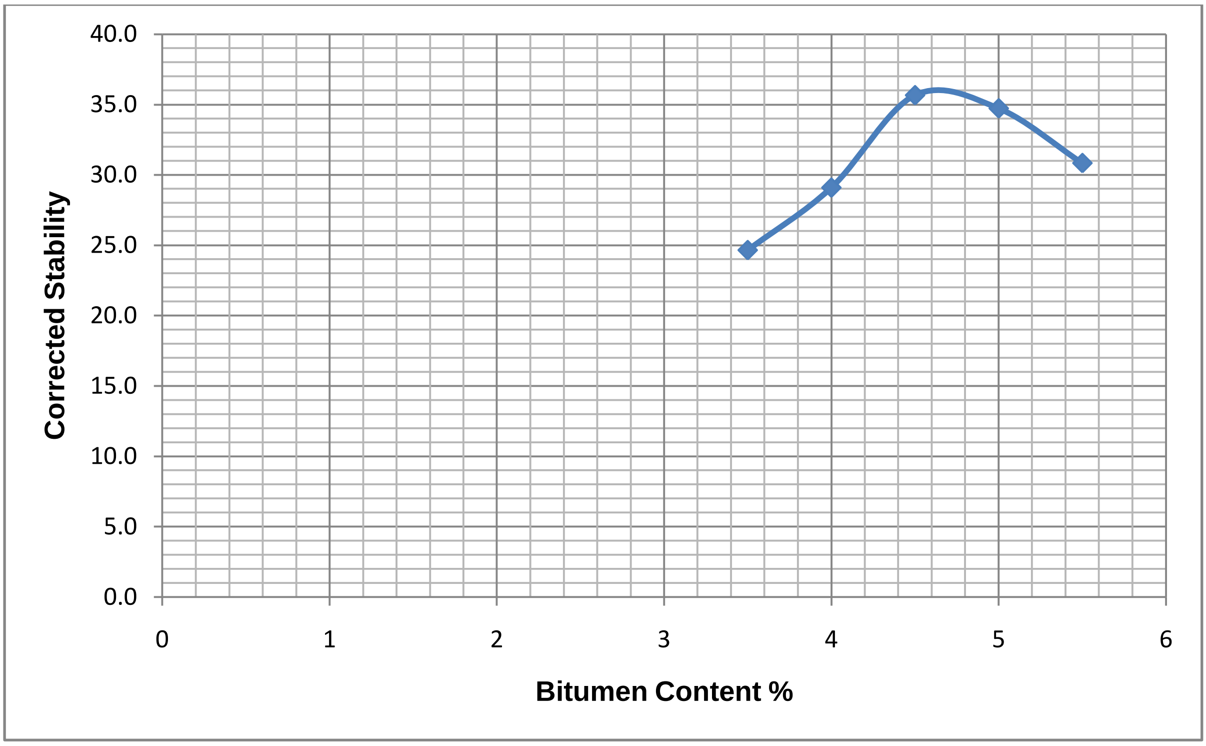

Figure 4.1 Variation of Stability Value to the Variation in Bitumen Content

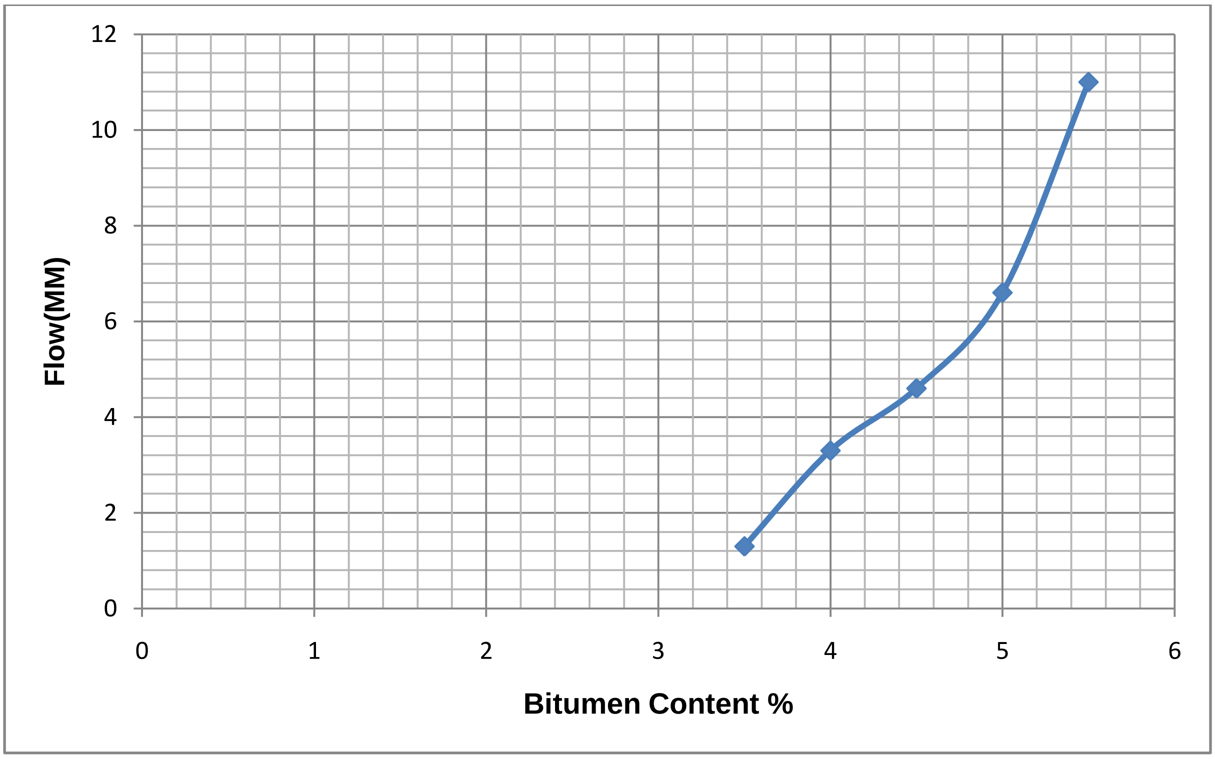

Figure 4.2 Variation of Flow Value to the Variation in Bitumen Content

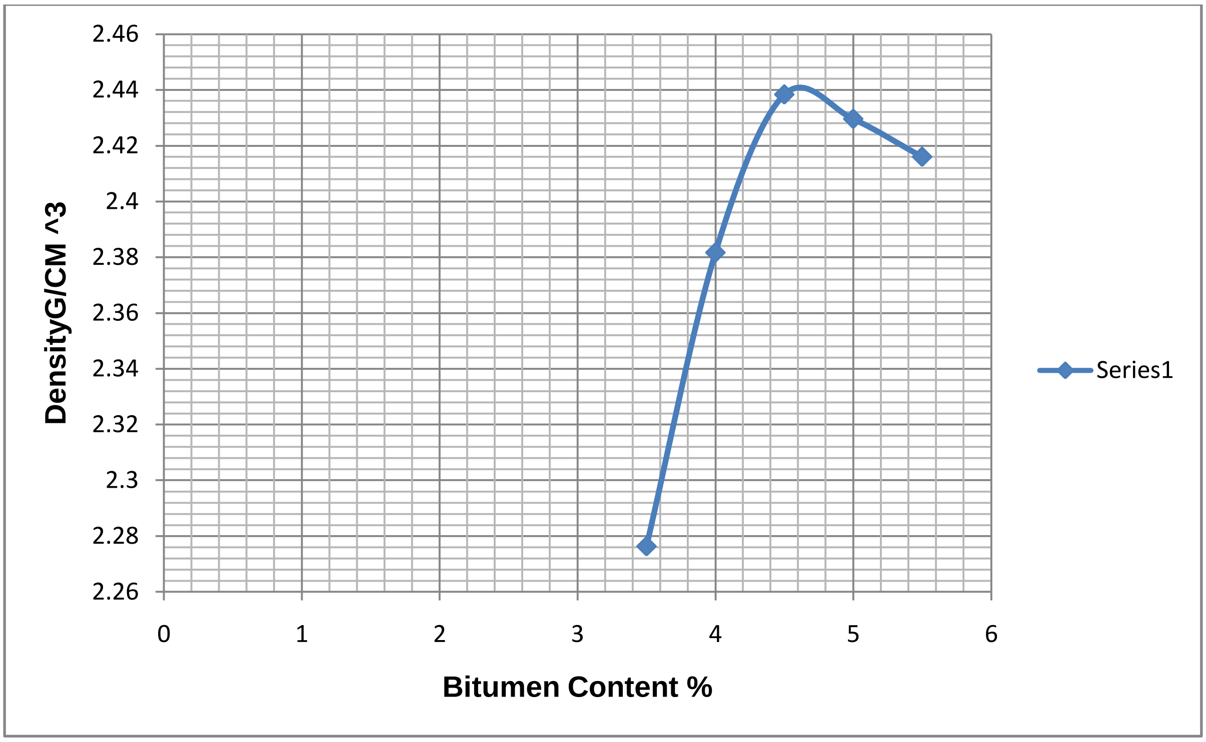

Figure 4.3 Variation of Density Value to the Variation in Bitumen Content

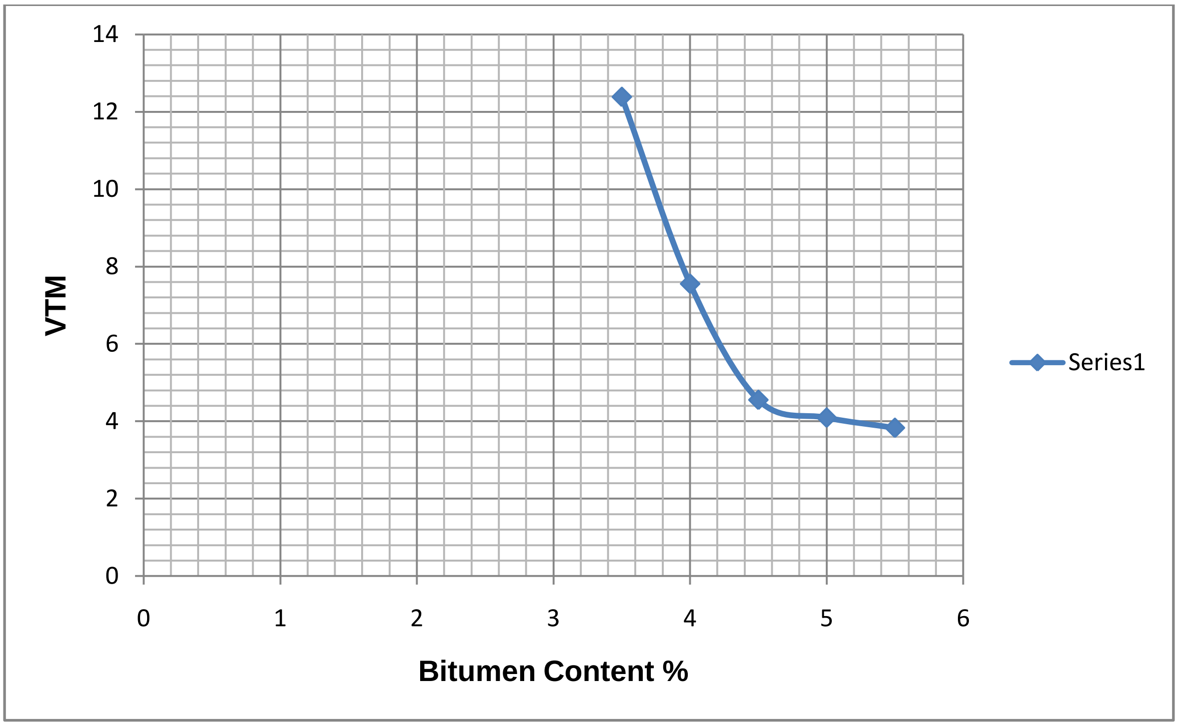

Figure 4.4 Variation of VTM to the Variation in Bitumen Content

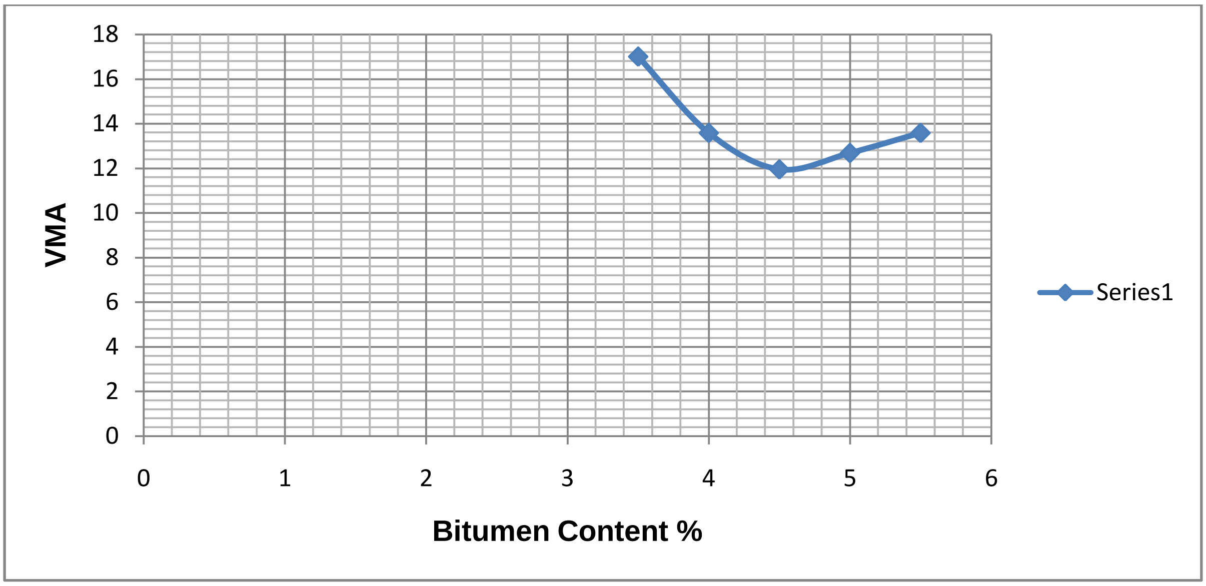

Figure 4.5 Variation of VMA to the Variation in Bitumen Content

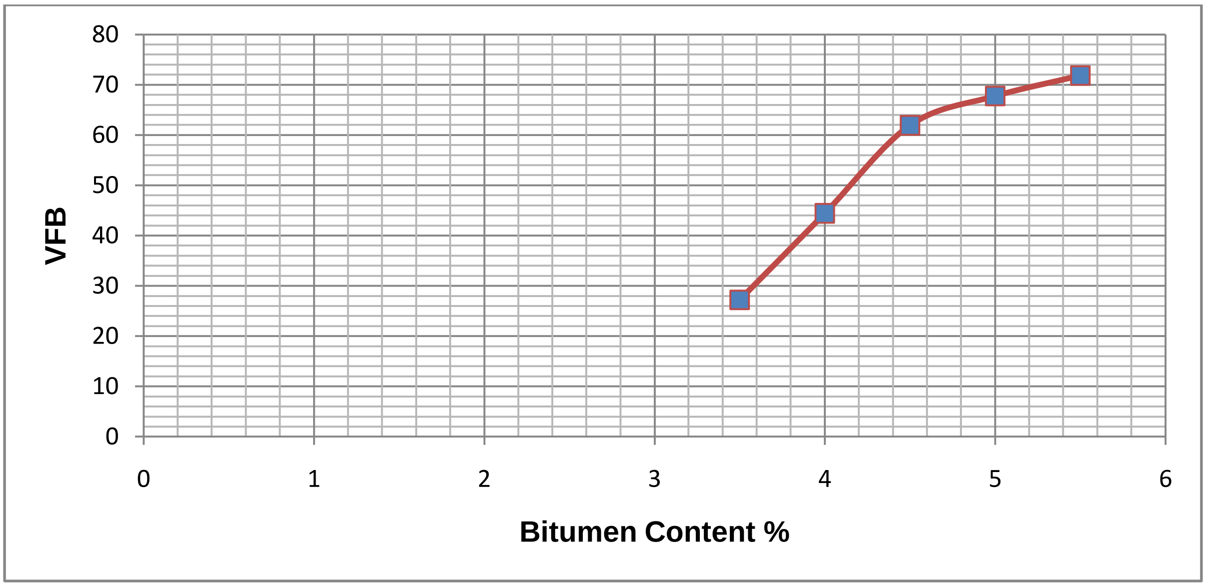

Figure 4.6 Variation of VFB to the Variation in Bitumen content

