STABILITY AND FLOW ANALYSIS OF BITUMINOUS CONCRETE GRADE 2 USING DIFFERENT WASTE MATERIALS AS ADDITIVES

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Submitted by

AMIT RANDHAWA

(ROLL NO. 801223001)

UNDER THE GUIDANCE OF

Mr. TANUJ CHOPRA

Assistant Professor
Department of Civil Engineering
Thapar University Patiala

CIVIL ENGINEERING DEPARTMENT

THAPAR UNIVERSITY, PATIALA 147004

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CERTIFICATE

I hereby declares that this dissertation entitled **"Stability and flow analysis of Bituminous Concrete Grade 2 using different waste materials as additives"**, is an authentic record of my study carried out as requirements for the award of the degree of **Master of Engineering in Infrastructures Engineering** at **Thapar University, Patiala** under the supervision of **Mr. Tanuj Chopra,** Assistant Professor, Civil Engineering Department, Thapar University, Patiala during July, 2012 to July, 2014. The matter embodied in this report has not been submitted in partial or full to any other university or institute for the award of any degree.

Date: 17-07-2014

(Amit Randhawa)
Roll No. 801223001

It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

Mr. Tanuj Chopra
Assistant Professor
Department of Civil Engineering
Thapar University, Patiala 147004

COUNTERSIGNED

Dr. Naveen Kawatra
Associate Professor & Head of Department
Department of Civil Engineering
Thapar University, Patiala - 147004

Dr S.K. Mohapatra
Dean of Academic Affairs
Thapar University,Patiala - 147004

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Amit Randhawa

801223001

ABSTRACT

Generally a bituminous mixture is a mixture of coarse aggregate, fine aggregate, filler and binder. A Hot Mix Asphalt is a bituminous mixture where all constituents are mixed, placed and compacted at high temperature. HMA can be Dense Graded mixes (DGM) known as Bituminous Concrete (BC). Bituminous mix is generally used as a surface course and wearing course in flexible pavements since it is necessary that the wearing course must provide a smooth riding surface that is dense and at the same time take up wear and tear due to traffic. The development of transportation plays an important role in the development of nation. With flexible pavements being widely used in India, steps must be taken to increase the life of the bituminous pavements. Flexible pavements are often plagued with problems of cracking and rutting due to repeated traffic loads. Hence one needs to address these problems in order to improve the performance of flexible pavements.

The project studies the suitability of waste plastic bottles, discarded tyre rubber and coconut fibres as a reinforcing material in bituminous mixes for Bituminous concrete Grade 2. Marshall method of mix design was adopted for the mixes and the optimum bitumen content are determined for bituminous mixes and their performance is analysed. The optimum binder content is calculated as 6% for 60/70 penetration grade bitumen. In this study stability and flow analysis for Bituminous Concrete Grade 2 mixture with different percentage replacement of bitumen with waste material such as waste plastic bottle , discarded tyre rubber and coconut fibres has been done. After experimental study it has been found that replacement of optimum binder content with 10% waste plastic, 6% crumb tyre rubber, 1% coconut fibre increases the stability of the mix by 10.67%, 10.37%, 10.08% respectively. Also the flow criteria as specified by the MORT&H for BC Grade 2 has been satisfied by all the additives. Out of the three additives used in the study it has been found that replacement of OBC by 10% waste plastic has the highest Marshall stability value.

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INTRODUCTION

1.1 GENERAL

Roadways are considered one of the most important elements of infrastructure and they play an essential role in our daily lives. Pavement is most important component of highway section. Therefore the overall functioning of highway system is greatly relying on performance of its pavement. In India, bituminous pavement is commonly used for highways. Due to increasing traffic intensity, distress such as rutting and cracking of pavements are very common in Indian roads. Under varying seasonal temperature flexible pavement tend to become soft in summer and brittle in winter. In India almost 90 percent road network is occupied by bituminous pavement only 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. Investigations revealed that properties of bitumen can be improved with the incorporation of modifiers. In this study, bitumen of grade VG30 is selected and improved its properties by the addition of modifiers. Marshall Stability value of modified bitumen is also improved when compared to the selected raw bitumen.
Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in service highway can be achieved. Two things are of major consideration in flexible pavement engineering – pavement design and the mix design. Mix design for the different layers of the pavement can have a major impact on the performance, cost and sustainability of the bituminous surfaces.

A good design of bituminous mix is expected to result in a mix which is adequately
i) strong ii) durable iii) resistive to fatigue and permanent deformation
iv) environment friendly (v) economical and so on.
A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one.

1.2 EVOLUATION OF MIX DESIGN

As per **Das et al.(2004);** During 1900's, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called *pat test* was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape, and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged. The first formal mix design method was Habbard field method, which was originally developed on sand-asphalt mixture. Mixes with large aggregates could not be handled in Hubbard field method. This was one of the limitations of this procedure. Francis Hveem, a project engineer of California Department of Highways, developed the Hveem stabilometer. Hveem did not have any prior experience on judging the just right mix from its colour, and therefore decided to measure various mix parameters to find out the optimum quantity of bitumen. Hveem used the surface area calculation concept (which already existed at that time for cement concrete mix design), to estimate the quantity of bitumen required. Moisture susceptibility and sand equivalent tests were added to the Hveem test in 1946 and 1954 respectively. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpes of Engineers in 1930's and subsequently modified in 1940's and 50's.

1.3 FLEXIBLE PAVEMENT

Flexible pavements support loads through bearing rather than flexural action. They comprise several layers of carefully selected materials designed to gradually distribute loads from the pavement surface to the layers underneath. The design ensures the load transmitted to each successive layer does not exceed the layer's load-bearing capacity. A typical flexible pavement section is shown in Fig. 1.1. Fig. 1.2 depicts the distribution of the imposed load to the subgrade. The various layers composing a flexible pavement and the functions they perform are described below:

a) Bituminous Surface (Wearing Course): The bituminous surface, or wearing course, is made up of a mixture of various selected aggregates bound together with asphalt cement or other bituminous binders. This surface prevents the penetration of surface water to the base course; provides a smooth, well-bonded surface free from loose particles, which might endanger aircraft or people; resists the stresses caused by aircraft loads; and supplies a skid-resistant surface without causing undue wear on tires.

b) Base Course: The base course serves as the principal structural component of the flexible pavement. It distributes the imposed wheel load to the pavement foundation, the subbase, and/or the subgrade. The base course must have sufficient quality and thickness to prevent failure in the subgrade and/or subbase, withstand the stresses produced in the base itself, resist vertical pressures that tend to produce consolidation and result in distortion of the surface course, and resist volume changes caused by fluctuations in its moisture content. The materials composing the base course are select hard and durable aggregates, which generally fall into two main classes: stabilized and granular. The stabilized bases normally consist of crushed or uncrushed aggregate bound with a stabilizer, such as Portland cement or bitumen. The quality of the base course is a function of its composition, physical properties, and compaction of the material.

c) Subbase: This layer is used in areas where frost action is severe or the subgrade soil is extremely weak. The subbase course functions like the base course. The material requirements for the subbase are not as strict as those for the base course since the subbase is subjected to lower load stresses. The subbase consists of stabilized or properly compacted granular material.

d) Frost Protection Layer: Some flexible pavements require a frost protection layer. This layer functions the same way in either a flexible or a rigid pavement.

e) Subgrade: The subgrade is the compacted soil layer that forms the foundation of the pavement system. Subgrade soils are subjected to lower stresses than the surface, base, and subbase courses. Since load stresses decrease with depth, the controlling subgrade stress usually lies at the top of the subgrade. The combined thickness of subbase, base, and wearing surface must be great enough to reduce the stresses occurring in the subgrade to values that will not cause excessive distortion or displacement of the subgrade soil layer.

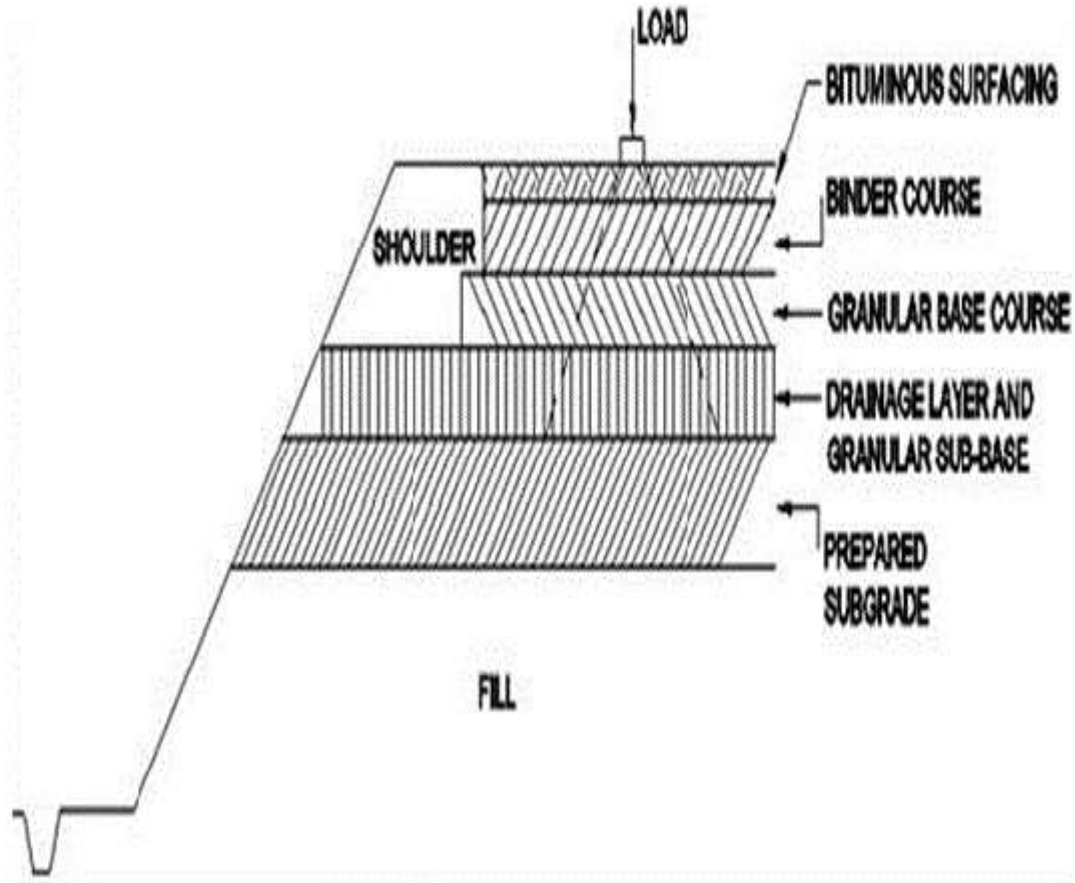

Figure 1.1: Typical flexible pavement structure

1.4 BITUMINOUS MIX DESIGN

1.4.1 Objective of Bituminous mix design

Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size , typically less than 25 mm, through the fine filler that is smaller than 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties.

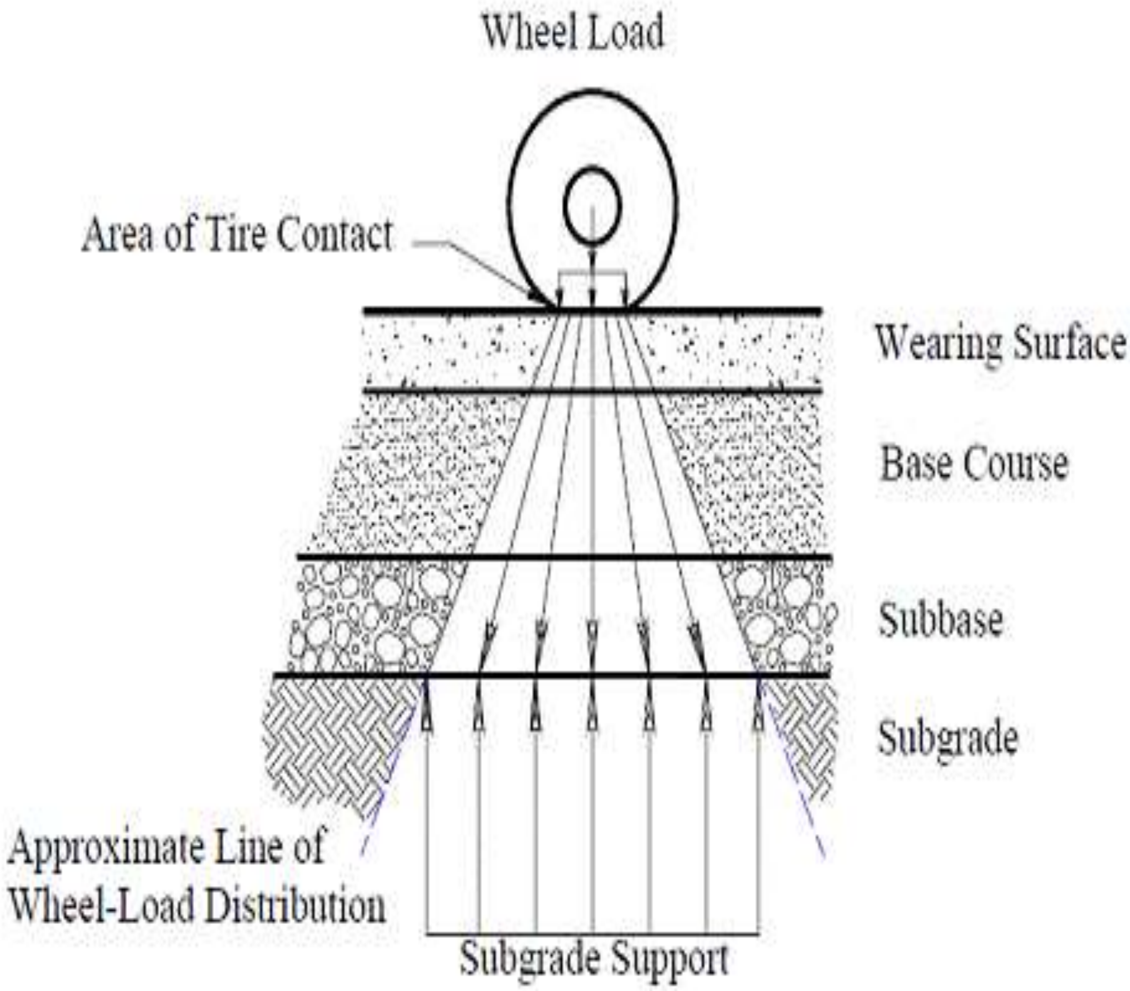

Figure 1.2: Distribution of load stress in flexible pavement

The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical. The objective of the mix design is to produce a bituminous mix by proportioning various components so as to have-

1. Sufficient bitumen to ensure a durable pavement
2. Sufficient strength to resist shear deformation under traffic at higher temperature
3. Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic
4. Sufficient workability to permit easy placement without segregation

5. Sufficient resistance to avoid premature cracking due to repeated bending by traffic

6. Sufficient resistance at low temperature to prevent shrinkage cracks

1.4.2 Requirements of bituminous mixes:

i) Stability

Stability is defined as the resistance of the paving mix to deformation under traffic load. Two examples of failure are

(i) Shoving - a transverse rigid deformation which occurs at areas subject to severe acceleration and

(ii) Grooving - longitudinal ridging due to channelization of traffic.

