STUDY AND IMPROVEMENT OF THE ENGINEERING PROPERTIES OF MATERIALS USED IN A FLEXIBLE PAVEMENT

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CERTIFICATE

This is to certify that the work entitled, "**Study and improvement of engineering properties of materials used in a flexible pavement**" submitted by **SHIVAM GARG** AND **VISHWAVIJAY SINGH** in partial fulfilment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

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ACKNOWLEDGEMENT

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ABSTRACT

In the present project, study and improvement of engineering properties of materials used in a flexible pavement have been carried out by conducting various tests on highway materials. In the First Phase of the project, the coarse aggregates have been tested for the important engineering properties. In the second phase tests have been conducted on bitumen and improved bitumen has been designed by adding different amounts of crumb rubber, ethylene vinyl acetate and styrene butadiene styrene at varying temperature. In the final phase of the project, tests have been conducted on the sub grade (black cotton soil) and then its properties have been improved by adding lime to it. Finally the results are compared and an improvement in the strength and durability of the bitumen pavement is observed.

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CHAPTER 1
INTRODUCTION

1.1 General

It may be said that poor quality of roads in India has contributed greatly to the setbacks in agriculture, commercial and industrial sectors. The prosperity around the urban areas alone does not reflect the economic and living conditions of the people of the country. Overall economic prosperity can be achieved only if good quality pavements are made that can withstand any environmental aggression. India is a very vast country, having widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Environmental factors such as temperature, air and water can have a profound effect on the durability of asphalt concrete mixes.

The flexible roads constitute about 98 percent of the total roads network. The use of quality binder is one of the requirements for the satisfactory pavement performance. The aim of binder modification is to produce new binders with better rheological and mechanical characteristics which allow the manufacturing and application of road bituminous mixes with improved performance. Increased traffic factors such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. The purpose of bitumen modification using polymers and rubbers is to achieve desired engineering properties such as reduced plastic flow at high temperatures and increased resistance to thermal fracture at low temperatures. Similarly good quality sub grade material is required to prevent the failure of pavement. Therefore it is important to improve the engineering properties of the soil in order to make it able to bear large loads without causing damage to the pavement.

It has been shown that a paved surface with good properties can contribute 15-40 % savings in vehicle operation cost. This is very important from point of view of energy crisis and conservation of petroleum fuel. Moreover it will also reduce the maintenance cost of pavements by a great value.

1.2 Objective

- To study the engineering properties of the materials used in the construction of flexible pavements.
- To improve these engineering properties by adding various modifiers to the materials.
- The materials to be testes are the aggregates, subgrade (i.e. the soil) and bitumen.

1.3 Introduction to pavements

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural sub grade, whose primary function is to distribute the applied vehicular loads to sub grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reacting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

1.3.1 Requirements of a pavement

An ideal pavement should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil.
- Structurally strong to withstand all types of stresses imposed upon it.
- Adequate coefficient of friction to prevent skidding of vehicles.
- Smooth surface to provide comfort to road users even at high speed.
- Produce least noise from moving vehicles.
- Dust proof surface so that traffic safety is not impaired by reducing visibility.
- Impervious surface, so that sub-grade soil is well protected.

1.3.2 Types of pavements

The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.

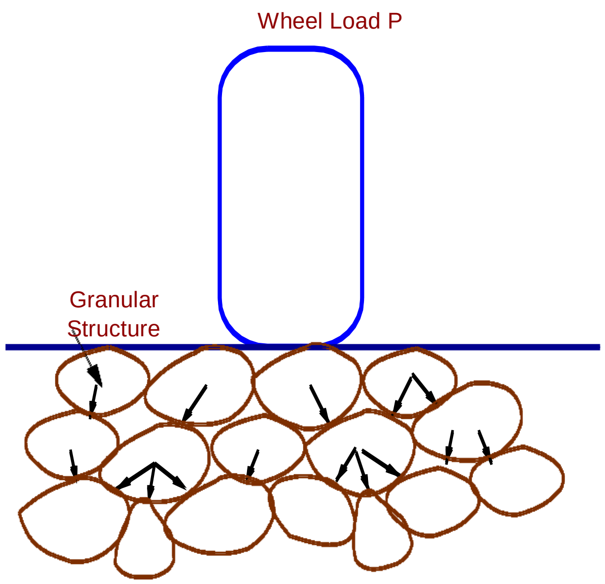

Figure 1: Load transfer in granular structure

1.4 Flexible pavements

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure. The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of these stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of Flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways). Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer). In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer.