This optimum binder content of 4.5% was used for evaluating the effect of different percentage of waste plastics, tyre tube, rice husk ash, crumb rubber and polymers on the Strength and flow characteristics of mixes.

4.6 RESULTS OF DBM GRADE 1 MIX DESIGN WITH PLASTIC WASTE

The waste plastic bottles were used in the bituminous mixes of DBM Grade 1 and stability flow characteristics of the mix was carried out using Marshall Method of bituminous mix design. The optimum binder content (OBC) of 4.5% was replaced with

8%, 12% and 16% of plastic content to determine the Stability and Flow characteristics of the modified mix. The outputs are shown in table 4.8 and figure 4.7 and 4.8.

Plate 4.1 Waste Bottle

Plate 4..2 Small Pieces of Waste Bottles

Plate 4.3 Mixing of Waste Bottle Pieces with Bitumen

Table 4.8 Test Outputs for Stability and Flow by Varying Plastic Content.

Replacement of OBC with plastic%	Height of sample (mm)	Stability (kN)	Correction factor	Corrected stability (kN)	Flow (mm)
8	100	29.2	0.92	26.864	3.9
12	101	34.8	0.9	31.32	9.3
16	100	24.8	0.92	22.816	6.4

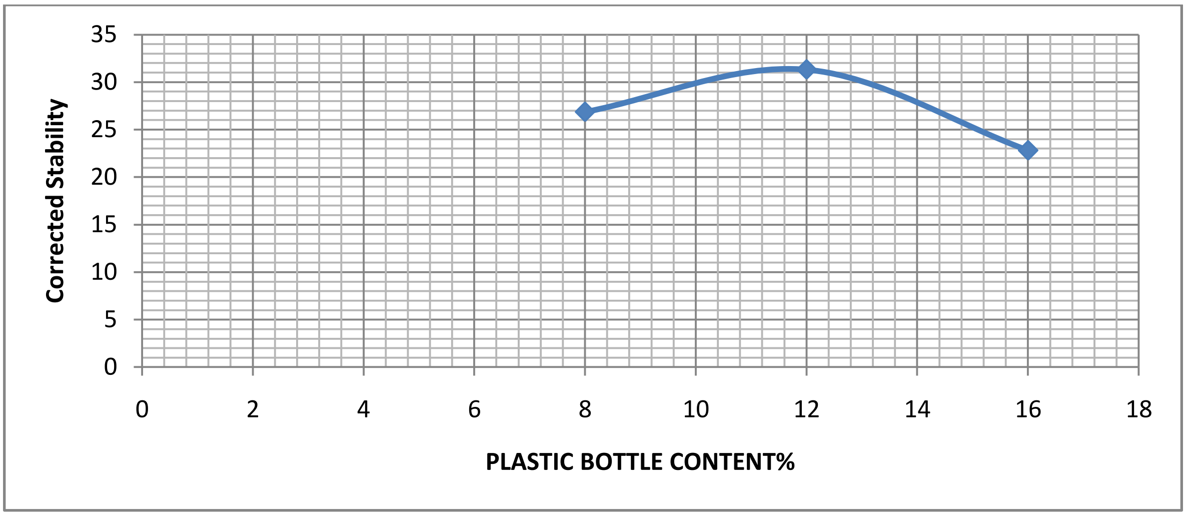

Figure 4.7 Variation of Stability of the Variation in Waste Plastic Content

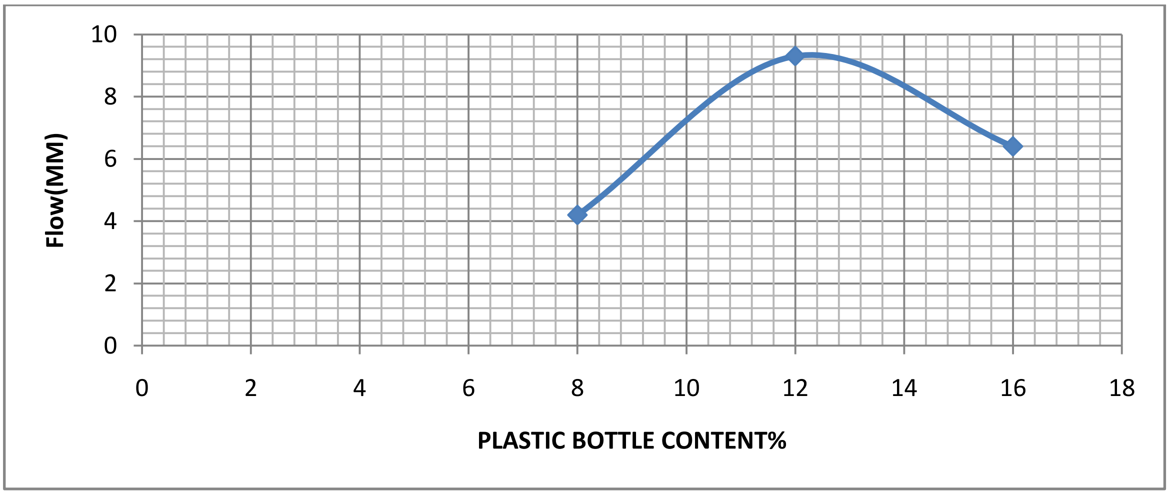

Figure 4.8 Variation of flow to the Variation in Waste Plastic Content.