Stability depends on the inter-particle friction, primarily of the aggregates and the cohesion offered by the bitumen. Sufficient binder must be available to coat all the particles at the same time should offer enough liquid friction. However, the stability decreases when the binder content is high and when the particles are kept apart.

ii) Durability

Durability is defined as the resistance of the mix against weathering and abrasive actions. Weathering causes hardening due to loss of volatiles in the bitumen. Abrasion is due to wheel loads which causes tensile strains. Typical examples of failure are (i) Pot-holes, deterioration of pavements locally (ii) Stripping, lost of binder from the aggregates and aggregates are exposed. Disintegration is minimized by high binder content since they cause the mix to be air and waterproof and the bitumen film is more resistant to hardening.

iii) Flexibility

Flexibility is a measure of the level of bending strength needed to counteract traffic load and prevent cracking of surface. Fracture is the cracks formed on the surface (hairline-cracks, alligator cracks), main reasons are shrinkage and brittleness of the binder. Shrinkage cracks are due to volume change in the binder due to aging. Brittleness is due to repeated bending of the surface due to traffic loads. Higher bitumen content will give better flexibility and less fracture.

iv) Skid resistance

It is the resistance of the finished pavement against skidding which depends on the surface texture and bitumen content. It is an important factor in high speed traffic. Normally, an open graded coarse surface texture is desirable.

v) Workability

Workability is the ease with which the mix can be laid and compacted, and formed to the required condition and shape. This depends on the gradation of aggregates, their shape and texture, bitumen content and its type Angular, flaky, and elongated aggregates workability. On the other hand, rounded aggregates improve workability.

vi) Desirable properties

From the above discussion, the desirable properties of a bituminous mix can be summarized as follows:

- Stability to meet traffic demand
- Bitumen content to ensure proper binding and water proofing
- Voids to accommodate compaction due to traffic
- Flexibility to meet traffic loads, esp. in cold season
- Sufficient workability for construction
- Economical mix

1.5 ASPHALT CONCRETE (BITUMINIOUS MIXTURE)

Asphalt concrete is a composite material commonly used in construction projects such as road surfaces, airports and parking lots. It consists of asphalt (used as a binder) and mineral aggregate mixed together, then are laid down in layers and compacted. Mixing of asphalt and aggregate is accomplished in one of several ways:

1.5.1 Hot mix asphalt concrete (HMAC or HMA) is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300 °F (roughly 150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt, and the asphalt cement at 200 °F (95 °C). Paving and compaction must be performed while the asphalt is sufficiently hot. In many countries paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is packed to the optimal air content. HMAC is the form of asphalt concrete most commonly used on highly trafficked pavements such as those on major highways, racetracks and airfields.

1.5.2 Warm mix asphalt Concrete (WMA) is produced by adding either zeo-lites waxes, asphalt emulsions, or sometimes even water to the asphalt binder prior to mixing. This allows significantly lower mixing and laying temperatures and results in lower consumption of fossil fuels, thus releasing less carbon dioxide, aerosols and vapours. Not only are working conditions improved, but the lower laying-temperature also leads to more rapid availability of the surface for use, which is important for construction sites with critical time schedules. The usage of these additives in hot mixed asphalt (above) may afford easier compaction and allow cold weather paving or longer hauls.

1.5.3 Cold mix asphalt concrete is produced by emulsifying the asphalt in water with (essentially) soap prior to mixing with the aggregate. While in its emulsified state the asphalt is less viscous and the mixture is easy to work and compact. The emulsion will break after enough water evaporates and the cold mix will, ideally, take on the properties of cold HMAC. Cold mix is commonly used as a patching material and on lesser trafficked service roads.

1.5.4 Cut-back asphalt concrete is produced by dissolving the binder in kerosene or another lighter fraction of petroleum prior to mixing with the aggregate. While in its dissolved state the asphalt is less viscous and the mix is easy to work and compact. After the mix is laid down the lighter fraction evaporates. Because of concerns with pollution from the volatile organic compounds in the lighter fraction, cut-back asphalt has been largely replaced by asphalt emulsion.

1.5.5 Mastic asphalt concrete or sheet asphalt is produced by heating hard grade blown bitumen (oxidation) in a green cooker (mixer) until it has become a viscous liquid after which the aggregate mix is then added. Then bitumen aggregate mixture is cooked (matured) for around 6- 8 hours and once it is ready the mastic asphalt mixer is transported to the work site where experienced layers empty the mixer and either machine or hand lay the mastic asphalt contents on to the road. Mastic asphalt concrete is generally laid to a thickness of around 3/4–3/16 inches (20-30 mm) for footpath and road applications and around 3/8 of an inch (10 mm) for flooring or roof applications. In addition to the asphalt and aggregate, additives, such as polymers, and antistripping agents may be added to improve the properties of the final product.

1.5.6 Natural asphalt concrete can be produced from bituminous rock, found in some parts o the world, where porous sedimentary rock near the surface has been impregnated with upwelling bitumen.

1.6 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.

1.7 BITUMINOUS CONCRETE MIX

Bituminous Concrete is used in wearing and profile corrective courses. This work shall consist of construction in a single or multiple layers of bituminous concrete on a previously prepared bituminous bound surface. A single layer shall be 25mm to 100mm in thickness. In BC 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 Bituminous concrete mix.

1.7.1 Material specifications for BC mix

i) Bitumen

The bitumen for the BC is a paving bitumen of penetration Grade complying with Indian Standard Specifications for “Paving Bitumen” IS: 73, and of the penetration as indicated in the table specified by MOSRT&H Specifications for Road and Bridge Works (Fourth Revision) Re-print March 2007 for Bituminous Concrete .

ii) Coarse Aggregates

The coarse aggregates for the BC 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 Table1.2 (Ref: MOSRT&H Specifications for Road and Bridge Works (Fourth Revision) for Bituminous Concrete.).

ii) Fine Aggregates

Fine aggregates for BC 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.

iii) Filler

Filler for the BC consists of finely divided mineral matter such as rock dust, hydrated lime or cement. Where the aggregates fail to meet the requirements of the water sensitivity test in Table then 2 per cent by total weight of aggregate, of hydrated lime shall be added without additional cost. The filler shall be graded within the limits indicated in Table 1.1.

Table 1.1: Grading requirements for mineral filler

Is sieve(mm)	**Cumulative percent passing by weight of aggregate**
0.6	100
0.3	95-100
0.075	85-100

Table 1.2: Physical requirements for coarse aggregate for BC pavement layers

Property	**Test**	**Specification**
Cleanliness	Grain size analysis	Max 50% passing 0.075 mm sieve
Particle shape	Flakiness and elongation index	Max 30%
Strength	Los angles abration value aggregate impact value	Max 35% Max 27%
Durability	Soundnesss, sodium sulphate magnesium sulphate	Max 12% Max 18%
Water absorption	Water absorption	Max 2%
Stripping	Coating and stripping bitumen aggregate mixtures	Minimum retained coating 95%
Water sensitivity	Retained tensile strength	Min 80%

1.8 AGGREGATE GRADING AND BINDER CONTENT

When tested in accordance with IS:2386 Part 1 (Wet grading method), the combined grading-of the coarse and fine aggregates and added filler shall fall within the limits shown in Table 1.3 for grading 1 or 2 as

Table 1.3: Composition of Bituminous Concrete Pavement Layers

EXISTING MORTHS GRADATION FOR BITUMENOUS CONCRETE		
Grading	1	2
Thickness	50-65 mm	30-45 mm
Nominal Aggregate Size	19mm	13 mm
Sieve, mm		
26.5	100	-
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen grade	VG30(PENETRATION 65)	VG30(PENETRATION 65)
Bitumen Content, %	5-6	5-7

1.9 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: Requirements for Bituminous Pavement Layers

Minimum stability (KN at 60°C)	9.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (number of blows)	75 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

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

1.10 BINDER CONTENT

The binder content shall be optimised to achieve the requirements of the mixture set out in Table 500-19 and the traffic volume as specified in the Contract. The Marshall method for determining the optimum binder content shall be adopted as described in the Asphalt Institute Manual MS-2, replacing the aggregates retained on the 26.5mm sieve and retained on the 22.4mm sieve, where approved by an Engineer.

1.11 ADDITIVES IN THE BITUMINOUS MIXES

1.11.1 Plastic waste: Bitumen is a useful binder for road construction. Different grades of bitumen like 30/40, 60/70 and 80/ 100 are available on the basis of their penetration values. The steady increase in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature demand improved road characteristics. Any improvement in the property of the binder is the needed. Today the availability of the waste plastics is enormous, as the plastic materials have become part and parcel of daily life. They either get mixed with Municipal Solid Waste and/or thrown over land area. If not recycled, their present disposal is either by landfilling or by incineration. Both the processes have certain impact on the environment. Under this circumstance, an alternate use for the waste plastics is also the needed Waste plastics (polythene carry bags, etc.) on heating soften at around 130°C. Thermogravimetric analysis has shown that there is no gas evolution in the temperature range of130-180°C. Moreover the softened plastics have a binding property. Hence, the molten plastics materials can be used as a binder and/or they can be mixed with binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen, used for road construction.

Need for the study:

1) Disposal of waste plastic is a major problem.
2) It is non-biodegradable.
3) Burning of these waste plastic bags causes environmental pollution.
4) It mainly consists of low-density polyethylene.
5) To find its utility in bituminous mixes for road construction.

6) Laboratory performance studies were conducted on bituminous mixes. Laboratory studies proved that waste plastic enhances the property of the mixes.
7) Improvement in properties of bituminous mix provides the solution for disposal in a useful way.

Plastic waste classification

Plastics can be classified in many ways, but most commonly by their physical properties. Plastics may be classified also according to their chemical sources. The twenty or more known basic types fall into four general groups: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics, Natural Resins, Elastomers and Fibers. But depending on their physical properties, may be classified as thermoplastic and thermosetting materials. Thermoplastic materials can be formed into desired shapes under heat and pressure and become solids on cooling. If they are subjected to the same conditions of heat and pressure, they can be remoulded. Thermosetting materials which once shaped cannot be softened/remolded by the application of heat. The examples of some typical thermoplastic and thermosetting materials are tabulated in Table 1.6.

Table 1.6: Typical Thermoplastic and Thermosetting Resins

S.No.	**Thermoplastic Thermosetting**
1	Polyethylene Teryphthalate (PET) Bakelite
2	Polypropylene (PP) Epoxy
3	Polyvinyl Acetate (PVA) Melamine
4	Polyvinyl Chloride (PVC) Polyester
5	Polystyrene (PS) Polyurethane
6	Low Density Polyethylene (LDPE) Urea – Formaldehyde
7	High Density Polyethylene (HDPE) Alkyd

Table 1.7: Waste Plastic and its Source Waste Plastic Origin

High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.
Low Density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
Polyethylene Teryphthalate (PET)	Drinking water bottles etc
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit wafers packets, microwave trays for readymade meal etc.,
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps. Foamed
Polystyrene	food trays, egg boxes, disposable cups, protective packaging etc
Polyvinyl Chloride (PVC)	Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc

Plate 1.1: Pieces of plastic bottles

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.