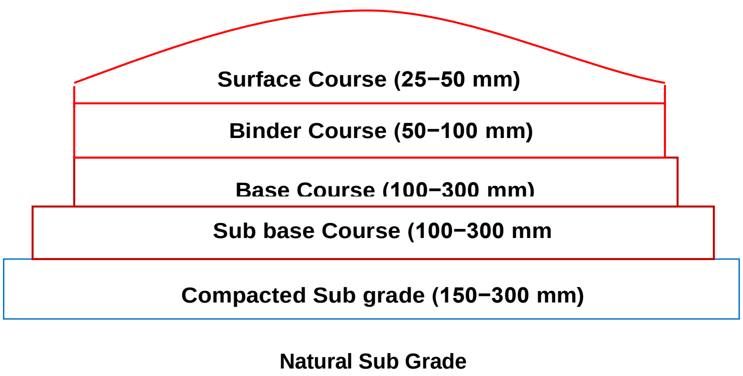

Figure 2: Typical cross section of a flexible pavement

1.4.1 Types of Flexible Pavements

The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement,
- Full - depth asphalt pavement, and
- Contained rock asphalt mat (CRAM).

Conventional Flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water.

1.4.2 Typical layers of a flexible pavement

Surface course

Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete (AC). The functions and requirements of this layer are:

- It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade.
- It must be tough to resist the distortion under traffic and provide a smooth and skid-resistant riding surface.
- It must be water proof to protect the entire base and sub-grade from the weakening effect of water

Binder course

This layer provides the bulk of the asphalt concrete structure. Its chief purpose is to distribute load to the base course The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.

Base course

The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Sub-Base course

The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features covered by a sub-base course. In such situations, sub-base course may not be provided.

Sub-grade

The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content

1.4.3 Failure of flexible pavements

The major flexible pavement failures are fatigue cracking, rutting, and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. The failure criterion relates allowable number of load repetitions to tensile strain and this relation can be determined in the laboratory fatigue test on asphaltic concrete specimens. Rutting occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path. Two design methods have been used to control rutting: one to limit the vertical compressive strain on the top of sub grade and other to limit rutting to a tolerable amount (12 mm normally). Thermal cracking includes both low-temperature cracking and thermal fatigue cracking.

CHAPTER 2
Literature Review

2.1 The Sustainable Use of High Specification Aggregates for Skid-Resistant Road Surfacing

This is a comprehensive report on the subject of High Specification Aggregates, and aggregate properties, containing a wealth of information on the subject of highway surfacing. This report raises serious issues on the use of scarce resources of premium quality aggregate. This document contains a number of tables that give an indication of the properties of aggregates from various sources in the UK, however the properties of aggregate within quarries can change as blasting moves into different seams of stone within the quarry and verification of current aggregate properties.
It is important that we know that aggregate will not wear away, abrade, too quickly. This applies in particular to aggregate present in wearing courses and surface treatment Maximum(Aggregate abrasion value) AAV's for various highway situations are now stated in the, Dot Design Manual for Roads and Bridges, HD 36/06 - Surfacing Materials for New and Maintenance Construction. The information was formerly included in, DOT Design Manual for Roads and Bridges, HD 28/04 - Skid Resistance AAV's required differ according to "weight" of commercial traffic per lane. A maximum value of 10 is specified for chippings/pre coats for lanes carrying over 3250 commercial vehicles per day. A maximum value of 14 is sufficient for less than 250 commercial vehicles per lane per day. N.B. The smaller the number, the less the aggregate abrades.
The exclusion of aggregate with low AAV's is particularly relevant to coated 20mm chippings, i.e. "pre coats" applied to hot rolled asphalt wearing course layers. The aggregate crushing value is a value which indicates the ability of an aggregate to resist crushing. The lower the figure the stronger the aggregate, i.e. the greater its ability to resist crushing. In brief, in BS 812:Part 110, a sample of 14mm. size chippings of the aggregate to be tested is placed in a steel mould and a steel plunger inserted into the mould on top of the chippings.
The fine material, (passing a 2.36mm. sieve), produced, expressed as a percentage of the original mass is the aggregate crushing value, (ACV).

2.2 Soil stabilization using additives

Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include theblendingof soils to achieve adesired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil. The process of reducing plasticity and improving the texture of a soil is called soil modification. Monovalent cations such as sodium and potassium are commonly found in expansive clay soil and thecationscanbeexchangedwithcationsof higher valenciessuch as calcium which are found in li me andflyash. This ionexchange process takes place almost rapidly, within a few hours. The c alciumcations replace the sodium cations around the clay particles, decreasing the size of bound water layer, and enable the clay particle to flocculate. The flocculation creates a reduction in plasticity, an increase in shear strength of clayey soil and improvement in texture from a cohesive material to a more granular, sand-like soil. The change in the structure causes a decrease in the moisture sensitivity and increase the workability and constructability of soil. Soil stabilization includes the effects from modification with a significant additional strength