4.7 RESULTS OF DBM GRADE 1 MIX DESIGN WITH TYRE TUBE (POLY ISO BUTYLENE)

Marshal method of bituminous mix design for DBM grade 1 was carried out by replacing the optimum binder content with varying percentages of 6%, 10% and 14% tyre tube to determine the Stability-Flow characteristics of the modified mix.

The outputs are shown in table no 4.9 and figure 4.9 and 4.10.

Plate 4.4 Tyre Tube Small Pieces

Plate 4.5 Mixing of Bitumen in Aggregate

Table 4.9 Test Outputs of Stability, Flow with Replacement of OBC by Varying Tyre Tube Content

Replacement of OBC with tyre tubes (%)	Height of sample (mm)	Stability (kN)	Correction factor	Corrected stability (kN)	Flow(mm)
6	100	40	0.92	36.8	1.8
10	100	44.8	0.92	41.216	3.6
14	101	48.8	0.9	43.92	7.9

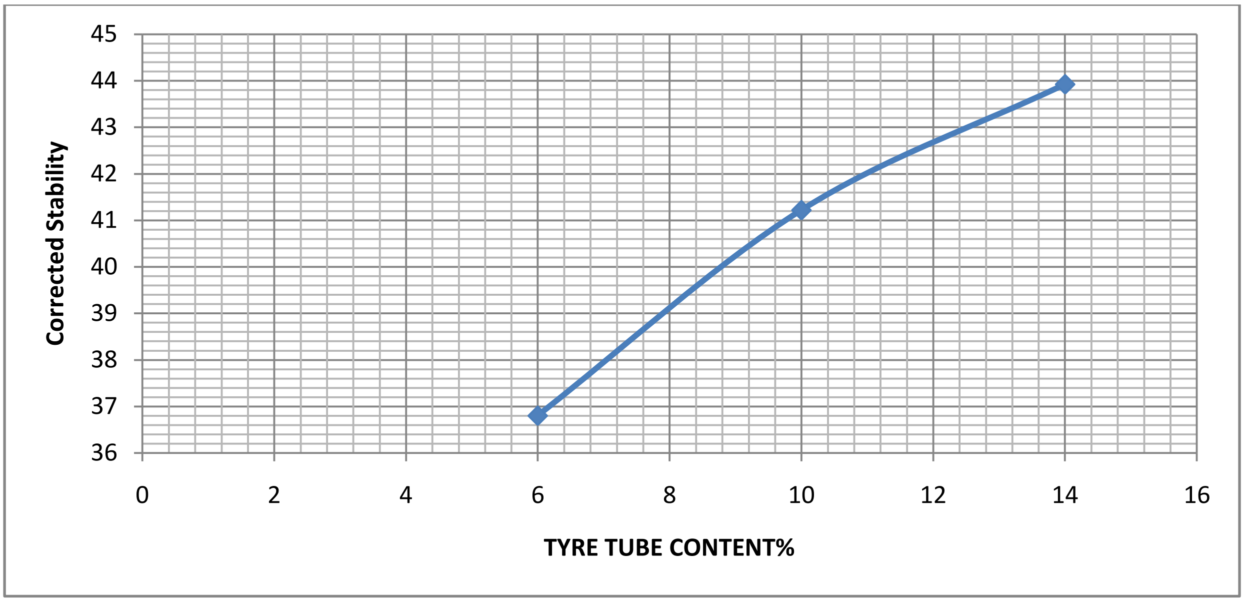

Figure 4.9 Variation of Stability to the Variation in Tyre Tube Content

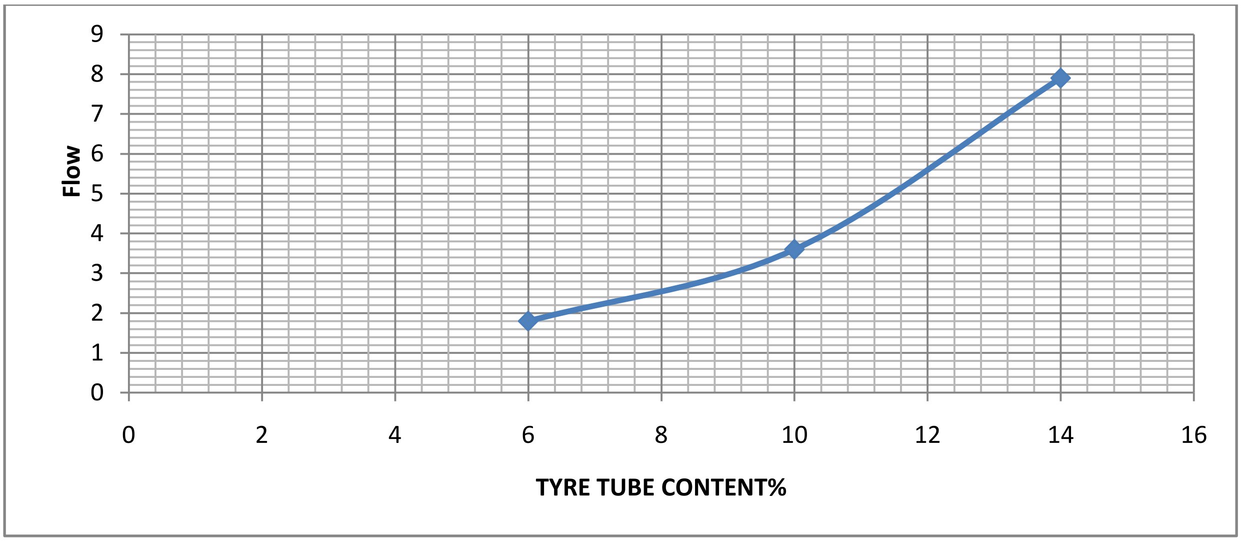

Figure 4.10 Variation of Flow to the Variation in Tyre Tube Content

4.8 RESULTS OF DBM GRADE 1 MIX DESIGN WITHRICE HUSK ASH

Marshal method of bituminous mix design for DBM grade 1 was carried out by replacing the optimum binder content with varying percentages of 6%, 10% and 14% rice husk ash to determine the Stability-Flow characteristics of the modified mix. The outputs are as shown in table 4.10 and figure 4.11 and 4.12.

Table 4.10 Test Outputs of Stability, Flow with Replacement of OBC by Varying Rice Husk Ash Content.