1.12 COCONUT FIBRES

Coconut fibre/ coir fibre is a natural fibre derived from the mesocarp tissue or husk of the coconut fruit. It is also termed as 'Golden Fibber' due to its colour. The individual coconut fibre cells are narrow and hollow, with thick walls made up of cellulose. These fibres are pale when immature but later they become hardened and yellowed as a layer of lignin gets deposited on it. Brown coir fibres are stronger as they contain more lignin than cellulose, but they are less flexible. Coconut fibres are made up of small threads, each less than 1.3 mm long and 10 to 20 micrometers in diameter. This fibre is relatively water proof and is the only natural fibre resistant to damage by salt water. The utilization of coconut coir waste can play a role in reducing environmental pollution. Their use as a construction material to improve the properties of the composites costs very little when compared to the total cost of the composites. Due to the large consumption of coconut water, disposal of this waste has caused several problems, such as environmental pollution, insect outbreaks, stench, disease risks, methane emissions, reduced life from landfills and increasing costs of street cleaning. The incorporation of natural fibres in asphalt mixtures aims at providing a new technology engineering road construction, sustainable and durable, using environmentally friendly material available. With the increase of traffic volume and load of vehicles in major cities, and highways being the main form of transport in the country, it becomes increasingly important that a pavement meets the requirements of high durability and safety providing ease and comfort to the user in a sustainable manner. Moreover, the cost- benefit is a factor that strongly influences the choice of the asphalt coating, and the option for an alternative high durability reduces costs roads maintenance and operation, during the time of service.

The discarded coconut produces a fibre as shown in Plate 1.2 with distinctive features that can be used in the formulation of composites of high environmental value. Compared to other vegetable fibre, coconut fibre has the lowest percentage of cellulose (36-43%), however the amount of lignin (41-45%) is about twice the existing values for jute and sisal, giving it, greater resistance and hardness, compared to other fibres.

1.13 CRUMB TYRE RUBBER

Crumb rubber or waste tyre rubber is a blend of synthetic rubber, natural rubber, carbon black, antioxidants, fillers, and extender type of oils which are soluble in hot paving grade. Rubberised asphalt is obtained by the incorporation of crumb rubber from ground tyres in asphalt binder at certain conditions of time and temperature using either dry process method that adds granulated or crumb rubber modifier (CRM) from scrap tires as a substitute for a percentage of the aggregate in the asphalt concrete mixture, not as part of the asphalt binder, or wet processes (method of modifying the asphalt binder with CRM from scrap tires before the binder is added to form the asphalt concrete mixture)

Currently, the addition of crumb rubber (CR) to modify bitumens is widely used to solve the environmental problem of scrap tires and to develop high-quality, hot bituminous mixes, especially using the wet process. .

Plate 1.2: Coconut fibres

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. 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

Plate 1.3: Crumb tyre rubber

binder properties and durability, but it also has a potential to be cost effective. In recent years, researches on applications of rubberised bitumen binders have reported many advantages. 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 .

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

Prasad et al., (2012) studied the importance 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 was 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%. For both 60/70 and 80/100 grade bitumen with plastic content 8%, the maximum stability was achieved in 80/100 grade bitumen. Hence there is an increase in stability with the addition of PET plastic in asphalt mix by incorporating dry process this can be used in highway construction for better stability for the appropriate traffic.

Sharma D K., (2009) investigated the use of plastic/polymer as modifiers. The waste plastic/polymer was added on the aggregate before mixing Optimum Binder Content (OBC) in dry process at 150-160˚C temperature. This type of mixing increases the bonding between aggregates coated with plastic/polymer which increases the strength of the bituminous concrete mixes. Stability values and indirect tensile strength values were observed to be more in polymer modified bitumen than in conventional bitumen. Rutting values were also higher in polymer modified bitumen mixes than in conventional mixes.

Veeraragavan et al., (2000) used 60/70 penetration grade bitumen and Styrene Butadiene Styrene (SBS) modified binder. Here tests were conducted by two methods, marshal stability and Superpave Gyratory Compactor (SGC) and results of these two methods were compared. The test results showed that SBS modified bitumen mixes were superior to the conventional mixes. But as far as Marshall Method is concerned SGC method shows better results. Strength parameters like tensile strength, marshal stability values of SBS modified mixes were higher than 21% to 25% than that of conventional mixes. Fatigue life of SBS modified binder mix was 2.1% to 2.4% higher than the conventional mix.

Arora T R., (2013) made an attempt to add the shredded waste PP to use bituminous concrete (BC) mix and to evaluate the various mix properties like Marshall Stability number, flow, bulk density, voids in the mix and voids field with bitumen (VFB) and 8% PP coated on aggregates which had yielded the highest marshal stability. Construction and repairs work, bituminous work in India is cost too much amount every year and by using waste PP @ 8%. The cost can be reduced considerably, beside that modified CRMB surface reduced vehicle wear and tear. The optimum PP content for CRMB-60 grade bitumen was 8% bitumen with PP content 8%, the maximum stability was achieved.

Justo et al., (2002) reported the possible use of the processed plastic bags as an additive in bituminous concrete mixes at the Centre for Transportation Engineering of Bangalore University. 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.

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.

Bindu et al., (2010) investigated the benefits of stabilizing the stone mastic asphalt (SMA) mixture in flexible pavement with shredded waste plastic. Conventional (without plastic) and the stabilized SMA mixtures were subjected to performance tests including Marshall Stability, tensile strength and compressive strength tests. Triaxial tests were also conducted with varying percentage bitumen by weight of mineral aggregate (6% to 8%) and by varying percentage plastic by weight of mix (6% to 12% with an increment of 1%). Plastic content of 10% by weight of bitumen is recommended for the improvement of the performance of Stone Mastic Asphalt mixtures. 10% plastic content gives an increase in the stability, split tensile strength and compressive strength of about 64%, 18% and 75% respectively compared to the conventional SMA mix.

Tayde et al., (2012) intended to find the effective ways to reutilize the hard plastic waste particles as bitumen modifier for flexible pavements. The use of recycled waste plastic in pavement asphalt represents a valuable outlet for such materials. The use of modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, resulting which improves the longevity and pavement performance with marginal saving in bitumen usage. The process is environment friendly. The use of waste plastics in the manufacture of roads and laminated roofing also help to consume large quantity of waste plastics. Thus, these processes are socially highly relevant, giving better infrastructure.

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.

Hamedi et al., (2014) investigated the effects of waste plastic bottles (Polyethylene Terephthalate (PET)) on the stiffness and especially fatigue properties of asphalt mixes at two different temperatures of 5 and 20 ˚C. Likewise, the effect of PET was compared to styrene butadiene styrene (SBS) which is a conventional polymer additive which has been vastly used to modify asphalt mixes. Different PET contents (2–10% by weight of bitumen) were added directly to mixture as the method of dry process. Then the resilient modulus and fatigue tests were performed on cylindrical specimens with indirect tensile loading procedure. Overall, the mix stiffness reduced by increasing the PET content. Although stiffness of asphalt mix initially increased by adding lower amount of PET. Based on the results of resilient modulus test, the stiffness of PET modified mix was acceptable and warranted the proper deformation characteristics of these mixes at heavy loading conditions. At both temperatures, PET improved the fatigue behaviour of studied mixes. PET modified mixes revealed comparable stiffness and fatigue behaviour to SBS at 20^0C. However, at 5^0C the fatigue life of SBS modified mixes was to some extent higher than that of PET modified ones especially at higher strain levels of *200 microstrain.*

2.3 USE OF CRUMB RUBBER IN BITUMINOUS MIXES

Wang et al., (2007) studied the effect of Crumb Rubber Modifier on the sensitivity of high temperature of the surface mixture. In this paper, they evaluated the effect of different sizes of crumb rubber on high temperature sensitivity of three type of surface mixture. The evaluation was conducted in two parts: First, the properties of the modified and unmodified bitumen in a wide range of test temperatures and aging conditions have been compared. Then rutting resistance of modified mixtures is compared with conventional. The results of this research showed that the bitumen modified with crumb rubber have better performance to resist against rutting.

Tortum et al., (2005) used the results of Marshall Test to determine the optimal conditions for the use of tire rubber in Asphalt Concrete. They considered granulated crumb rubber, fusion temperature, aggregate gradation, the amount of crumb rubber, density temperature, the amount of bitumen and fusion time as experimental variables. In this study, the method of dry mixing crumb rubber in asphalt concrete was used. The results of this research showed that rubber asphalt mixtures have more favourable Marshall’s resistance than conventional mixtures.

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.

Celauro et al., (2012) evaluated the performance improvement that was possible to achieve when modifying road bitumen with CRM (Crumb Rubber Modifier) from discarded tire rubber (TR), using a Wet Process. This study proved that with the proposed optimization protocol it was possible to obtain improved bitumen with high content of recycled materials that, with respect to specific need of binders with a reduced temperature susceptibility for use in countries with warm climates such as those in the Mediterranean area, can be considered as ''high- performance blends''. The results of this study showed that the mixing protocol presented allowed one to optimize these blends with high ecological benefit.

Ahmet et al., (2005) used Taguchi method 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 (110–135^{0}C), and mixing time (5–30min). The optimum conditions were obtained for tire rubber gradation (sieve #40), mixing temperature (155^{0}C), aggregate gradation (grad. 1), tire rubber ratio (10%), binder ratio (5.5%), compaction temperature (135^{0}C), mixing time (15min).

Kumar et al., (2010) investigated to improve the mechanical properties of asphalt mixes by adding additives to the base asphalt binder. These binders are called modified asphalt binders. The objective of the study was 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 were 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.

Paez et al., (2010) analyzed the influence of some additives on the rheological and technological properties of crumb rubber modified binders and focused on the degree of bitumen modification, measured as the improvement of the mechanical properties, produced by the additives used, and the storage stability of these binders at high temperature. The experimental results obtained reveal that all the polymeric additives used yield an improvement in both rheological and technological properties of the binder.

Atis et al., (2007) evaluated the compactibility of hot asphalt mixtures (HAM) made with crump rubber modified bitumen, which was manufactured by incorporating the waste shredded-tire rubber particles in base bitumen in different sizes and concentration. Type of binder and binder viscosity during compaction had a great effect on the compactibility of HAM. Compaction Coefficient (CC), which is variation in porosity line throughout compaction, could be related with the energy needed to compact the mixture. Less energy is needed for the mixture having low CC. Modification of bitumen with rubber makes the mixture less compactable when compared with the mixtures made without rubber.

2.4 USE OF COCONUT FIBRES IN BITUMINOUS MIXES

Silva., (2013) concluded that coconut fibres have little porous microstructural characteristics preventing runoff from binder and contributing to the hardening of the asphalt mix, their physical characteristics, tensile strength were similar to other fibres analyzed, in other literatures. From the results obtained with the test RICE, observed that the volume of voids in blends with coconut fibres were below the established norm, which resulted in higher asphalt mixture stiffness and consequent increase in resilient modulus and tensile strength. The addition of coconut fibre in asphalt mixtures not only serves as a reduction of the passive environmental, but also to improve the performance of such mixtures.

Hadiwardoyo., (2013) made an attempt to study the structural changes in the asphalt mixture cause an increase in the temperature of the surface of the road, approaching the softening point of asphalt. Short coconut fibres are waste from coconut processing, with a length of 5-12.5 mm. The addition of 0.5%, 0.75%, 1%, 1.25%, and 1.50% coconut fibre changed the characteristics of the asphalt. The fibre size was varied (5, 7.5, 10, and 12.5 mm) to determine its effect on the asphalt characteristics. The fibre size variation was also conducted to determine its effect on the asphalt aggregate mixture at 60 °C using the Marshall immersion test. The addition of 0.75% 5-mm fibres by weight of the asphalt increased the value of the Marshall stability by 0-15% and produced lower penetration-grade bitumen. The temperature of the mixing fibres in the asphalt must be below the flash point of the fibres during the heating of the asphalt-fibre mixture.

Vale et al., (2006) studied the use of resistant and durable asphalt mixtures, such as mixtures with discontinuous graduation like the SMA (Stone Matrix Asphalt) for the surface layer. The SMA contains a high percentage of coarse aggregates, typically 70-80% retained in sieve Nº 4, with approximately 4% air voids. SMA mixtures have high binder contents, 6% to 7%, due to their discontinuous gradation. Fibres were used to prevent the asphalt flow at high mixing and compaction temperatures. This research presents the evaluation of the potential use of coconut fibres in the mixture by means of laboratory tests in which a flow parameter is analyzed, as well as the mechanical properties of the mixture: tensile strength, resilient modulus, fatigue life. Results were compared with the ones obtained from mixtures using cellulose fibre considering the same aggregate gradation and the results showed that coconut fibres meet the flow requirement and do not affect the mechanical properties of mixture.

Subramani., (2012) analyzed the addition of coir fibre to semi dense bituminous concrete mix contributes significantly in improving the performance of the mix. Stability value increased by 1.3 times when compared to the reference mix made the mix more stable for the traffic load. However, flow value showed an increment of about 1.8 times on comparison with the reference mix. The strength and void parameters of the coir fibre reinforced bituminous mix also satisfied the requirements of Specifications for Road and Bridge Works (up-gradation of third revision), MORTH. No significant variation in the optimum bitumen content was observed even with addition of coir fibre. The OBC for coir fibre reinforced bituminous mix reduced by 8.9% when compared to the reference mix. With this, it can be concluded that additional bitumen was not required to prepare fibre reinforced SDBC mix. From the test results obtained, the optimum fibre content computed was 0.46% by weight of the total mix. The Marshall parameters corresponding to this fibre content satisfies the requirements of MORTH. The optimum fibre length determined from the results was 17.25 mm whose results also satisfy MORTH specifications for SDBC. The values of OFC and OFL obtained were in agreement with already published literature on coir fibre (OFC – 0.5-0.7%; OFL – 10-20 mm) reinforced bituminous mixes.