2.3 Recycled Tyre Rubber Modified Bitumen for road asphalt mixtures:

In order to face this problem, in Europe in 1989, a used tyres group composed of experts from the main tyre manufacturers producing in Europe, was set up under the strategic guidance of the European Tyre and Rubber Manufacturers Association (ETRMA). This Group was dedicated to the management of end of life tyres (ELTs). Also thanks to this group, since 1996, the collection rate has increased steadily while there has been a continuous decline in the land filling of used tyres In 2009 the European Union was faced with the challenge of managing, in an environmentally sound manner, more than 3.2 million tonnes of used tyres of which 95% were recovered. This confirms Europe as one of the most active areas in the world in the recovery of ELTs. Country arise and recovery rates demonstrate that ELTs management in Europe is allowing the progressive elimination of land filling and raises the availability of Recycled Tyre Rubber (RTR) to be recycled for other purposes. In fact, the same characteristics that make waste tyres such a problem also make them one of the most re-used waste materials, as RTR is very resilient and can be reutilised in other products. These efforts should for example help to further develop the use of ELTs in rubberised asphalt in road construction, which has high growth potential in Europe and it is still relatively underutilised **.**The tyre is a complex and high-tech safety product representing a century of manufacturing innovation, which is still on-going. From the material point of view the tyre is made up of three main components materials: (i) elastomeric compound, (ii) fabric and (iii) steel. The fabric and steel form the structural skeleton of the tyre with the rubber forming the "flesh" of the tyre in the tread, side wall, apexes, liner and shoulder wedge. This engineering process is necessary to transform natural rubber in a product able to ensure performance, durability and safety. In fact, natural rubber is sticky in nature and can easily deform when heated up and it is brittle when cooled down. In this state it cannot be used to make products with a good level of elasticity. The reason for inelastic deformation of not-vulcanised rubber can be found in the chemical nature as rubber is made of long polymer chains. These polymer chains can move independently relative to each other, and this will result in a change of shape. By the process of vulcanisation cross-links are formed between the polymer chains, so the chains cannot move independently anymore. As a result, when stress is applied the vulcanised rubber will deform, but upon release of the stress the rubber article will go back to its original shape. Compounding is finally used to improve the physical properties of rubber by incorporating the ingredients and ancillary substances necessary for vulcanisation, but also to adjust the hardness and modulus of the vulcanised product to meet the end requirement. Different substances can be added according to the different tyre mixtures; these include mineral oil and reinforcing fillers as carbon black and silica. In general, truck TR contains larger percentages of natural rubber compared to that from car tyres**.**

2.4 Marshall Mix design basic concepts:

The basic concepts of the Marshall mix design method were originally developed by Bruce Marshall of the Mississippi Highway Department around 1939 and then refined by the U.S. Army. Currently, the Marshall method is used in some capacity by about 38 states. The Marshall method seeks to select the asphalt binder content at a desired density that satisfies minimum stability and range of flow values The most promising method eventually proved to be the Marshall Stability Method developed by Bruce G. Marshall at the Mississippi Highway Department in 1939. WES took the original Marshall Stability Test and added a deformation measurement (using a flow meter) that was reasoned to assist in detecting excessively high asphalt contents. This appended test was eventually recommended for adoption by the U.S. Army because:

1. It was designed to stress the entire sample rather than just a portion of it.
2. It facilitated rapid testing with minimal effort.
3. It was compact, light and portable.
4. It produced densities reasonably close to field densities.

2.5 Asphalt Binder Evaluation

The Marshall test does not have a common generic asphalt binder selection and evaluation procedure. Each specifying entity uses their own method with modifications to determine the appropriate binder and, if any, modifiers. Binder evaluation can be based on local experience, previous performance or a set procedure. The most common procedure is the Super pave PG binder system. Once the binder is selected, several preliminary tests are run to determine the asphalt binder's temperature-viscosity relationship.

The Marshall method, like other mix design methods, uses several trial aggregate-asphalt binder blends (typically 5 blends with 3 samples each for a total of 15 specimens), each with a different asphalt binder content. Then, by evaluating each trial blend's performance, an optimum asphalt binder content can be selected. In order for this concept to work, the trial blends must contain a range of asphalt contents both above and below the optimum asphalt content. Therefore, the first step in sample preparation is to estimate an optimum asphalt content. Trial blend asphalt contents are then determined from this estimate.

Optimum Asphalt Binder Content Estimate

The Marshall mix design method can use any suitable method for estimating optimum asphalt content and usually relies on local procedures or experience.

Sample Asphalt Binder Contents

Based on the results of the optimum asphalt binder content estimate, samples are typically prepared at 0.5 percent by weight of mix increments, with at least two samples above the estimated asphalt binder content and two below.