Rice husk content%	Height of sample(mm)	Stability(kN)	Correction factor	Corrected stability(kN)	Flow (mm)
6	100	44.0	0.92	40.48	7.3
10	99	33.6	0.95	31.92	4.3
14	100	30.76	0.92	28.3	4.3

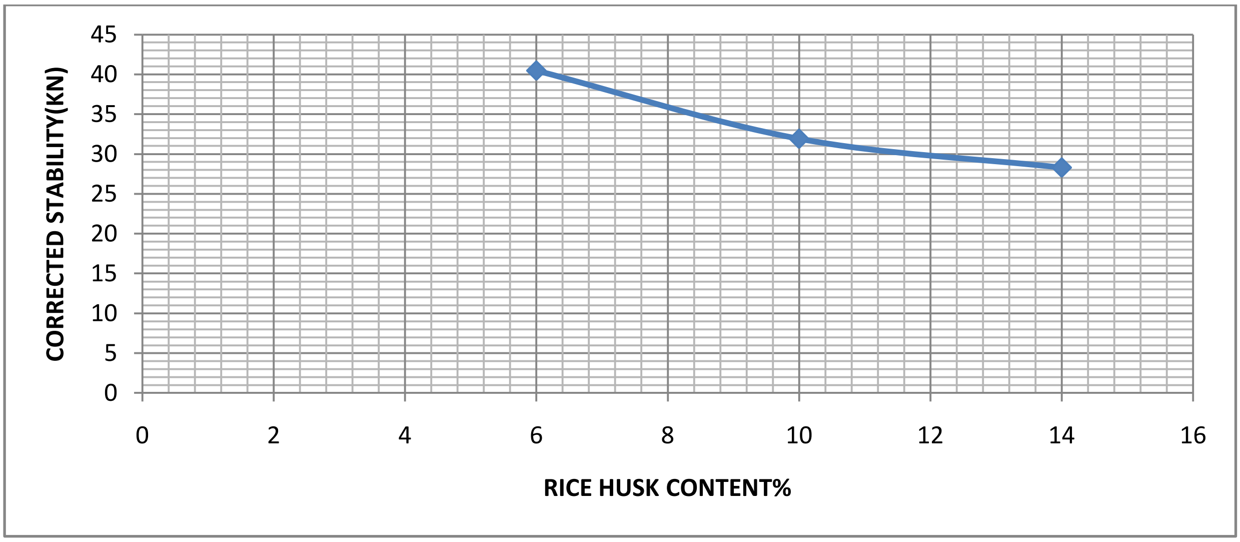

Figure 4.11 Variation of Stability to the Variation in Rice Husk Ash Content

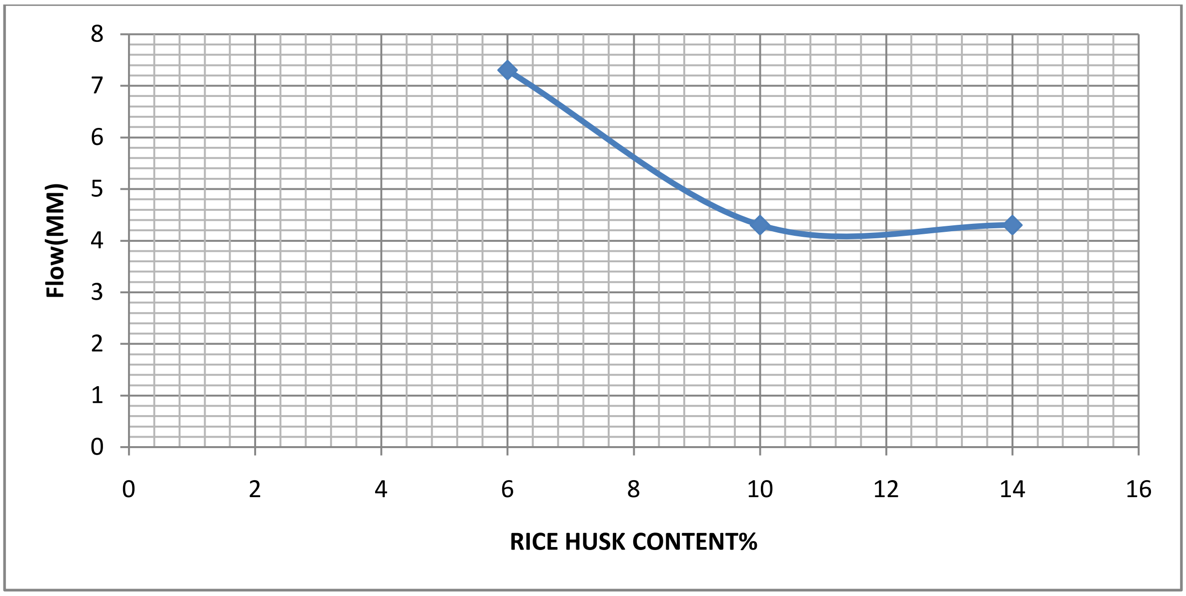

Figure 4.12 Variation of Flow to the Variation in Rice Husk Ash Content

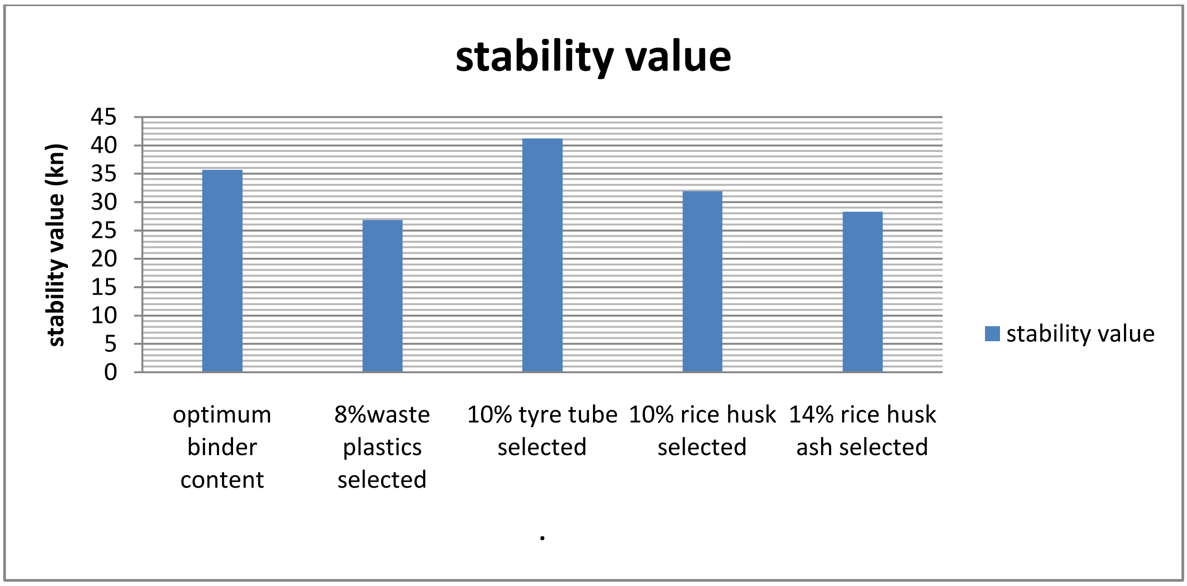

Figure 4.13 Stability Value of optimum binder content v/s waste plastic, tyre tube and rice husk ash.

4.9 RESULTS OF DBM GRADE 1 MIX DESIGN WITH CRMB (CRUMB RUBBER MODIFIED BITUMEN)

Test outputs of the CRMB sample are as per Table 4.11. The identification chart is given in table 4.12.