Cook et al., (1978) reported the use of randomly distributed coir fibre reinforced cement composites as low cost materials for roofing. The studied parameters were fibre lengths (2.5 cm, 3.75 cm and 6.35 cm), fibre volumes (2.5, 5, 7.5, 10 and 15%) and casting pressure (from 1 to 2 MPa with an increment of 0.33 MPa). Different properties like bending, impact, shrinkage, water absorption, permeability and fire resistance were investigated and concluded that the optimum composite was a composite with a fibre length of 3.75 cm, a fibre volume fraction of 7.5 % and cast at pressure of 1.67 MPa. Cost comparison revealed that this composite was substantially cheaper than the locally available roofing materials.

CHAPTER-3

MIX DESIGN FOR BITUMINOUS CONCRETE (GRADE 2)

Mix designs for DBM and BC are based on guideline given by MORTH. In mix design method improvements should finally aim to achieve long lasting perpetual pavements. In a flexible pavement bituminous mixes serve the following three important functions: Provide structural strength, Facilitate subsurface drainage and Provide surface friction especially when pavement in wet condition. The bituminous mix design aims to determine the proportion of bitumen, Filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical.

It is necessary to design the bituminous mixes so as to withstand the repeated stresses and deformation and the resultant fatigue, the mix should also possess adequate resistance to low temperature cracking, moisture induced damage and resistance to permanent deformation during hot weather caused by climatic variations.

The properties of bituminous mixes depend upon the gradation and properties of aggregate and also the type and percentage of bituminous binder used in the mix.

3.1 MARHALL MIX DESIGN METHOD

Marshall test is used for the asphalt mix design as per Indian recommendation. The various mix specifications are available in the MORTH specifications for road and bridge works and other in IRC specifications. Two things are of primary concern in a asphalt mix, namely the aggregate gradation and the mix design requirements. Various mixes have various gradations. The acceptable volumetric parameters and Marshall Stability requirements are different for different mixes Thus for various individual mixes a separate Marshall mix design needs to be carried out to find out the OBC value.

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

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).

3.2 APPARATUS DETAILS

Marshall Stability testing machine is as shown in plate 3.3 and essential accessories consist of the following:

a) Compaction Mould Assembly : This consist of

Compaction mould of cylindrical shape of diameter 101.6mm and height 75 mm a collar extension and a base plate . Both the end of the cylindrical mould are interchangeable and may be placed on base plate is as shown in plate 3.2

- Compaction hammer with a flat circular plate of diameter 98.4 mm and a hammer of weight 4.5kg which can be lifted and released to obtain 457 mm drop
- Compaction pedestal and mould holder, consisting of a wooden block capped with a steel plate to hold the mould assembly in position during compaction, a mould holder with spring tension device to hold compaction mould in place of the compaction pedestal.

b) **Specimen extractor:** A specimen extractor suitably fitted with a jack or compression machine, for extruding the compacted specimen from mould is as shown in plate 3.1

c) **Testing head:** It consist of upper and lower cylindrical segments of test head with an inside radius of curvature of 51mm. The lower segment is mounted on a base having two vertical guide rods which facilitate insertion in the holes of upper test head. Testing head is as shown in plate 3.6

d) **Testing machine:** It consists of a motorised loading unit provided with a gear system to lift the base plate upward at the specified rate. A calibrated proving ring of 5 tonne capacity with a dial gauge or a load cell with a digital load display unit is fixed on the upper end of the machine to measure the load applied. In between the base and the proving ring /load cell, the testing head with the specimen inside is placed in position The strain controlled loading machine produces a moment of the base plate at the rate of 51 mm per minute. By operating the lever of the gear it is possible to reverse the moment of the base plate downwards to enable removal of the testing head and specimen after each test.

e) **Deformation measuring dial gauge:** A dial gauge with least count of .01mm or.025 mm fixed to the guide rods of the testing machine to measure the vertical deformation of the specimen placed inside the test head due to the load applied.

f) **Other accessories:** These include thermostatically controlled oven, hot plate, mixing device, thermostatically controlled waterbath and thermometers of suitable ranges and sensitivity to be used in the oven and water bath.

3.3 PROCEDURE OF SAMPLE PREPERATION

Approximately 1200g of the ingredients were taken to prepare each mould of the BC mix. The weight of the mix was taken in such a manner that compacted specimens of BC mix specimen of thickness 63.5 mm approximately. Before placing in the mould, the aggregates and filler is heated to a temperature of 175 to 190°C. The face of the compaction hammer was thoroughly cleaned and heated at a temperature of 95 to 150°C. The temperature of the laboratory during compaction of the specimens was between 20 and 30°C.

Plate 3.1: Specimen extractor

Plate 3.2: Mould with specimen

Plate 3.3: Marshall stability testing machine

b) Bitumen binder is heated to a temperature of 120 to 165°C.

C) The weighed quantity of heated bitumen is added to the heated aggregate and the mixture is thoroughly mixed at the specified mixing temperature, by a mechanical mixer or by hand mixing with trowel. It is suggested that the bituminous binder is heated such that its kinematic viscosity is in the range of 150-190 centistokes.

d) After mixing thoroughly such that the surfaces of aggregates are uniformly and fully coated with binder. The bituminous mix may be allowed to slightly cool down to a recommended compacting temperature. The recommended compacting temperature is about 149°C for VG30 grade (60/70 penetration grade) bitumen.

e) The mix is placed in the pre-heated mould and is compacted by the rammer at the specified temperature, by applying 75 blows on either side.

f) After the compaction the specimen with the mould is allowed to cool down to room temperature.

g) Extrude the specimen from the mould. 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 3.4

Plate 3.4: Samples extracted from Marshall mould

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 57.2 to 69.8 mm in height.
b) Determine the specific gravity of the specimens.
c) Determine the bulk density of each of the specimens, by multiplying the respective specific gravity by 998kg/m. Record the individual bulk densities to the nearest 1kg/m.
d) Determine the average specific gravity of the specimens and record to the nearest 0.001.
e) Bring the specimens to 60±1°C by immersing in the water bath 30 to 40 minutes. 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) 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 51mm 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 and the flow to the nearest0.1 mm.
i) Correct the stability obtained for each specimen, for the height of the specimen.
j) Determine and record the average corrected stability and the average flow to the nearest0.1 mm.

Plate 3.5: Specimen testing in Marshall Stability machine

Plate 3.6: Testing head of Marshall stability machine

3.5 PROPRTIES OF THE MIX

The properties that are of interest include the theoretical specific gravity Gt, the bulk specific gravity of the mix Gm, percent air voids Vv, percent volume of bitumen Vb, percent void in mixed aggregate VMA and percent voids filled with bitumen VFB. These calculations are discussed next. To understand these calculation a phase diagram is given in Figure 3.1

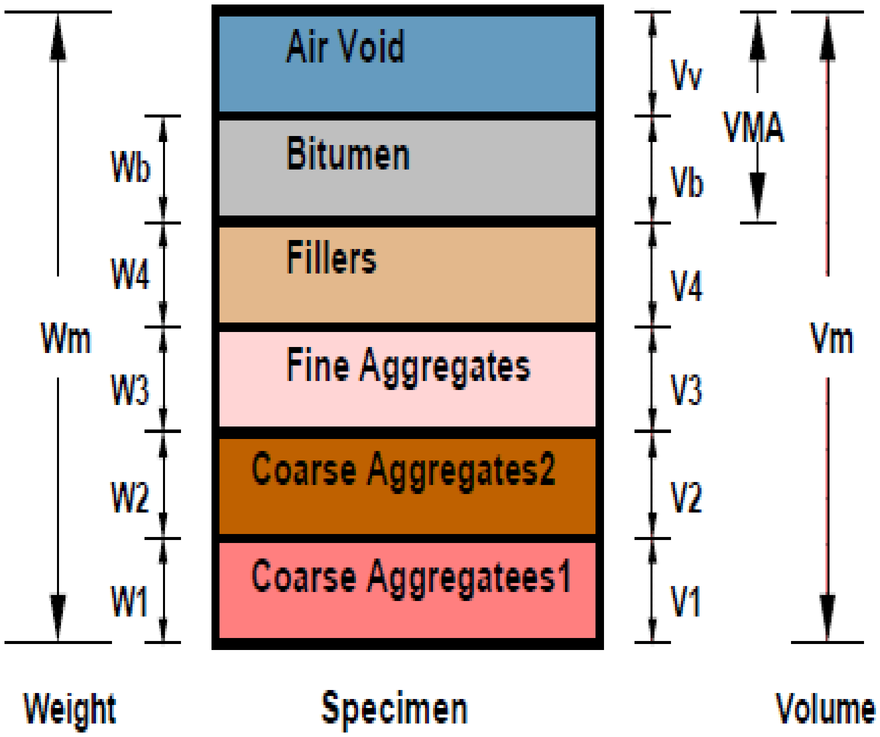

Figure 3.1: Phase Diagram of Bituminous Mix

3.5.1 THEORETICAL SPECIFC GRAVITY OF THE MIX GT

Theoretical specific gravity Gt is the specific gravity without considering air voids, and is given by:

$$Gt = \frac{W1 + W2 + W3 + Wb}{\frac{W1}{G1} + \frac{W2}{G2} + \frac{W3}{G3} + \frac{Wb}{Gb}}$$

where,

W1 is the weight of coarse aggregate in the total mix,

W2 is the weight of fine aggregate in the total mix,

W3 is the weight of filler in the total mix,

Wb is the weight of bitumen in the total mix,

G1 is the apparent specific gravity of coarse aggregate,

G2 is the apparent specific gravity of fine aggregate,

G3 is the apparent specific gravity of filler and

Gb is the apparent specific gravity of bitumen,

3.5.2 BULK SPECIFIC GRAVITY OF MIX "G_M"

The bulk specific gravity or the actual specific gravity of the mix Gm is the specific gravity considering air voids and is found out by:

$$\mathrm{Gm} = \frac{\mathrm{Wm}}{\mathrm{Wm} - \mathrm{Ww}}$$

where, Wm is the weight of mix in air,

Ww is the weight of mix in water,

3.5.3 AIR VOIDS PERCENT "V_V"

Air voids Vv is the percent of air voids by volume in the specimen and is given by:

$$V = \frac{(\mathrm{Gt} - \mathrm{GM})100}{\mathrm{Gt}}$$

where Gt is the theoretical specific gravity of the mix.

and Gm is the bulk or actual specific gravity of the mix.

3.5.4 PERCENT VOLUME OF BITUMEN "V_B"

The volume of bitumen Vb is the percent of volume of bitumen to the total volume and given by:

$$Vb = \frac{\frac{Wb}{Gb}}{\frac{W1 + W2 + W3 + W4}{Gm}}$$

where,

W1 is the weight of coarse aggregate in the total mix,

W2 is the weight of fine aggregate in the total mix,

W3 is the weight of filler in the total mix,

Wb is the weight of bitumen in the total mix,

Gb is the apparent specific gravity of bitumen, and

Gm is the bulk specific gravity of mix.

3.5.5 VOIDS IN MINERAL AGGREGATE "VMA"

Voids in mineral aggregate VMA is the volume of voids in the aggregates, and is the sum of air voids and volume of bitumen, and is calculated from

$$VMA = V_v + V_b$$

where,

Vv is the percent air voids in the mix.

Vb is percent bitumen content in the mix.

3.5.6 VOIDS FILLED WITH BITUMEN "VFB"

Voids filled with bitumen V FB is the voids in the mineral aggregate frame work filled with the bitumen, and is calculated as:

$$VFB = VB * \frac{100}{VMA}$$

where, Vb is percent bitumen content in the mix, and

VMA is the percent voids in the mineral aggregate.

3.6 TESTS ON BITUMEN

There are a number of tests to assess the properties of bituminous materials. The following tests as shown in table 3.1 were conducted to evaluate different properties of binder to be used.

Table 3.1: IS code reference of various tests on bitumen sample

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

3.6.1 Penetration Test

The consistencies of bituminous materials vary depending upon several factors such as constituents, temperature, etc. As temperature ranges between 25° and 50°C most of the paving bitumen grades remain in semi solid or in plastic states and their viscosity is so high that they do not flow as liquid. Determination of absolute viscosity of bituminous material is not so simple. Therefore the consistency of these materials is determined by indirect methods. The consistency of bitumen is determined by penetration test which is a very simple test. Various types and grades of bituminous materials are available depending on their origin and refining process. The penetration test determines the consistency of these materials for the purpose of grading them, by measuring the depth (in units of one tenth of a millimetre or one hundredth of a centimetre) to which a standard needle will penetrate vertically under specified conditions of standard load, duration and temperature. Thus the basic principle of the penetration test is the measurement of the penetration (in units of one tenth of a mm) of a standard needle in a bitumen sample maintained at 25C during five seconds, the total weight of the needle assembly being 100gm. The softer the bitumen, the greater will be the penetration. The test is conducted as per IS-1203 for paving bitumen. The penetration test apparatus is as shown in plate 3.7

PROCEDURE

- The bitumen is softened to a paving consistency between 75° and 100°C above the approximate temperature at which bitumen softens.
- The sample material is thoroughly stirred to make it homogeneous and free from air bubbles and water.
- The sample containers are cooled in atmosphere of temperature not lower than 13°C for one hour. Then they are placed in temperature controlled water bath at a temperature of 25°C for a period of one hour.
- The weight of needle, shaft and additional weight are checked. The total weight of this assembly should be 100 gm.
- Using the adjusting screw, the needle assembly is lowered and the tip of the needle is made to just touch the top surface of the sample.
- The needle assembly is clamped in this position. The contact of the tip of the needle is checked using the mirror placed on the rear of the needle.
- The initial reading of the penetrometer dial is either adjusted to zero or the initial reading is noted.
- Then the needle is released by pressing a button and a stop watch is started. The needle is released exactly for a period of 5.0secs.
- At least 3 measurements are made on this sample by testing at distance of not less than 100 mm apart.
- The difference between the initial and final penetration readings are taken as the penetration value.