Compaction with the Marshall Hammer

Each sample is then heated to the anticipated compaction temperature and compacted with a Marshall hammer, a device that applies pressure to a sample through a tamper foot (Figure 1). Some hammers are automatic and some are hand operated. Key parameters of the compactor are:

- Sample size = 102 mm (4-inch) diameter cylinder 64 mm (2.5 inches) in height (corrections can be made for different sample heights)
- Tamper foot = Flat and circular with a diameter of 98.4 mm (3.875 inches) corresponding to an area of 76 cm^2 (11.8 in^2).
- Compaction pressure = Specified as a 457.2 mm (18 inches) free fall drop distance of a hammer assembly with a 4536 g (10 lb.) sliding weight.
- Number of blows = Typically 35, 50 or 75 on each side depending upon anticipated traffic loading.
- Simulation method = The tamper foot strikes the sample on the top and covers almost the entire sample top area. After a specified number of blows, the sample is turned over and the procedure repeated.

CHAPTER 3
MATERIALS USED

3.1 AGGREGATES

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete). By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements. Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often a bye product of other manufacturing industries. The requirements of the aggregates in pavement are also discussed in this chapter.

3.2 BITUMEN

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

3.2.1 Modified Bitumen

Certain additives or blend of additives called as bitumen modifiers can improve properties of Bitumen and bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen. Polymer modified bitumen (PMB)/ crumb rubber modified bitumen (CRMB) should be used only in wearing course depending upon the requirements of extreme climatic variations. The detailed specifications for modified bitumen have been issued by IRC: SP: 53-1999. It must be noted that the performance of PMB and CRMB is dependent on strict control on temperature during construction.

3.3 Ethyl-Vinyl Acetate

Ethyl-vinyl acetate (also known as **EVA**) is the copolymer of ethylene and vinyl acetate, available as pellets 4 to 5 mm in diameter supplied by **SATIJA** Polymers, New Delhi was used. It is a polymer that approaches elastomeric materials in softness and flexibility, yet can be processed like other thermoplastics. The material has good clarity and gloss, low-temperature toughness, stress-crack resistance, hot-melt adhesive waterproof properties, and resistance to UV radiation.

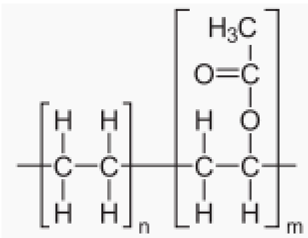

Figure 3: Structure of Ethyl-vinyl acetate

EVA is one of the materials popularly known as expanded rubber or foam rubber. EVA foam is used as padding in equipment for various sports such as ski boots, bicycle saddles, hockey pads, boxing and mixed martial arts gloves and helmets, fishing rods and fishing reel handles. It is typically used as a shock absorber in sports shoes. EVA slippers and sandals are currently very popular because of their properties like light weight, easy to form, odourless, glossy finish, and cheaper compared to natural rubber. EVA used in testing was supplied by Satija Polymers, New Delhi.

3.4 Crumb Rubber

Crumb rubber is the name given to any material derived by reducing scrap tires or other rubber into uniform granules with the inherent reinforcing materials such as steel and fiber removed along with any other type of inert contaminants such as dust, glass, or rock. Crumb rubber is manufactured from two primary feed stocks: tire buffing, a by -product of tire retreading and scrap tire rubber. Scrap tire rubber comes from three types of tires: passenger car tires, which represent about 84 percent of units or approximately 65 percent of the total weight of scrap tires; truck tires, which constitute 15 percent of units, or 20 percent of the total weight of. scrap tires; and off-the-road tires, which account for 1 percent of units, or 15 percent of the total weight of scrap tires. Crumb rubber used in testing was supplied by Maruti Reclaim Rubber Industry, Ghaziabad.

3.5 Styrene Butadiene Styrene

Styrene-butadiene or styrene-butadienerubber (SBR) describes families of synthetic rubbers derived from styrene and butadiene. These materials have good abrasion resistance and good aging stability when protected by additives. About 50% of car tires are made from various types of SBR. The styrene/butadiene ratio influences the properties of the polymer: with high styrene content, the rubbers are harder and less rubbery. SBR is not to be confused with a thermoplastic elastomer made from the same monomers, styrene-butadiene block copolymer. SBS used in testing was supplied by Satija Polymers, New Delhi.

3.6 Black Cotton soil

Black cotton soil is one an Expansive soils that increases in volume or expand as they get wet and shrink as they dry out. It swells and shrinks excessively with change of water content. It is due to the presence of fine clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure.Stabilization of black cotton soil has been done in this project work by using lime. The soil used in testing has been collected from JUET campus Guna, (MP). The black cotton soil was collected by method of disturbed sampling after removing the top soil at 150mm depth. The soil was air dried and sieved with IS sieve 4.75mm as required for laboratory test.