From the test outputs, sample was identified as CRMB 60. The mix design of DBM grade 1 was carried out with CRMB by making various trial samples with varying CRMB content starting from 3.5% and the optimum content of CRMB was calculated as shown in table 4.13 and figure 4.14 and 4.15.

Table 4.11 Outputs of Various test Performed on CRMB

OUTPUTS OF THE CRMB SAMPLE	
Penetration at 25 Deg. C, 0.1 mm, 100g, 5s	45
Softening Point, (R&B), Deg. C Min.	60
Flash Point, COC, Deg. C. Min.	230

Table 4.12 Grade Identification of CRMB Sample

Characteristics	Grade and Requirements			Method of Test, Ref. To	
	CRMB 50	CRMB 55	CRMB 60	IS No.	Annex
Penetration at 25 Deg. C, 0.1 mm, 100g, 5s	<70	<60	<50	1203	-
Softening Point, (R&B), Deg. C Min.	50	55	60	1205	-
Flash Point, COC, Deg. C. Min.	220	220	220	1209	-

Table 4.13 Outputs of Stability, Flow with Varying Crumb Rubber Modified Bitumen (CRMB) Content.

CRMB content %	Height of sample (mm)	Stability (kn)	Correction factor	Corrected stability(kn)	Flow (mm)
3.5	100	22.9	0.92	21.1	3.2
4	100	24.3	0.92	22.4	3.8
4.5	99	22.7	0.95	21.6	4.0
5	100	27.4	0.92	25.2	4.2
5.5	99	24.1	0.95	22.9	5.8

4.10 RESULTS OF DBM GRADE 1 MIX DESIGN WITH POLYMER MODIFIED BITUMEN

The penetration test was conducted to the sample of polymer modified bitumen. The penetration value of the sample of PMB was 45 and the sample was identified as PMB (E) 40.

The polymer modified bitumen (PMB) was added in varying contents of 3.5% to 5.5% for the DBM Grade 1 mix design with PMB. The following results were obtained with PMB as binder in DBM grade 1 as shown in table 4.14 and figure 4.16 and 4.17:-

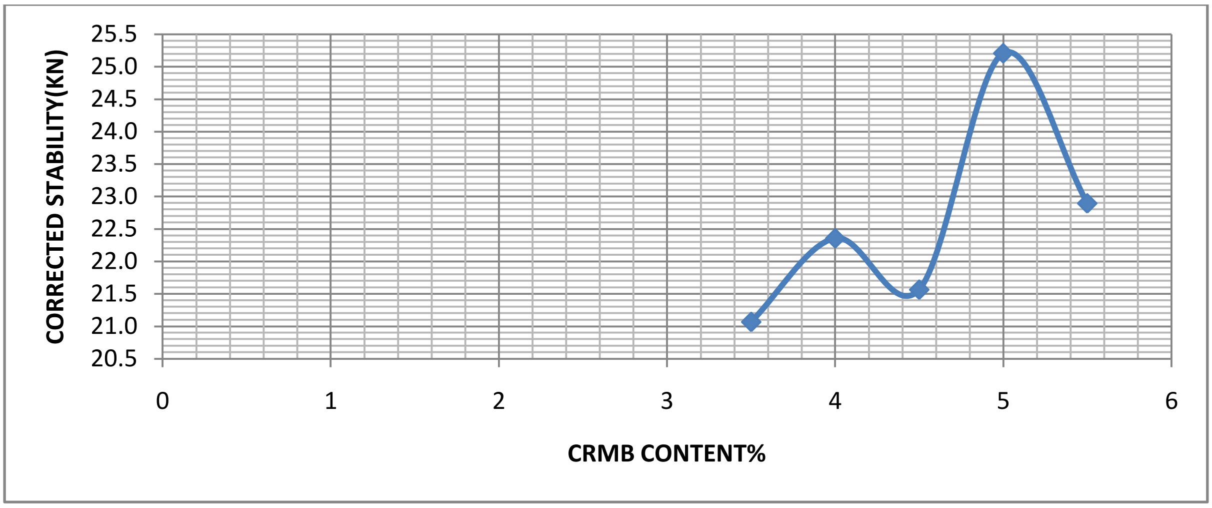

Figure 4.14 Variation of Stability to the Variation in CRMB Content

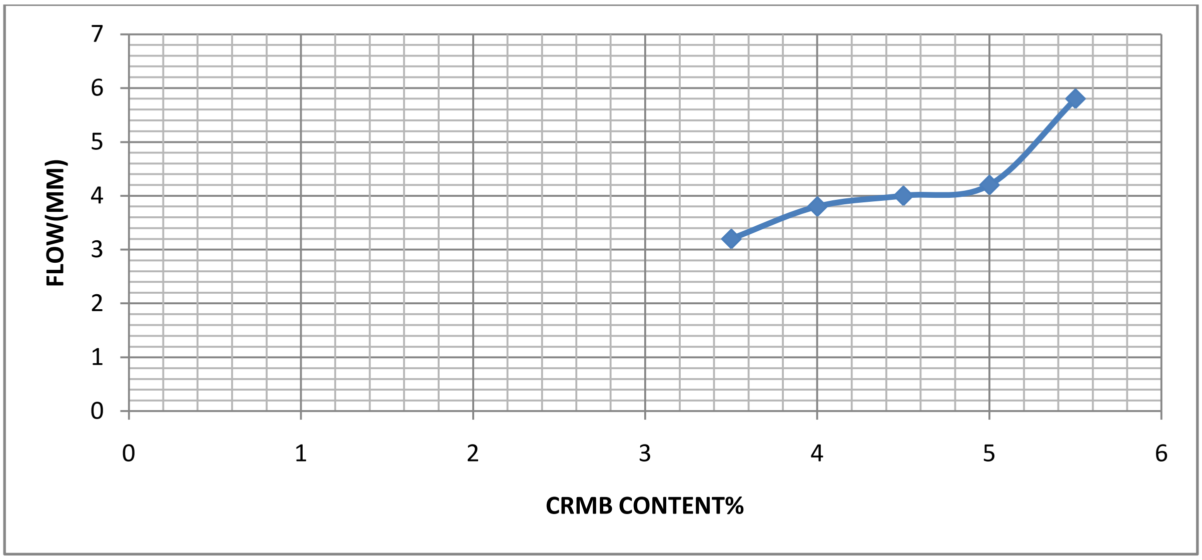

Figure 4.15 Variation of flow to the Variation in CRMB Content

Table 4.14 Outputs of Stability, Flow with Varying Polymer Modified Bitumen (PMB) Content

PMB content%	Height of sample (mm)	Stability (kN)	Correction factor	Corrected stability(kN)	Flow(mm)
3.5	100	21.6	0.92	19.872	3.3
4	98	22.4	0.95	21.28	3.4
4.5	100	23.8	0.92	21.896	3.9
5	**98**	**28.9**	**0.95**	**27.455**	**4.5**
5.5	99	25.4	0.95	24.13	5.5