Plate 3.7: Penetration test apparatus

3.6.2 Ductility Test

A certain minimum ductility is necessary for a bitumen binder. This is because of the temperature changes in bituminous mixes and the repeated deformations that occur in flexible pavements due to the traffic loads. It is of significant importance that the binders form ductile thin films around the aggregates. The binder material which does not possess sufficient ductility would crack and thus provide previous pavement surface. This is in turn results in damaging effect to the pavement structure. The ductility is expressed as the distance in centimetres to which a standard briquette of bitumen can be stretched before the thread breaks. The test is standardized by the **IS: 1208.** The test is conducted at 27°±0.5°C and a rate of pull of 50±2.5 mm per minute.

Procedure:

- The bitumen sample is method to a pouring temperature (75°C to 100°C) and poured into the mould assembly and placed on a brass plate, where a solution of glycerine or soap solution is applied at all surfaces of briquette mould exposed to bitumen.
- After the sample is poured to the mould, thirty to forty minutes the entire assembly is placed in a water bath at 27°C.
- Then the sample is removed from the water bath maintained at 27°C and excess bitumen material is cutoff by levelling the surface using hot knife.
- After trimming the specimen, the mould assembly containing sample is replaced in water bath maintained at 27°C for 85 to 95 minutes. Then the sides of mould are removed and the clips are carefully booked on the machine without causing any initial strain. Two or more specimens may be prepared in the moulds and clipped to the machine so as to conduct these test simultaneously.
- 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, it is checked whether the sample is immersed in water at depth of atleast 10 mm. The distance at which the bitumen thread of each specimen breaks is recorded (in cm) to report as ductility value.

3.6.3 Softening point test

Bitumen does not suddenly change from solid to liquid state, but as the temperature increase, it gradually becomes soften until it flows readily. The softening point is the temperature at which the substance attains particular degree of softening under specified condition of test. For bitumen it is usually determined by Ring and Ball apparatus. The test is conducted as per **IS: 1205.** Plate no.3.8 shows Softening point test apparatus

Plate 3.8: Softening point test apparatus

Procedure:

- Sample material is heated to a temperature between 75° and 100°C above the approximate softening point until it is completely fluid and is poured in heated rings placed on the metal plate.
- To avoid sticking of the bitumen to metal plate, coating is done to this with a solution of glycerine and dextrin.
- After cooling the rings in air for 30 minutes, the excess bitumen is trimmed and rings are placed in the support.
- At this time the temperature of distilled water is kept at 5°C. This temperature IS maintained for 15 minutes after which the balls are placed in position.
- Then the temperature of water is raised at uniform rate of 5°C per minute with a controlled heating unit, until the bitumen softens and touches the bottom plate by sinking of balls. At least two observations are made. For material whose softening point is above 80°C, glycerine is used for heating medium and the starting temperature is 35°C instead of 5°C.
- The temperature at the instant when each of the ball and sample touches the bottom plate of support is recorded as softening point value.

3.6.4 Specific Gravity Test

The density of a bitumen binder is a fundamental property frequently used as an aid in classifying the binders for use in paving jobs. In most applications, the bitumen is weighed, but finally in use with aggregate system, the bitumen content is converted on volume basis. Thus an accurate density value is required for conversion of weight to volume. The specific gravity is greatly influenced by the chemical composition of binder. The specific gravity is defined by ISI as the ratio of the mass of a given volume of the bituminous material to the mass of an equal volume of water, the temperature of both being specified at 27°C±O.1 °C. The code of practice used to determine the specific gravity is IS: 1202.

Procedure:

- The clean, dried specific gravity bottle is weighed let that be W Igm.
- Then it is filled with fresh distilled water and then kept in water bath for at least half an hour at temperature 27°C±O.1 °C.
- The bottle is then removed and cleaned from outside. The specific gravity bottle containing distilled water is now weighed. Let this be W 2gm.
- Then the specific gravity bottle is emptied and cleaned. The bituminous material is heated to a pouring temperature and the material is poured half the bottle, by taking care to prevent entry of air bubbles. Then it is weighed. Let this be W 3gm.
- The remaining space in specific gravity bottle is filled with distilled water at 27°C and is weighed. Let this be W4gm. Then specific gravity of bituminous material is given by formula.

3.6.5 Viscosity Test

Viscosity is defined as the increase of fluidity. The degree of fluidity at the application temperature greatly influences the ability of bituminous material to spread, penetrate in to void and also coat the aggregates and hence affects the strength characteristics of the resulting paving mixes.

There is an optimum value of fluidity or viscosity for mixing and compacting for each aggregate gradation of the mix and bitumen grade. At high fluidity or low viscosity, the bitumen binder simply "lubricates" the aggregate particles instead of providing a uniform film thickness for binding action. Similarly, low fluidity or high viscosity does not enable the bitumen to coat the entire surface of aggregates. It will increase the compactive force or effort. The test is conducted as per **IS: 1206.**

Procedure:

- The tar cup is properly levelled and water in the bath is heated to the temperature specified for the test and is maintained throughout the test.
- The sample material is heated at the temperature 20 above the specified test temperature and the material is allowed to cool. During cooling the material continuously, stirred.
- When material reaches slightly above test temperature, the same is poured in the tar cup, until the levelling peg on the value rod is just immersed.
- A graduate receiver (cylinder) and a 20ml of mineral oil or one percent by weight solution of soft soap is poured.
- When the sample material reaches the specified test temperature within ±O.I°C and then valve is opened.
- The stop watch is started with the valve opening and time is noted for collecting a 50ml of test sample to flow through the orifice and collected in the receiver kept below the orifice Viscometer.
-

3.6.6 Flash and Fire Point Test

Flash and Fire point test is a safety test conducted on a bituminous material so that it gives an indication of the critical temperature at and above where precautions should be taken to eliminate fire hazards during its applications. Bituminous materials leave out volatiles at high temperature depending upon their grade. These volatile vapours catch fire causing a flash. This condition is very hazardous and it is therefore essential to qualify this temperature for each bitumen grade, so that the paving engineers may restrict the mixing or application temperature well within the limits.

Flash and Fire point test is conducted as per **IS: 1209.**

As per IS: 1209 the definitions of flash and fire point are:

Flash Point: The flash point of a material is the lowest temperature at which the vapour of substance momentarily takes fire in the form of a flash under specified conditions of test.

Fire Point: The fire point is the lowest temperature at which the material gets ignited and burns under specified condition of test.

Procedure

- All parts of the cup are cleaned and dried thoroughly before the test is started.
- The material is filled in the cup upto a mark. The lid is placed to close the cup in a closed system. All accessories including thermometer of the specified range are suitably fixed.
- The bitumen sample is then heated. The test flame is lit and adjusted in such a way that the size of a bed is of 4mm diameter. The heating of sample is done at a rate of 5° to 6°C per minute. During heating the sample the stirring is done at a rate of approximately 60 revolutions per minute.
- The test flame is applied at intervals depending upon the expected flash and fire points and corresponding temperatures at which the material shows the sign of flash and fire are noted.

3.7 TESTING OF AGGREGATES

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.

CHAPTER-4

TEST RESULTS AND DISCUSSION

4.1 GENERAL

This chapter includes the test results obtained after the laboratory testing of the BC 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 75 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 BC Grade 2. The sieve analysis test results are presented in Table 4.1.

Table 4.1: Sieve analysis results

Sieve size	**Percentage passing 20mm**	**Percentage passing 10mm**	**Percentage stone dust**	**Percentage passing lime**
26.5	100	100	100	100
19	100	100	100	100
13.2	14.83	100	100	100
9.5	4.76	83.93	100	100
4.75	2	14.6	100	100
2.36	0	4.26	92.33	100
0.600	0	1.6	74.83	99.4
0.300	0	0	58.16	98.4
0.15	0	0	39	92.6
.075	0	0	27	72.6

The MORTH's gradations of bituminous concrete are shown in table 4.2. The blending selected for the gradation of bituminous concrete-Grade 2 is shown in table 4.3. The combined gradation of the sample taken is shown in table 4.5.

Table 4.2: Gradations for Bituminous concrete pavement layers

EXISTING MORTHS GRADATION FOR BITUMENOUS CONCRETE		
Grading	1	2
Thickness	50-65 mm	30-45 mm
Nominal Aggregate Size	19mm	13 mm
Sieve, mm	-	-
26.5	100	-
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen grade	VG30(PENETRATION 65)	VG30(PENETRATION 65)
Bitumen Content, %	5-6	5-7

Table 4.3: Percentage of aggregate size taken

Calculated Blending for BC grading no-2				
20 mm	**10MM**	**Stone dust**	**Lime**	**Total**
22	25	49	4	100

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 4.6

Table 4.4: Target gradation of the sample as per MORTH

	SPECIFICATIONS FOR BC GRADE 2		
IS Sieve (mm)	% PASSING		
	COARSER LIMIT	FINER LIMIT	TARGET GRADATION
26.5	100	100	100
19	100	100	100
13.2	79	100	89.5
9.5	70	88	79
4.75	53	71	62
2.36	42	58	50
1.18	34	48	41
0.6	26	38	32
0.3	18	28	23
0.15	12	20	16
0.075	4	10	7

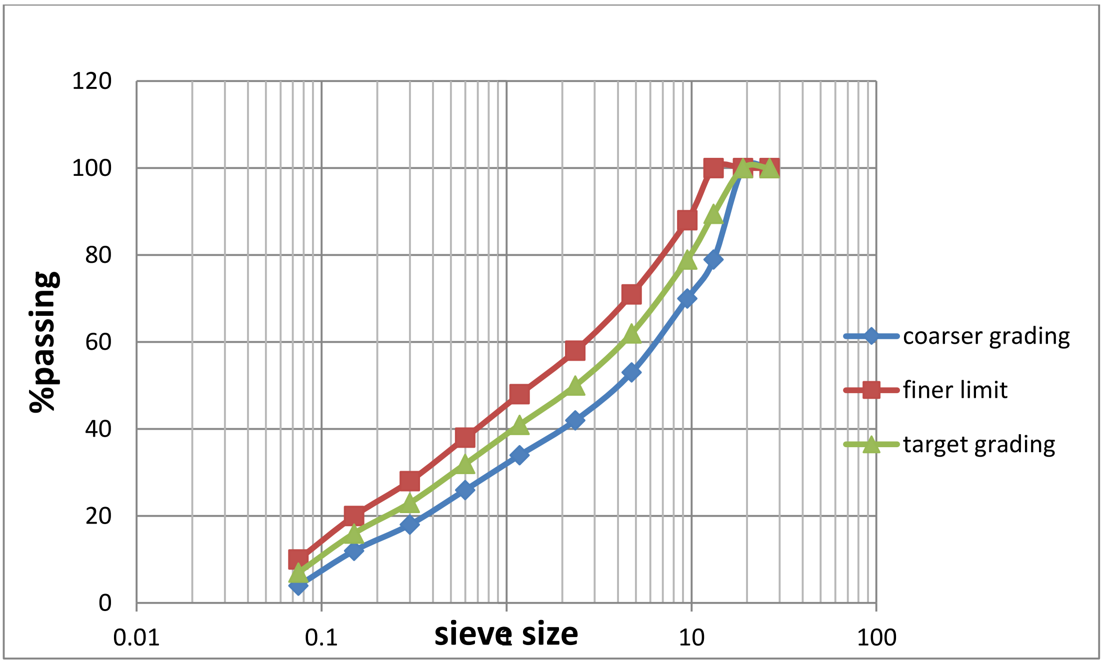

Figure 4.1 Target gradation compared with specified grading envelope

Table 4.5: Combined gradation of the sample taken

Required sieve	Percentage passing 20mm	Percentage passing 10mm	Percentage passing stone dust	Percentage passing lime	Combined gradation	LIMIT AS PER MORTH	
						Min.	Max.
26.5	22	25	49	4	100	100	100
19	22	25	49	4	100	100	100
13.2	3.263	25	49	4	81.26	79	100
9.5	1.048	20.98	49	4	75.032	70	88
4.75	0.44	3.65	49	4	56.65	53	71
2.36	0	1.06	45.24	4	50.31	42	58
1.18	0	0.4	36.66	3.976	41.04	34	48
0.6	0	0	28.50	3.936	32.43	26	38
0.3	0	0	19.11	3.704	22.814	18	28
0.15	0	0	13.23	2.904	16.134	12	20

Table 4.6: 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	

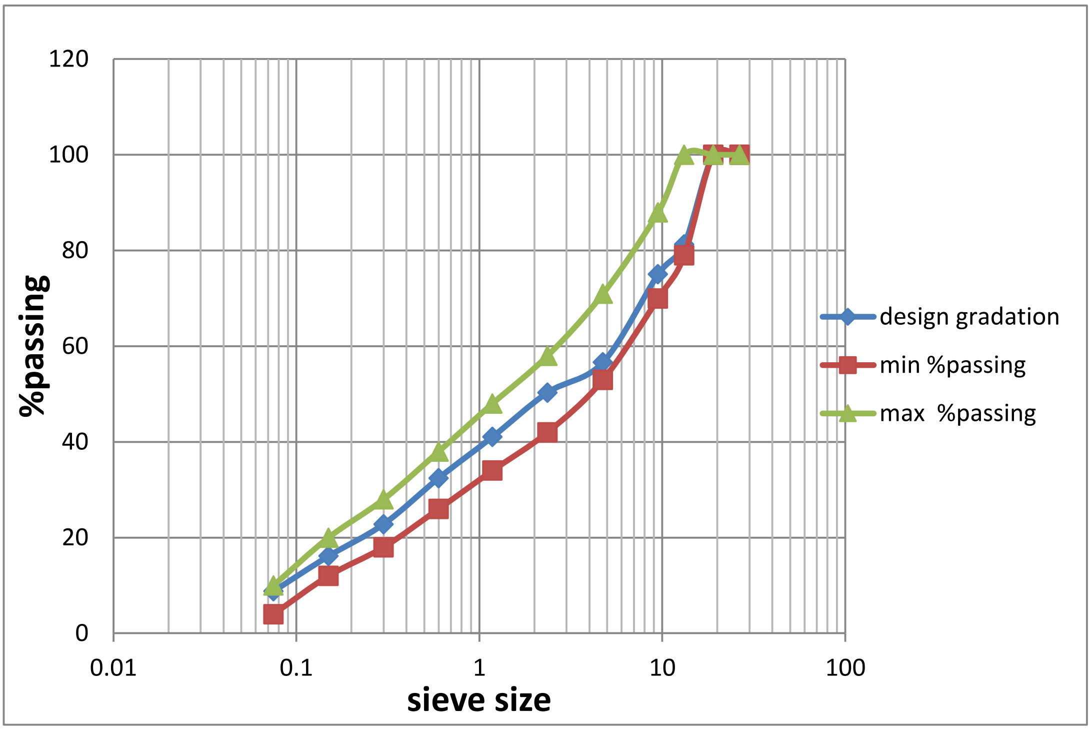

Figure 4.2: Design gradation of aggregates

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 4.7.