CHAPTER 4

PREPARATION OF MODIFIED SAMPLE

4.1 Procedure to prepare modified sample of bitumen.

In preparing the modified binders, about 250 g of the bitumen was heated to fluid condition in a 500 ml capacity glass container. The mixing was performed in the laboratory using a mechanical stirrer and rotated at 1350 rpm for mixing the bitumen and modifiers. The sample was kept on a heating plate during the entire time. For blending of crumb rubber with bitumen, bitumen was heated to a temperature of 170 °C and crumb rubber was then added along with a small amount of calcium carbonate. For measuring the temperature a thermometer was inserted in the sample at regular intervals. The blend was mixed manually for about 3-4 minutes. The mixture was then heated to 210 °C and the whole mass was stirred using a mechanical stirrer for about 50 minutes. Care was taken to maintain the temperature between 200 °C to 210 °C. For preparation of EVA blends, bitumen was heated to a temperature of 170 °C. As the bitumen attained a temperature of 170 °C, the different EVA polymer contents by mass (1 to 6%) were added to the bitumen and vigorously agitated. The temperature was maintained between 175 °C and 180 °C and mixing was then continued for 45-50 minutes. The modified bitumen was cooled to room temperature and suitably stored for testing.

4.2 Procedure to prepare stabilized sample of soil

Stabilized sample of soil was prepared by mixing varying quantities of lime with soil. The sample was well mixed with lime by hand mixing and kept undisturbed for 24 hours before testing. In this project lime content was varied at 9%, 12% and 15%.

CHAPTER 5
TESTS CONDUCTED ON HIGHWAY MATERIALS

5.1Tests on Aggregate

5.1.1 AGGREGATE CRUSHING VALUE TEST (IS: 2386-PART-4)

1. Apparatus/Equipments Required:

1. Steel cylinder of 15.2 cm internal diameter with base plate and plunger. The height of the Cylinder may vary from 13 to 14 cm. The thickness of cylinder walls may be 1.6 cm.

2. Cylindrical measure of internal diameter 11.5 cm. and height 18 cm.

3. Steel tamping rod 45 to 60 cm. long and 1.6 cm diameter having a pointed end.

4. Compression testing machine capable of applying load of 40 tonnes, at a uniform rate of loading of 4 tonnes per minute.

5. Balance of cap. 3 kg with accuracy up to 1 g

6. Sieves of 12.5 mm, 10 mm and 2.36 mm.

2. Theory:

The principal mechanical properties required inroad stones are (i) satisfactory resistance to crushing under the roller during construction and (ii) adequate resistance to surface abrasion under traffic. Also surface stresses under rigid tyre rims of heavily loaded and drawn vehicle are high enough to consider the crushing strength of road aggregates as essential requirements in India.

3. Procedure:

1. Aggregate passing 12.5 mm I.S. sieve and retained on 10 mm sieve is taken and dried. This aggregate filled in the cylindrical measure in three equal layers and each layer tamped 25 times by the tamping rod.

2. Now the test sample is weighed and filled in the test cylinder in three equal layers and tamped each layer 25 times. Let the weight of aggregate be W_1 Kg.

3. Now the plunger is placed on the top of the test specimen and whole apparatus is put in the compression testing machine.

4. Now the specimen is loaded to a total load of 40 tonnes at the rate of 4 tonnes per minute i.e., the total load s reached in 10 minutes in the compression machine.

5. Now the test cylinder is removed from the compression machine and aggregate sieved through 2.36 mm sieve. The material passed through the 2.36 mm sieve is weighed. Let the weight be W_2 Kg.

5.1.2 WATER ABSORPTION TEST IS: 2386 (Part III) – 1963

1. Apparatus

1. Wire basket
2. Water-tight container for suspending the basket
3. Dry soft absorbent cloth – 75cm x 45cm (2 nos.)
4. Shallow tray of minimum 650 sq.cm area
5. Air-tight container of a capacity similar to the basket
6. Oven.

2. Theory:

Specific gravity of an aggregate is considered as a measure of the quality or strength of material. Stones having low specific gravity values are generally weaker than those having higher values. Stones having higher water absorption value are porous and thus weak. They are unsuitable unless found acceptable based on crushing and hardness tests.

3. Procedure:

1. The sample should be thoroughly washed to remove finer particles and dust.
2. After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 + ½ hrs afterwards.
3. The basket and aggregates should then be removed from the water, allowed to drain for a few minutes, after which the aggregates should be gently emptied from the basket on to one of the dry clothes and gently surface-dried with the cloth, transferring it to a second dry cloth when the first would remove no further moisture. The aggregates should be spread on the second cloth and exposed to the atmosphere away from direct sunlight till it appears to be completely surface-dry. The aggregates should be weighed (Weight 'A').
4. The aggregates should then be placed in an oven at a temperature of 100 to 110^{o}C for 24hrs. It should then be removed from the oven, cooled and weighed (Weight 'B')

5.1.3 AGGREGATE ABRASION VALUE TEST (IS: 2386-PART-4)

1. Apparatus/Equipments Required:

1. It consists of a hollow cylindrical machine closed at both ends having 70 cm internal diameter and 50 cm long, mounted on supports so that it may rotate about its horizontal axis.