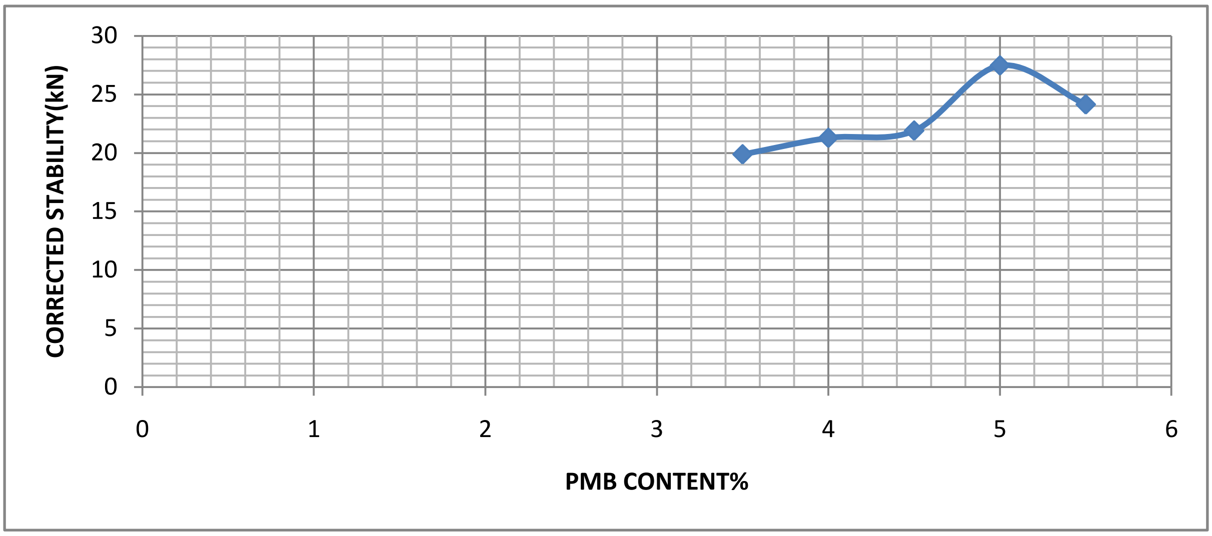

Figure 4.16 Variation of Stability to the Variation in PMB Content

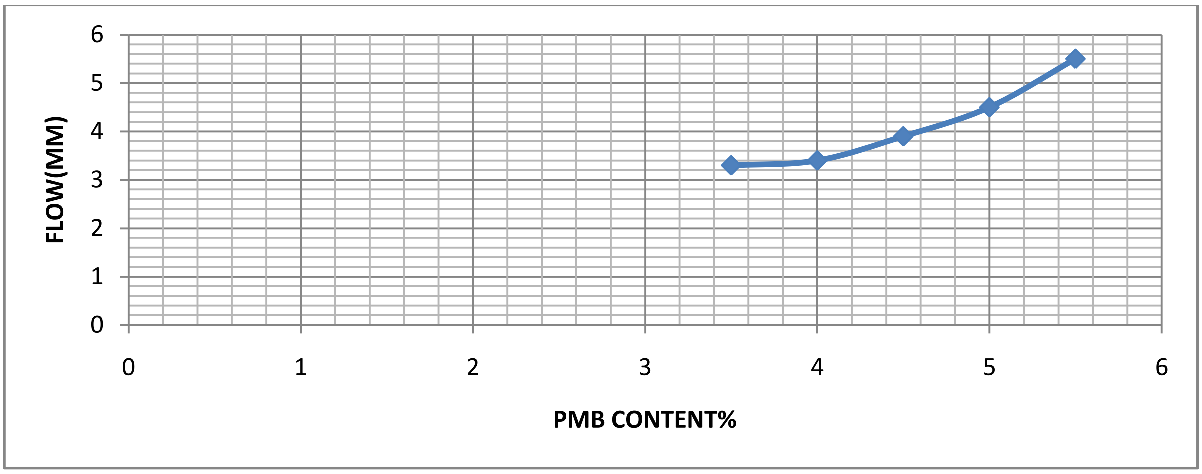

Figure 4.17 Variation of Flow to the Variation in PMB Content

4.11 EFFECT OF BLENDING ON THE MIX DESIGN CHARACTERSTICS OF CRMB AND PMB

The three gradations of dense bituminous macadam are selected for the test performance with constant percentage of crumb rubber modified bitumen and polymer modified bitumen.

The percentage of ingredients for blending case 1 are shown in table no 4.15, blending case-2 are shown in table no 4.16 and blending case -3 are shown in table no 4.17:-

Table4.15 Aggregate Blending Case 1of Dense Bituminous Macadam

Blending case 1 for DBM Grade 1(%)				
40 mm	20 mm	10mm	Stones dust	Total
16	16	29	39	100

Table 4.16 Aggregate Blending Case 2 of Dense Bituminous Macadam

Blending Case 2 for DBM Grade 1(%)				
40 mm	**20 mm**	**10mm**	**Stones dust**	**Total**
11	15	34	40	100

Table 4.17 Aggregate Blending Case 3 of Dense Bituminous Macadam

Blending Case 3 for DBM Grade 1(%)				
40 mm	**20 mm**	**10mm**	**Stones dust**	**Total**
13	**15**	**28**	**44**	**100**

The Optimum Polymer Modified Bitumen (PMB) 5% was added to the mixes with different aggregate blending for a DBM mix. The results obtained are as shown in table 4.18:-

Table 4.18 Stability Flow Analyses with Optimum PMB Content for Three Blending Options

PMB Content %	**40 mm %**	**20 mm %**	**10 mm %**	**Stone Dust %**	**Height (mm)**	**Stability(kN)**	**Correction Factor**	**Corrected Stability (kN)**	**Flow (mm)**
5	16	16	29	39	101	31.95	0.9	28.79	3.9
5	11	15	34	40	100	34.6	0.92	31.832	4.1
5	13	15	28	44	101	19.7	0.9	17.73	4.9

The Optimum Crumb Rubber Modified Bitumen (CRMB) 5% was added to the mixes with different aggregate blending for a DBM mix. The results obtained are as shown in table 4.19 and figure 4.17.

Table 4.19 Stability Flow Analysis with Optimum CRMB Content for Three Blending

CRMB Content %	**40 mm %**	**20 mm %**	**10 mm %**	**Stone dust %**	**Height (mm)**	**Stability (kN)**	**Correction factor**	**Corrected stability**	**Flow (mm)**
5	16	16	29	39	99	25.8	0.95	24.51	3.9
5	11	15	34	40	100	23.2	0.92	21.344	4.1
5	13	15	28	44	99	29.2	0.95	27.74	4.9

The variations in stability values with change in blends are shown in figure 4.18

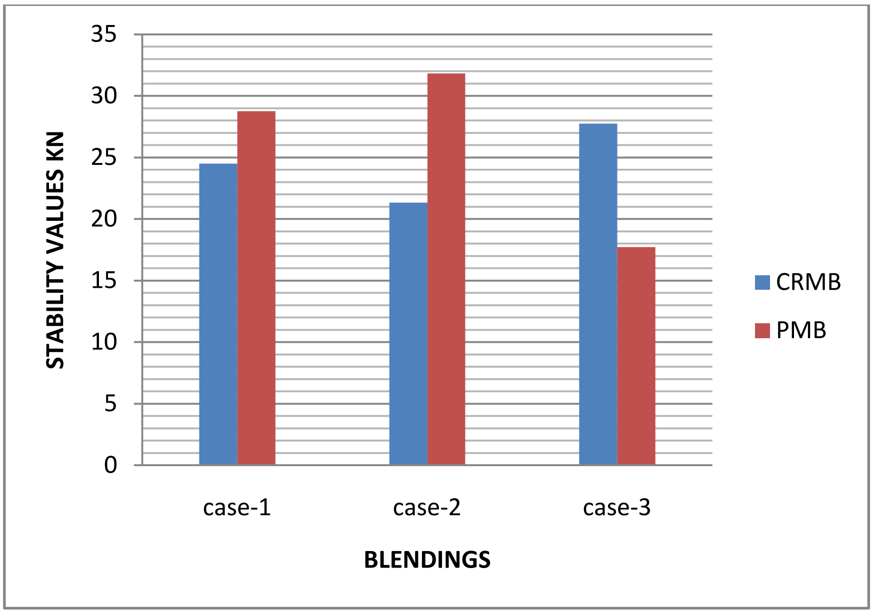

Figure 4.18 Variations in Stability Value with Change in blends.