4.5 RESULTS OF BC GRADE 2 MIX DESIGN WITHOUT ANY ADDITIVE OPTIMUM BINDER CONTENT

Optimum Binder Content is found out by taking average value of following seven bitumen content found from graph i.e.

- Bitumen content corresponds to maximum stability.
- Bitumen content corresponds to maximum unit weight.
- Bitumen content corresponding to the median of designed limits of percentage air voids in total mix.

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 4% to 7%.

Table 4.7: Test results of ingredient bitumen sample

TEST RESULTS FOR INGREDIENT BITUMEN			
Property	**Test Results**	**Specified Limits as per BIS : 73-1992**	**Test Method**
Penetration at 25ºC/100 gm /5 sec, mm	67	60-70	IS: 1203
Softening Point, ºC	52.2	40-55	IS: 1205
Ductility, cm	81	> 75	IS: 1208
Specific Gravity, at 27ºC	1.01	>0.99	IS: 1202
Viscosity at 135ºC, CST	265	>150	IS: 1206

The test values obtained are plotted graphically. From the graphs plotted from Fig 4.3 to 4.7, the optimum binder content was found to be 6 percent by wt. of aggregates using stability flow values. The outputs of stability and flow values are as in table no 4.7and fig 4.3 to 4.7:-

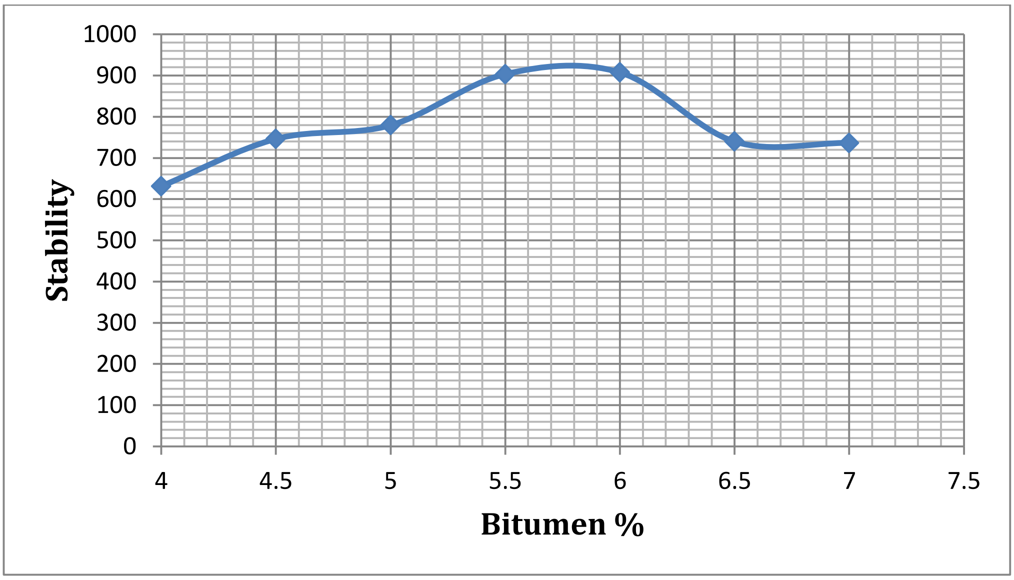

Figure 4.3: Variation of Stability Value to the Variation in Bitumen Content

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 (Kg)		Flow (mm)
						Correlation ratio	Corrected Stability (Kg)	
1	4	2.25	5.23	13.28	61.15	1	633.6	2.5
2		2.35	5.05	13.16	61.03	1	629.2	2.3
Average		2.30	5.14	13.22	61.09	1	631.4	2.4
1	4.5	2.34	4.57	11.06	60.2	1	745.3	3.3
2		2.36	4.37	10.76	60.6	1	747.1	3.26
Average		2.35	4.47	10.91	60.4	1	746.2	3.3
1	5	2.35	4.12	11.22	63.16	.96	779.9	3.45
2		2.35	4.04	10.88	63.00	.96	778.7	3.55
Average		2.35	4.08	11.05	63.08	.96	779.3	3.5
1	5.5	2.36	4.06	11.55	62.39	.94	903.46	3.9
2		2.35	4.05	11.53	62.27	.94	903.28	3.7
Average		2.36	4.06	11.54	62.33	.94	903.37	3.8
1	6	2.34	3.75	12.66	69.99	.93	909.49	4.1
2		2.33	3.68	12.12	69.97	.93	905.49	3.7
Average		2.33	3.71	12.39	69.98	.93	907.49	3.9
1	6.5	2.33	3.25	12.77	73.59	.93	738.7	5.2
2		2.32	3.37	12.99	73.33	.93	740.7	5.0
Average		2.33	3.31	12.88	73.46	.93	739.722	5.1
1	7	2.32	2.98	12.71	76.88	.90	736.42	7
2		2.31	2.86	12.57	76.80	.90	736.62	4
Average		2.32	2.92	12.64	76.84	.90	736.52	5.5