2. Steel spherical balls 4.5 cm diameter and weighing 390grams to 445 grams. The weight and number of balls per charge of aggregate depends upon the grading of aggregate sample.

3. Sieve of size 1.7 and balance of capacity 10 kg.

2. Theory:

Due to the movements of traffic, the road stones used in the surfacing course are subjected to wearing action at the top. Resistance to wear or hardness is hence an essential property for road aggregates especially when used in wearing course. Thus road stones should be hard enough to resist the abrasion due to the traffic.

3. Procedure:

1. Aggregate sample weighing 5 kg or 10 kg depending on the grading is put in the machine along with the abrasive charge.

2. The machine is rotated at a speed of 30 to 33 r.p.m for the specified number of revolutions (500 to 1000) depending on the grading of aggregate.

3. Now the sample is taken out of the machine and sieved through 1.7 mm I.S. Sieve and the weight of aggregate passing through 1.7 mm sieve is determined.

5.1.4AGGREGATE IMPACT VALUE TEST (IS :2386-PART-4)

1. Apparatus/Equipments Required:

1. Impact testing machine
2. Cylindrical measure
3. Tamping rod
4. Sieve 12.5, 10, and 2.36 mm.
5. Balance

2. Theory:

Toughness is the property of a material to resist impact. Due to traffic loads, the road stones are subjected to the pounding action or impact and there is possibility of stones breaking into smaller pieces. The road stones should therefore be tough enough to resist fracture under impact.

3. Procedure:

1. Dry aggregate specimen passing 12.5 mm sieve and retained on 10 mm sieve is filled in three equal layers by 25 blows with the help of tamping rod and weighed. Let the weight of sample be W_1 Kg.
2. The sample is now transferred to the cup of the impact test apparatus and compacted by tamping rod 25 times.
3. Now the hammer is raised to a height of 38 cm above the surface of the aggregate in the cup and is allowed to fall freely in the specimen. In this 15 blows are given to the aggregate specimen.
4. Now the aggregate sample is sieved through 2.36 mm I.S. Sieve and the fraction passing through this sieve is weighed. Let the weight of this fraction be W_2 Kg

5.1.5 AGGREGATE SHAPE TEST (IS: 2386-PART-1)

(Flakiness index and Elongation Index of Aggregates)

The particle shape of aggregates is determined by the percentages of flaky and elongated particles contained in it. For base course and construction of bituminous and cement concrete types the presence of flaky and elongated particles are considered undesirable as these cause inherent weakness with possibilities of breaking down under heavy loads. Thus, evaluation of shape of the particles, particularly with reference to flakiness and elongation is necessary.

Apparatus: -

The apparatus consists of

1. A standard thickness gauge,
2. Sieves of sizes 63, 50, 40, 31.5,25, 20, 16, 12.5, 10 and 6.3 mm and
3. A balance to weigh the samples.

Theory: - The flakiness index of aggregates is the percentage by weight of particles whose least dimension (thickness) is less than three-fifths (0.6) of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.

Procedure: -

The test is conducted by using a metal thickness gauge.

A sufficient quantity of aggregate is taken such that a minimum number of 200 pieces of any fraction can be tested.

Each fraction is gauged in turn for thickness on the meal gauge.

The total amount passing in the gauge is weighed to an accuracy of 0.1per cent of the weight of the samples taken.

The flakiness index is taken as the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken.

Table 1: Thickness and length gauges
(IS: 2386 (Part 1) -1963)

Size of Aggregate		Thickness gauge (0.6 times the mean sieve) mm	Length gauge (1.8 times the mean sieve) mm
Passing Through IS sieve mm	Retained on IS sieve mm		
63.0 mm	50 mm	33.90	-
50.0 mm	40 mm	27.00	81.0
40.0 mm	31.5mm	21.45	64.35
31.5 mm	25 mm	16.95	-
25.0 mm	20 mm	13.50	40.5
20.0 mm	16 mm	10.80	32.4
16.0 mm	12.5mm	8.55	25.6
12.5 mm	10.0mm	6.75	20.2
10.0 mm	6.3 mm	4.89	14.7

Test for Determination of Elongation Index

Apparatus

The apparatus consists of the length gauge, sieves of the sizes specified in table and a balance.