4.12 DISCUSSIONS OF RESULTS

4.12.1 Effect of Plastic waste on the Stability Flow analysis of DBM Grade 1 Mix:

Table 4.8 and Figs. 4.7 and 4.8 shows the variation of stability and flow of DBM mix with percentage replacement of OBC with plastic content. It is observed from the data obtained that on replacing OBC with 8%, 12% and 16% waste plastic, the stability value decreased. The stability value decreased by 24.76% with 8% plastic waste, 12.26% with 12% plastic waste and 36.10% with 16% plastic waste. However, all the three mixes have higher stability value than the minimum specified stability value as per MS2 and MORTH specifications. But the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied only for the mix with 8% plastic waste.

4.12.2 Effect of Discarded Tyre Tubes on the Stability Flow analysis of DBM Grade 1 Mix:

The Optimum binder content calculated for the DBM grade 1 was replaced with the 6%, 10% and 14% discarded tyre tube. Table 4.9 and Figs. 4.9 and 4.10 shows the variation of stability and flow of DBM mix with percentage replacement of OBC by discarded tyre tubes. With this replacement, the stability value increased by 3.1% with 6% discarded tyre tube, 15.4% with 10% discarded tyre tube and 23.02 % with 14% discarded tyre tube. Also, all the three mixes have higher stability value than the minimum specified stability value as per MS2 and MORTH specifications. But the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied only for the mix with 10% Discarded tyre tube.

4.12.3 Effect of Rice Husk ash on the Stability Flow analysis of DBM Grade 1 mix:

The Optimum binder content calculated for the DBM grade 1 was replaced with the 6%, 10% and 14% Rice Husk ash. Table 4.10 and Figs. 4.11 and 4.12 shows the variation of stability and flow of DBM mix with percentage replacement of OBC by varying percentages of rice husk ash as stated above. With this replacement, the stability value increased by 13.38% with 6% Rice Husk ash, however, the stability value decreased by 10.58% with 10% rice husk ash and by 20.72% with 14% rice husk ash replacement. However, all the three mixes have higher stability value than the minimum specified stability value as per MS2 and MORTH specifications. But the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied for the mix with 10% Rice Husk ash and 14% Rice Husk ash . Fig. 4.13 shows the comparison of the stability values for the selected replacement levels of the different materials used. It is observed that replacement of OBC by 10% discarded tyre tube has the highest stability value.

4.12.4 Effect of use of CRMB on the Stability Flow analysis of DBM Grade 1 mix:

Different percentage viz. 3.5%, 4%, 4.5%, 5% and 5.5% of CRMB was used to calculate the optimum CRMB content for the DBM GRADE-1. Table 4.13 and Figs. 4.14 and 4.15 shows the variation of flow and stability level for different percentages of CRMB content. It is observed that the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied for the entire range of mixes having 3.5%, 4%, 4.5%, 5% and 5.5% CRMB. On analysis it was found that the optimum CRMB content comes out to be 5%.

4.12.5 Effect of use of PMB on the Stability Flow analysis of DBM Grade 1 mix

Different percentages of 3.5%, 4%, 4.5%, 5% and 5.5% of PMB content was used to find out the optimum PMB content for the DBM GRADE-1. Table 4.14 and Figs. 4.16 and 4.17

shows the variation of flow and stability level for different percentages of PMB content. It is observed that the stability value decreased by 44.25% with 3.5% PMB, 40.33% with 4% PMB, 38.65% with 4.5% PMB, 22.96% with 5% PMB and 32.49% with 5.5% PMB. However, of all the five mixes four mixes have 1-7.25% higher stability value and one mix has 1.72% lower stability value than the minimum specified stability value as per MS2 and MORTH specifications. The flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied for the entire mix with3.5%, 4%, 4.5%, 5% and 5.5% PMB. On analysis again it was found that the optimum PMB content comes out to be 5% which is same as that for CRMB.

4.12.6 Effect of different blends on the Stability Flow analysis of DBM Grade 1 mix:

Table 4.18 shows the stability flow analysis with optimum PMB content for the three blending cases and Table 4.19 shows the same for optimum CRMB content. It is observed that for mixes with PMB the stability value increases with increase in stone dust percentage of 40% and reduces after that, whereas the pattern is reversed with CRMB content. The bituminous mixes of DBM Grade 1 with PMB having 40% stone dust shows the maximum stability value and the bituminous mixes of DBM Grade 1 with CRMB having 44% stone dust shows the maximum stability value. However, in all the three cases, the flow criteria are satisfied.

CHAPTER-5
CONCLUSION

5.1 GENERAL

The major conclusions drawn from the study carried out on stability flow analysis of DBM (GRADE 1) by using different additives are as under:

1. The flow criteria for DBM grade 1 is satisfied only if the Bitumen is replaced by 8% plastic waste, although the stability values lie within the specific range for all replacement levels.
2. The stability values for the DBM grade 1 mix increase with replacement of OBC by all the considered percentages of discarded tyre tube waste.
3. The flow criteria for DBM grade 1 as per MS2 and MORTH specifications is satisfied on replacing the optimum binder content of 4.5% with 10% discarded tyre tube waste only indicating that this percentage is the only suited level of replacement.
4. Although the stability value increased for 6% replacement of OBC by rice husk ash and reduced for 10% and 14% replacement levels, but the 6% replacement level only does not satisfy the flow criteria. It indicates that 10 to 15% replacement level of rice husk ash is suited for creating a stable and flow able DBM mix of grade 1. Higher limit of rice husk ash replacement needs further investigations.
5. Of the three materials used, replacement of OBC by 10% discarded tyre tube has the highest stability value.
6. The optimum content of CRMB and PMB for use in DBM Grade 1 mix is 5%.
7. The bituminous mixes of DBM Grade 1 with 5% PMB having 40% stone dust shows the maximum stability value and the bituminous mixes of DBM Grade 1 with 5% CRMB having 44% stone dust shows the maximum stability value.

5.2 SCOPE FOR FURTHER WORK

A trial section of a pavement, with DBM Grade 1 layer, can be prepared and investigated by using the optimum percentage replacement values of various additives obtained in the work. This trial section can be evaluated for the performance characteristics both in terms of structural evaluation as well as functional evaluation of the pavement.

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