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

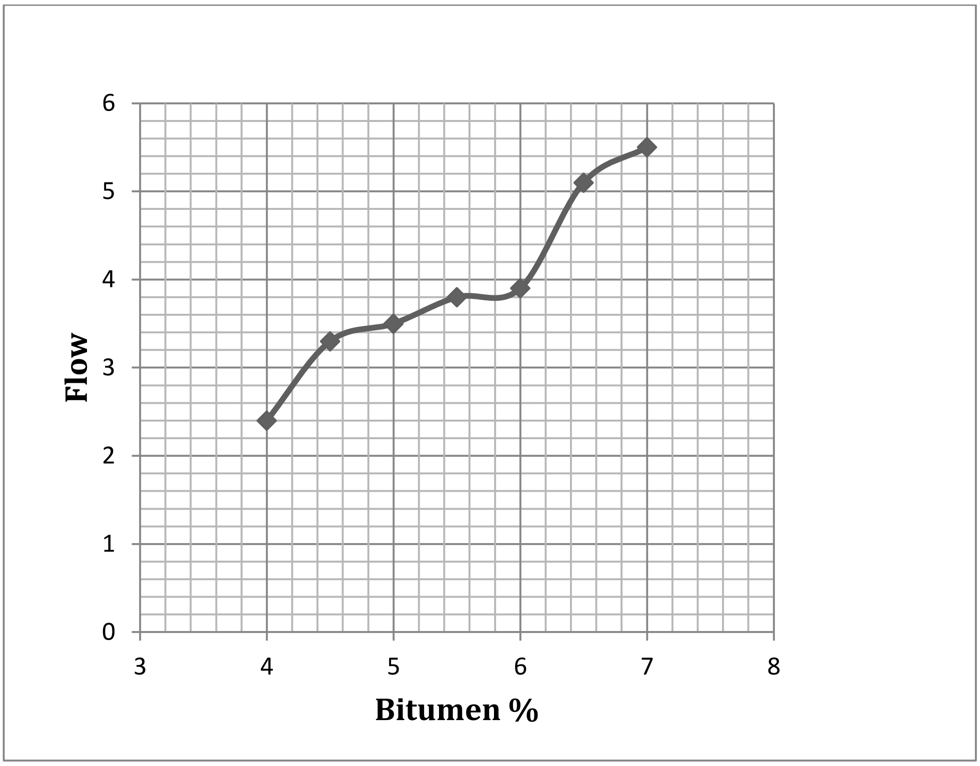

Figure 4.4: Variation of Flow Value to the Variation in Bitumen Content

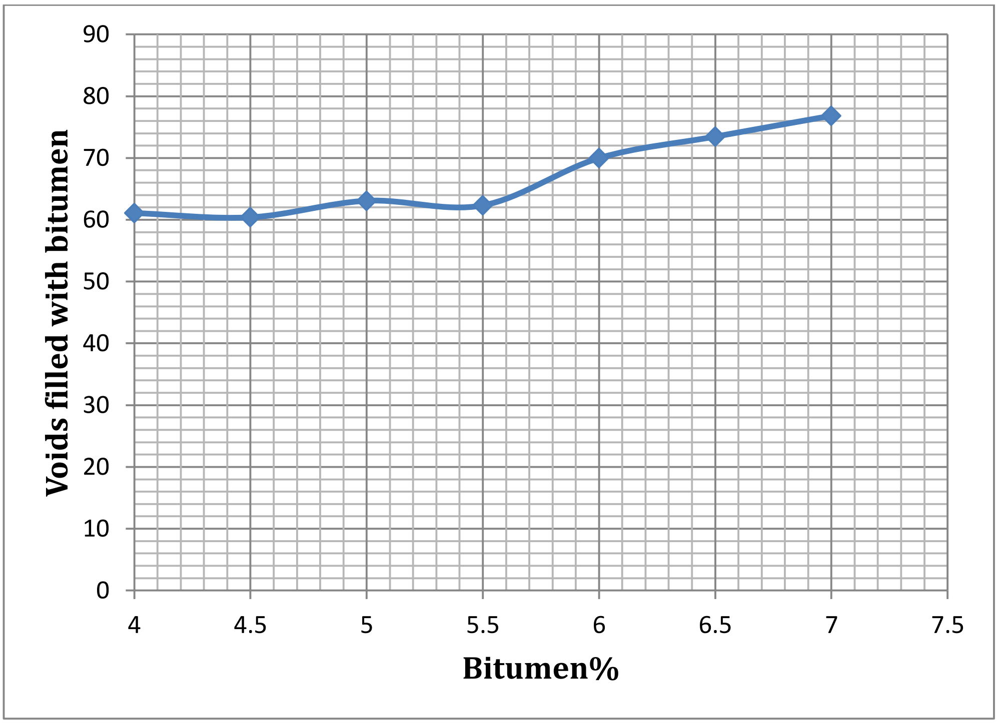

Figure 4.5: Variation of VFB to the Variation in Bitumen Content

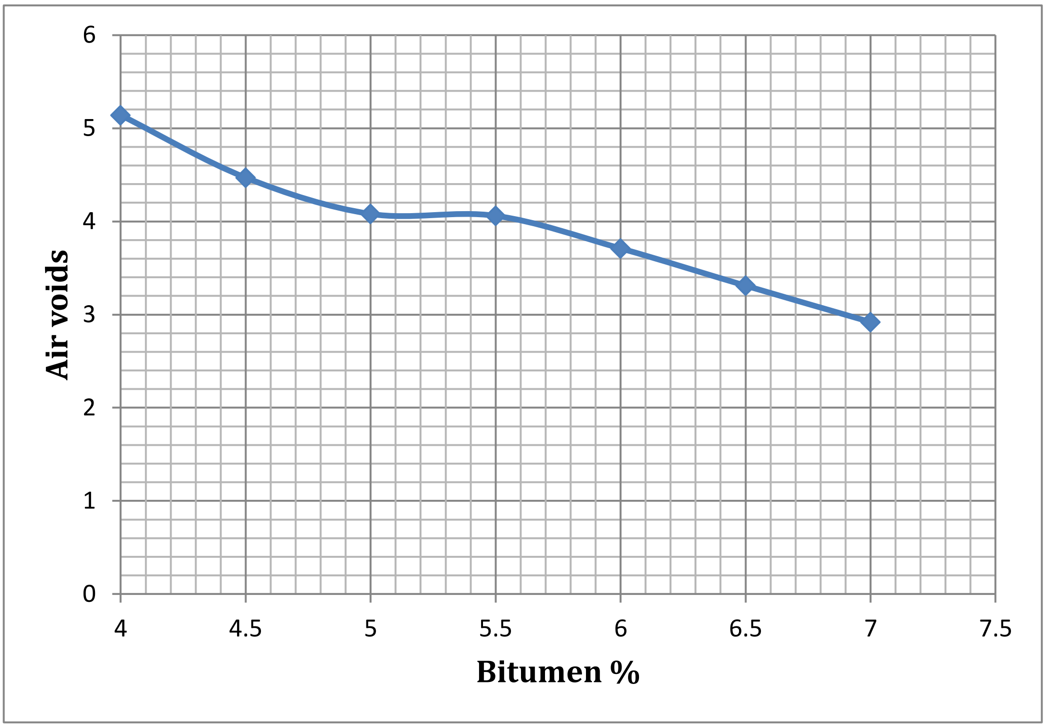

Figure 4.6: Variation of air voids to the Variation in Bitumen Content

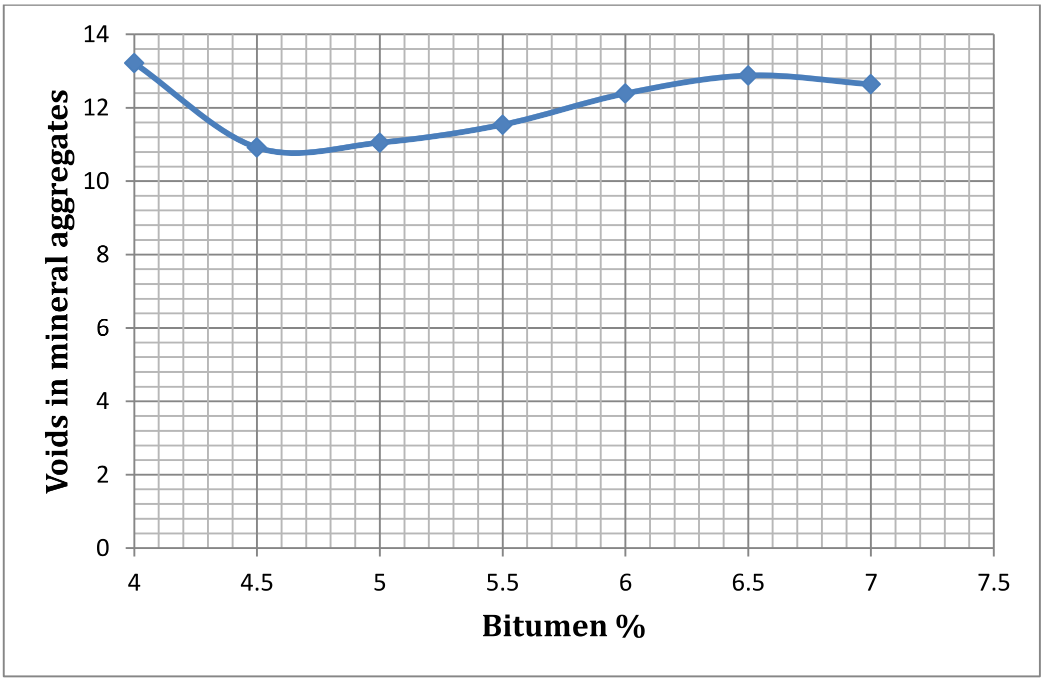

Figure 4.7: Variation of VMA to the Variation in Bitumen Content

4.6 RESULTS OF BC GRADE 2 MIX DESIGN WITH PLASTIC WASTE

The waste plastic bottles were used in the bituminous mixes of BC Grade 2 and stability flow characteristics of the mix was carried out using Marshall Method of bituminous mix design. The optimum binder content (OBC) of 6% was replaced with 4%,6% 8%,10% and 12% of plastic content to determine the Stability and Flow characteristics of the modified mix. The outputs are shown in table4.9 and figure 4.8 and 4.9.

Table 4.9: Test Outputs for Stability and Flow by Varying Plastic Content.

Addition of waste plastic(%)in OBC by wt of bitumen	Height of sample (mm)	Stability (kN)	Correction factor	Corrected stability (kN)	Flow (mm)
4	68.3	1037.49	.89	923.37	2.57
6	68.15	1054.61	.89	938.6	2.62
8	68.5	1116.55	.89	993.72	3.2
10	68.35	1141.00	.89	1015.98	3.35
12	68.25	1125.51	.89	1001.70	3.78

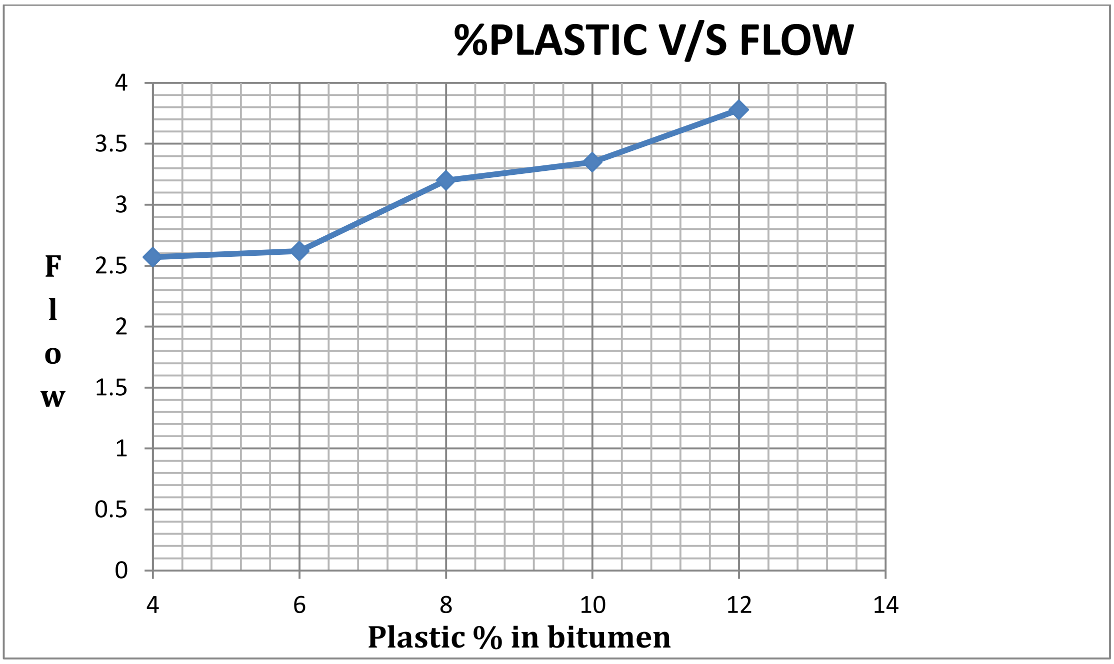

Figure 4.8: Variation of flow of the Variation in Waste Plastic Content

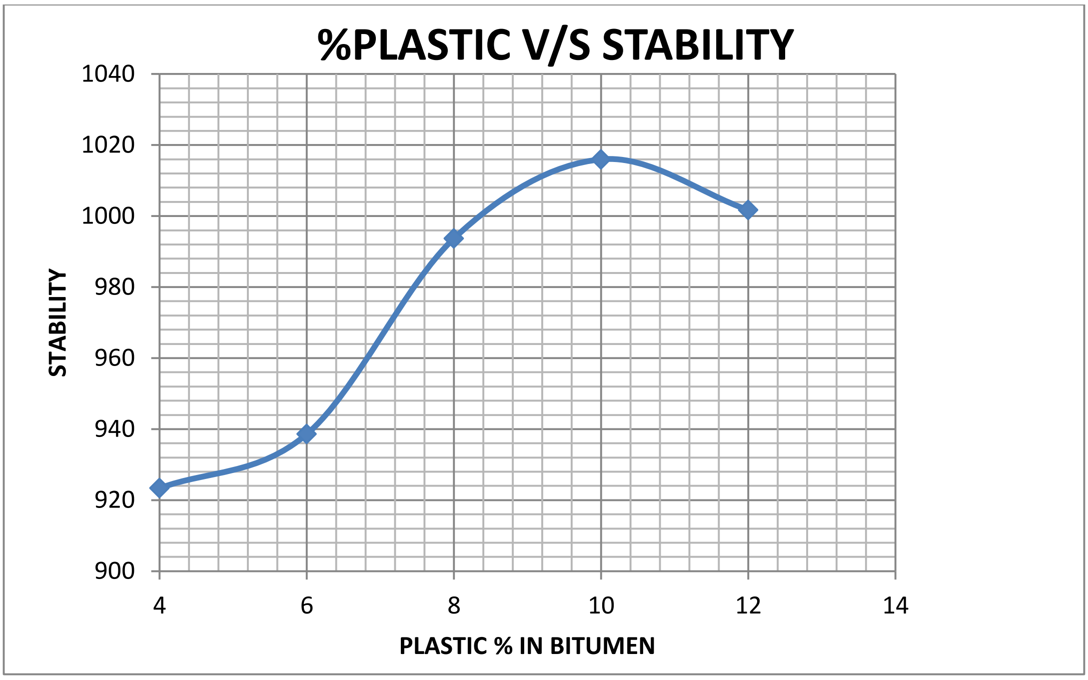

Figure 4.9: Variation of Stability to the Variation in Waste Plastic Content

4.7 RESULTS OF BC GRADE 2 MIX DESIGN WITH CRUMB TYRE RUBBER

Marshal method of bituminous mix design for BC grade 2 was carried out by replacing the optimum binder content with varying percentages of 2%, 6%, 10%, 14%and 18% tyre tube to determine the Stability-Flow characteristics of the modified mix.

The outputs are shown in table no 4.10 and figure 4.10 and 4.11

Table 4.10: Test Outputs for Stability and Flow by Varying tyre rubber content

Addition of tyre rubber (%)in OBC by wt of bitumen	Height of sample (mm)	Stability (kg)	Correction factor	Corrected stability (kg)	Flow(mm)
2	68.2	1039.12	0.89	924.82	2.85
6	68.3	1137.74	0.89	1012.58	3.5
10	68.45	1080.69	0.89	961.81	3.7
14	68.5	1056.24	0.8	940.05	4.45
18	68.4	1017.12	0.89	905.23	5.35

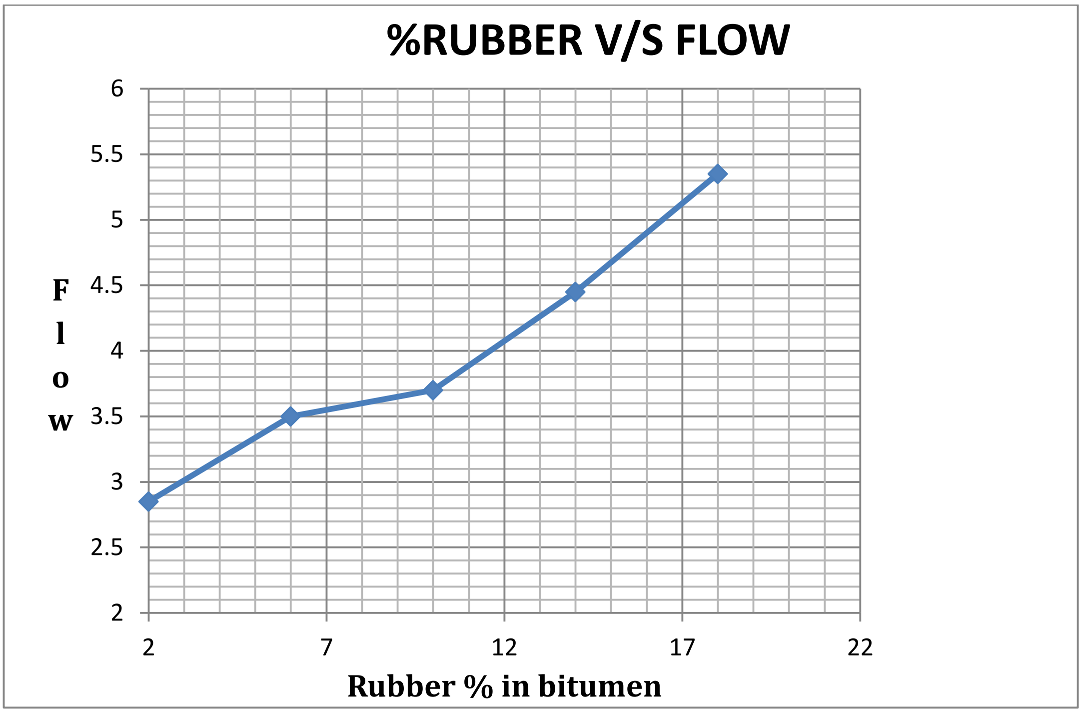

Figure 4.10: Variation of flow to the Variation in Tyre rubber Content

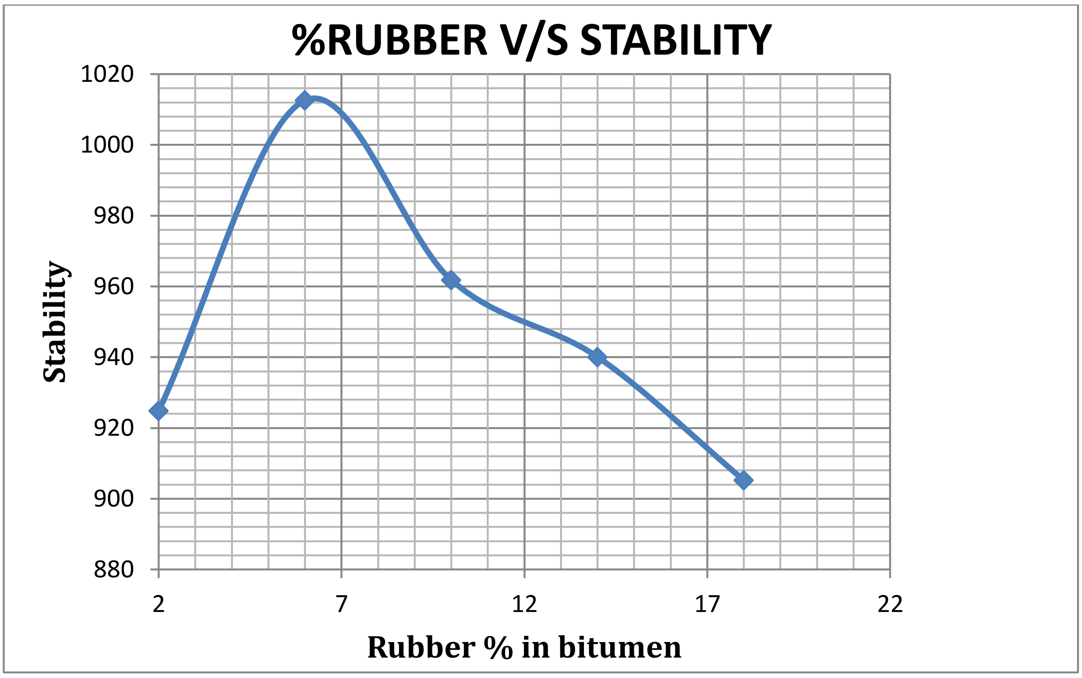

Figure 4.11: Variation of Stability to the Variation in Tyre rubber Content

4.8 RESULTS OF BC GRADE 2 MIX DESIGN WITH COCONUT FIBRES

The coconut fibres were used in the bituminous mixes of BC Grade 2 and stability flow characteristics of the mix was carried out using Marshall Method of bituminous mix design. The optimum binder content (OBC) of 6% was added with .5%,.75%,1%,1.25%,1.5% of plastic content to determine the Stability and Flow characteristics of the modified mix. The outputs are shown in table4.11 and figure 4.12 and figure 4.13