Theory:

The elongation index on an aggregate is the percentage by weight of particles whose greatest dimension (Length) is greater than 1.8 times their mean dimension .The elongation index is not applicable to sizes smaller than 6.3 mm

Procedure:

This test is conducted by using metal length gauge of the description. A sufficient quantity of aggregate is taken to provide minimum number of 200 piece of any fraction to be tested. Each fraction shall be gauged individually for length on the metal gauge. The gauge length used shall be that specified for the appropriate size of material. The elongation index is the total eight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauged. The presence of elongated particles in excess of 10 to 15 per cent is generally considered undesirable, but no recognized limits are laid down. Indian standard explain only the method of calculating both flakiness index and elongation index

Figure 4: Aggregate sample for testing

Figure 5: Los Angeles abrasion test

Figure 6: Elongation and flakiness index apparatus

Figure7: Aggregate impact test machine

5.2 Tests on Soil Sub grade

5.2.1 DERERMINATION OF LIQUID LIMIT

Apparatus

Mechanical liquid limited Device

Grooving Tool

Porcelain Evaporating Dish

Flat glass plate

Spatula

Palette Knives

Balance

Oven

Wash bottle or Beaker

Containers

Theory

The liquid limit is defined as the minimum moisture content at which a soil will flow upon application of a very small shearing force. When a soil becomes a viscous fluid, the soil will begin to flow under its own weight and very small amount of energy input

Procedure

i) Place a portion of the paste in the cup of the liquid limit device.

ii) Level the mix so as to have a maximum depth of 1cm.

iii) Draw the grooving tool through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.

iv) For normal fine grained soil: The Casagrande's tool is used to cut a groove 2mm wide at the bottom, 11mm wide at the top and 8mm deep.

v) For sandy soil: The ASTM tool is used to cut a groove 2mm wide at the bottom, 13.6mm wide at the top and 10mm deep.

vi) After the soil pat has been cut by a proper grooving tool, the handle is rotated at the rate of about 2 revolutions per second and the no. of blows counted, till the two parts of the soil sample come into contact for about 10mm length.

vii) Take about 10g of soil near the closed groove and determine its water content

viii) The soil of the cup is transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. Repeat the test.

ix) By altering the water content of the soil and repeating the foregoing operations, obtain at least 5 readings in the range of 15 to 35 blows. Don’t mix dry soil to change its consistency.

x) Liquid limit is determined by plotting a ‘flow curve’ on a semi-log graph, with no. of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points.

5.2.2 DETERMINATION OF PLASTIC LIMIT

This test is done to determine the plastic limit of soil as per IS: 2720 (Part 5) – 1985.The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm dia.

Apparatus:

Porcelain evaporating dish
Spatula
Container
Balance
Oven
Ground Glass plate
Rod-3 mm diameter and 10 cm long

PREPARATION

Take out 30g of air-dried soil from a thoroughly mixed sample of the soil passing through 425μm IS Sieve. Mix the soil with distilled water in an evaporating dish and leave the soil mass for naturing. This period may be upto 24hrs.

Procedure

i) Take about 8g of the soil and roll it with fingers on a glass plate. The rate of rolling should be between 80 to 90 strokes per minute to form a 3mm dia.
ii) If the dia. of the threads can be reduced to less than 3mm, without any cracks appearing, it means that the water content is more than its plastic limit. Knead the soil to reduce the water content and roll it into a thread again.
iii) Repeat the process of alternate rolling and kneading until the thread crumbles.
iv) Collect and keep the pieces of crumbled soil thread in the container used to determine the moisture content.

5.2.3 PLASTICITY INDEX:

The plasticity index is calculated as the difference between its liquid limit and plastic limit.

Plasticity index (I_p) = Liquid limit (w_L) – Plastic limit (w_p)

5.2.4 DETERMINE THE MAXIMUM DRY DENSITY AND THE OPTIMUM MOISTURE CONTENT OF SOIL

This test is done to determine the maximum dry density and the optimum moisture content of soil using heavy compaction as per IS: 2720 (Part 8) – 1983.

Apparatus:

i)Cylindrical metal mould – it should be either of 100mm dia. and 1000cc volume or 150mm dia. and 2250cc volume and should conform to IS: 10074 – 1982.
ii)Balances – one of 10kg capacity, sensitive to 1g and the other of 200g capacity.
iii)Oven
iv) IS Sieves of sizes – 4.75mm, 19mm and 37.5mm

Preparation

A representative portion of air-dried soil material, large enough to provide about 6kg of material passing through a 19mm IS Sieve (for soils not susceptible to crushing during compaction) or about 15kg of material passing through a 19mm IS Sieve (for soils susceptible to crushing during compaction), should be taken. This portion should be sieved through a 19mm IS Sieve and the coarse fraction rejected after its proportion of the total sample has been recorded. Aggregations of particles should be broken down so that if the sample was sieved through a 4.75mm IS Sieve, only separated individual particles would be retained.