Table 4.11: Test Outputs for Stability and Flow by varying coconut fibre content

Addition of coconut fibre (%)in OBC by wt of bitumen	Height of sample (mm)	Stability (kg)	Correction factor	Corrected stability (kg)	Flow(mm)
0.5	68.2	1077.43	0.89	926.59	3.35
0.75	68.25	1106.77	0.89	951.82	3.70
1.0	68.33	1174.41	0.89	1009.29	3.85
1.25	68.24	1118.18	0.8	961.63	4.45
1.50	68.4	1088.84	0.89	936.4	4.94

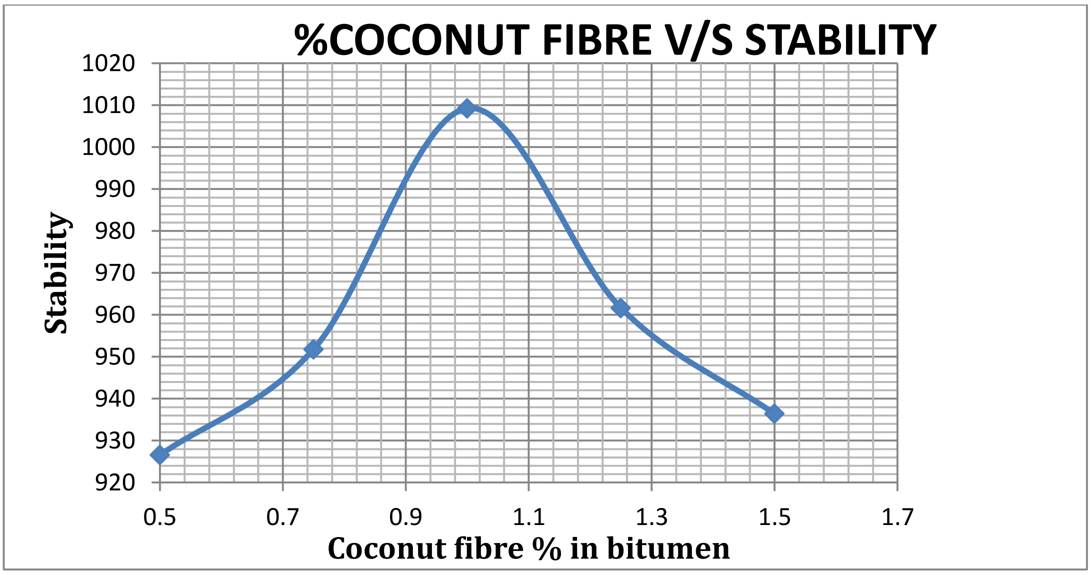

Figure 4.12: Variation of stability to the Variation in coconut fibre Content

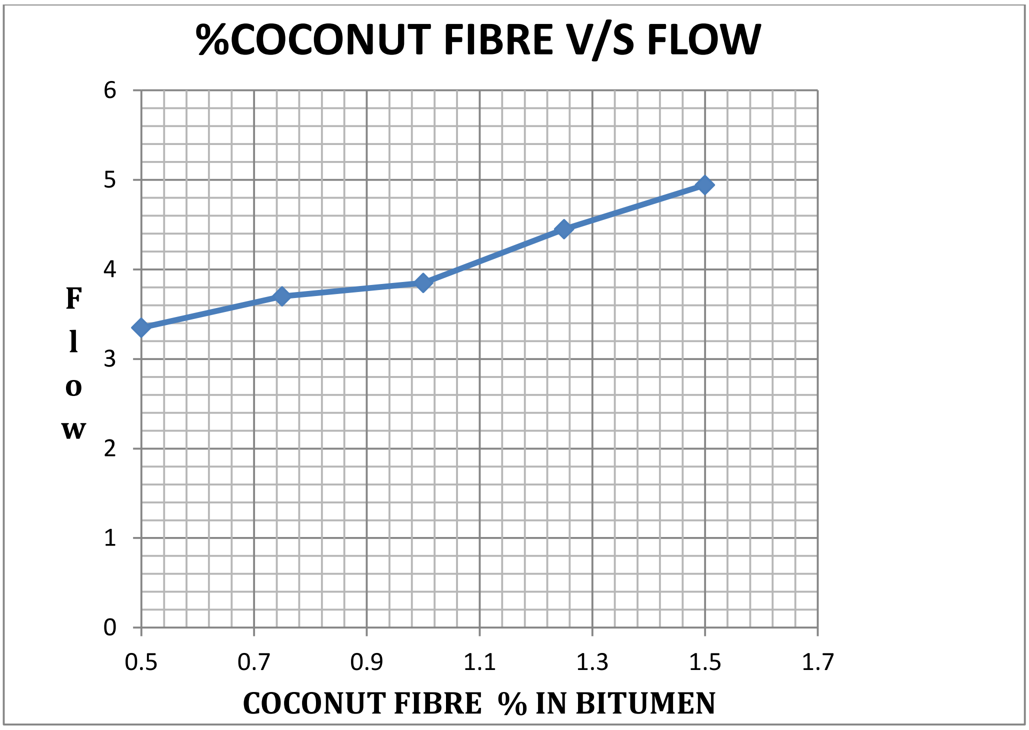

Figure 4.13: Variation of flow to the Variation in coconut fibre Content

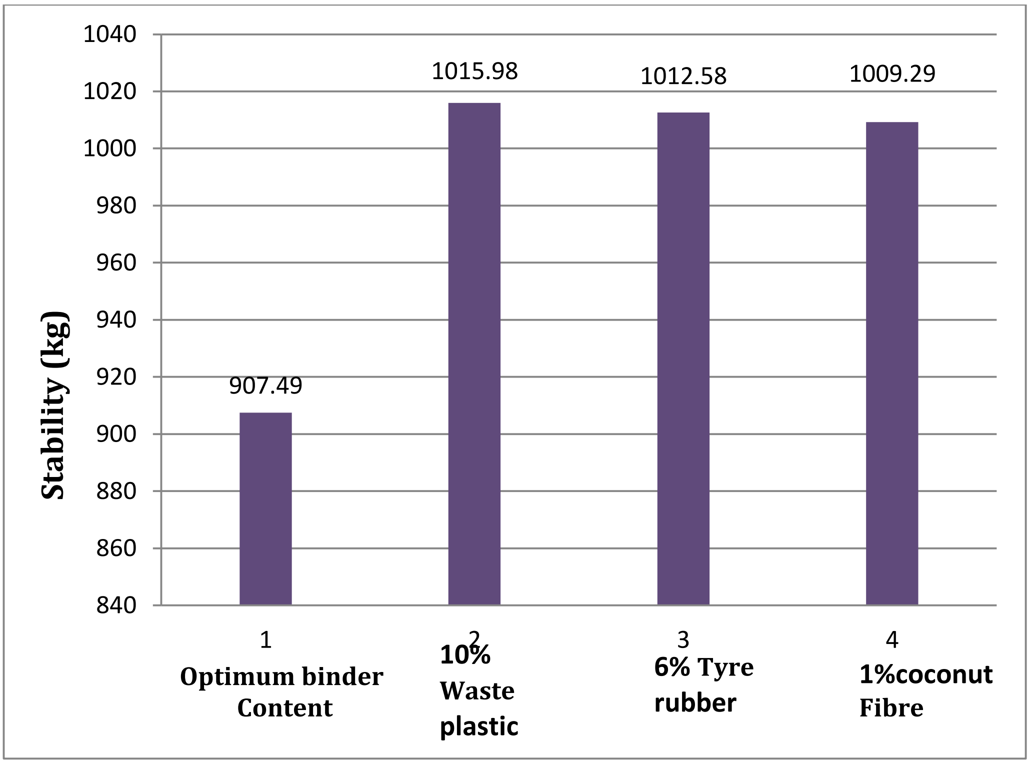

Figure 4.14: Stability Value of optimum binder content v/s waste plastic, tyre rubber and coconut fibre.

4.9 DISCUSSION OF RESULTS

4.9.1 Effect of Plastic waste on the Stability Flow analysis of BC Grade 2 Mix

Table 4.9 and Figs. 4.8 and 4.9 shows the variation of stability and flow of BC mix with percentage addition of waste plastic content in OBC. It is observed from the data obtained that on adding 4%, 6% ,8%, 10% and 12% plastic waste by weight of bitumen in OBC stability value increases upto 10% plastic waste and then decreases on further addition of plastic waste in bitumen . Also the flow criteria of 2-4 mm was satisfied by addition of 10% plastic waste in bitumen. Thus from the stability and flow analysis by Marshall method , it can be concluded that addition of 10% plastic in bitumen can increase the stability of mix by 10. 67%.

4.9.2 Effect of Crumb Tyre Rubber on the Stability Flow analysis of BC Grade 2 Mix

Table 4.10 and Fig. 4.10 and 4.11 shows the variation of stability and flow of BC mix with percentage addition of crumb tyre rubber in OBC. It is observed from the data obtained that on adding 2%, 6% ,10%, 14% and 18% crumb tyre rubber stability value increases upto 6% crumb tyre rubber and then decreases on further addition of crumb tyre rubber in bitumen . Also the flow criteria of 2-4 mm was satisfied by addition of 6% crumb tyre rubber in bitumen. Thus from the stability and flow analysis by Marshall method, it can be concluded that 6% crumb tyre rubber in bitumen can increase the stability of mix by 10.37%.

4.9.3 Effect of Coconut fibres on the Stability Flow analysis of BC Grade 2 Mix

Table 4.11 and Fig. 4.12 and 4.13 show the variation of stability and flow of BC mix with percentage addition of Coconut fibre in optimum binder content. It is observed from the data obtained that on adding coconut fibre with 0.5%, 0.75%, 1%, 1.25% and 1.5% by weight of bitumen in OBC stability value increases upto1% coconut fibre and then decreases on further addition of coconut fibre in bitumen .Also the flow criteria of 2-4 mm was satisfied by addition of 1% coconut fibre in bitumen. Thus from the stability and flow analysis by Marshall method, it can be concluded that addition of 1% coconut fibre in bitumen can increase the stability of mix by 10.08%.

CHAPTER-5
CONCLUSION

5.1 GENERAL

Based on the results and discussion of experimental investigation carried out on Bituminous concrete mix following conclusion are drawn.

1. From the results and discussions on the BC mix it can be concluded that stability of the mix can be improved by the addition of different waste material in OBC by weight of bitumen and also the flow criteria as given by the MORTH can be satisfied also .
2. The optimum binder content for BC grade 2 is 6%
3. The Marshall Stability value of the mix is increased by the addition of all the different waste material in OBC used in this experimental work. However increase in stability value is different for different material and for different percentages.
4. The Marshall stability value of BC grade 2 is increased by 10.67% by the addition of 10 % waste plastic in OBC, also the flow criteria as specified by the MORTH is satisfied by the addition of 10% waste plastic in OBC.
5. The Marshall stability value of BC grade 2 is increased by 10.37% by the addition of 6 % crumb tyre rubber in OBC, also the flow criteria as specified by the MORTH is satisfied by the addition of 6% crumb tyre rubber in OBC.
6. The Marshall stability value of BC grade 2 is increased by 10.08% by the addition of 1 % coconut fibre in OBC, also the flow criteria as specified by the MORTH is satisfied by the addition of 1% coconut fibre in OBC.
7. Fig.4.14 shows that out of the three materials used, addition of waste plastic by 10% in OBC has the highest Marshall Stability value.

5.2 SCOPE FOR FURTHER WORK

Many properties of BC mixes such as Marshall properties have been studied in this investigation. Only 60/70 penetration grade bitumen and waste plastic bottles, discarded tyre rubber and coconut fibre have been tried in this investigation. Some other synthetic and natural fibres and other type of binder can also be tried in mixes and compared. Only one gradation has been adopted here, so an attempt can be made to compare different gradations suggested by various agencies. Coconut fibres used in this study is a low cost material, therefore a cost-benefit analysis can be made to know its effect on cost of construction. Moreover, to ensure the success of this new material, experimental stretches may be constructed and periodic performance of these pavements with modified mixes can be evaluated.

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