Procedure:

i) A 5kg sample of air-dried soil passing through the 19mm IS Sieve should be taken. The sample should be mixed thoroughly with a suitable amount of water depending on the soil type (for sandy and gravelly soil – 3 to 5% and for cohesive soil – 12 to 16% below the plastic limit). The soil sample should be stored in a sealed container for a minimum period of 16hrs.
ii) The mould of 1000cc capacity with base plate attached, should be weighed to the nearest 1g (W_1). The mould should be placed on a solid base, such as a concrete floor or plinth and the moist soil should be compacted into the mould, with the extension attached, in five layers of approximately equal mass, each layer being given 25 blows from the 4.9kg rammer dropped from a height of 450mm above the soil. The blows should be distributed uniformly over the surface of each layer. The amount of soil used should be sufficient to fill the mould,

leaving not more than about 6mm to be struck off when the extension is removed. The extension should be removed and the compacted soil should be levelled off carefully to the top of the mould by means of the straight edge. The mould and soil should then be weighed to the nearest gram (W_2).

iii) The compacted soil specimen should be removed from the mould and placed onto the mixing tray. The water content (w) of a representative sample of the specimen should be determined.

iv) The remaining soil specimen should be broken up, rubbed through 19mm IS Sieve and then mixed with the remaining original sample. Suitable increments of water should be added successively and mixed into the sample, and the above operations i.e. ii) to iv) should be repeated for each increment of water added.

5.3 TESTS ON CRUMB RUBBER

5.3.1 SPECIFIC GRAVITY TEST

Objective

To Determine the specific gravity of crumb rubber by density bottle.

Apparatus

1. Density bottle of 50 ml with stopper having capillary hole.
2. Balance to weigh the materials (accuracy 10gm).

Procedure

1. Clean and dry the density bottle

2. Weigh the empty bottle with stopper (M_1)

3. Take about 10 to 20 gm of crumb rubber Transfer it to the bottle. Find the weight of the bottle and crumb rubber (M_2).

4. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.

5. Again fill the bottle completely with distilled water put the stopper .

6. Take the bottle outside and Now determine the weight of the bottle and the contents (M_3).

7. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be M_4 at room temperature

8. Repeat the same process for 2 to 3 times, to take the average reading of it.

5.3.2 SEPRATION TEST

Principle

The separation of modifier and bitumen during hot storage is evaluated by comparing the ring and ball softening point of the top and bottom samples taken from a conditioned, sealed tube of polymer modified bitumen. The conditioning consist of placing a sealed tube of modified bitumen in a vertical position at 163 ±5°C in an oven for a period of 48 h. It provides a reference for determining the relative separation properties between different types of bitumen modifiers and their respective bitumen. Modified bitumen's relative stability to separation under storage in static conditions is determined in heated oven storage without agitation.

Apparatus

- AluminumTubes-25.4 mm(1inch) diameter and 136.5 mm (5.5 inch) length blind aluminium tubes (thickness of foil 1 mm), used to hold the test sample during the conditioning.
- Oven, capable of maintaining 163 ± 5°C.
- Freezer, capable of maintaining 6.7 ± 5°C.

Procedure

1. Place the empty tube, with sealed end down in the rack. Heat the sample carefully until sufficiently fluid to pour. Care should be taken to prevent localized overheating. Pass the molten sample through IS Sieve of 600 micron mesh size. After through stirring, pour 50.0 g into the vertically held tube. Fold the excess tube over two times, and crimp and seal.
2. Place the rack containing the sealed tubes in a 163 ± 5 °C oven. Allow the tubes to stand undisturbed in the oven for a period of 24 ± 4 h. At the end of the period, remove the rack from the oven, and place immediately in the freezer at 6. 7 ± 5 °C, taking care to keep the tubes in a vertical position at all times. Leave the tubes in the freezer for a minimum of 4 h to solidify the sample completely.

3. Upon removing the tube from the freezer, place it on a flat surface. Cut the tube into three equal length portions with the spatula and hammer. Discard the centre section, and place the top and bottom portions of the tube into separate beakers; Place the beakers into a163± 5°C oven until the bitumen is sufficiently fluid to remove the pieces of aluminium tube.

4. After thoroughly stirring, pour the top bottom samples into appropriately marked rings for the ring and ball softening point test. Prepare the rings and apparatus according to details given in IS 1205. The top and bottom sample form the same tube should be tested at the same time for the softening point test

5.3.3 SIEVE ANALYSIS OF CRUMB RUBBER

It is a process for classifying rubber particles. Gradations are usually expressed in terms of total percent passing or retained. The percent passing indicates the total percent of rubber that will pass each given sieve size. The total percent retained is the opposite of percent passing or the total percent passing each given sieve.

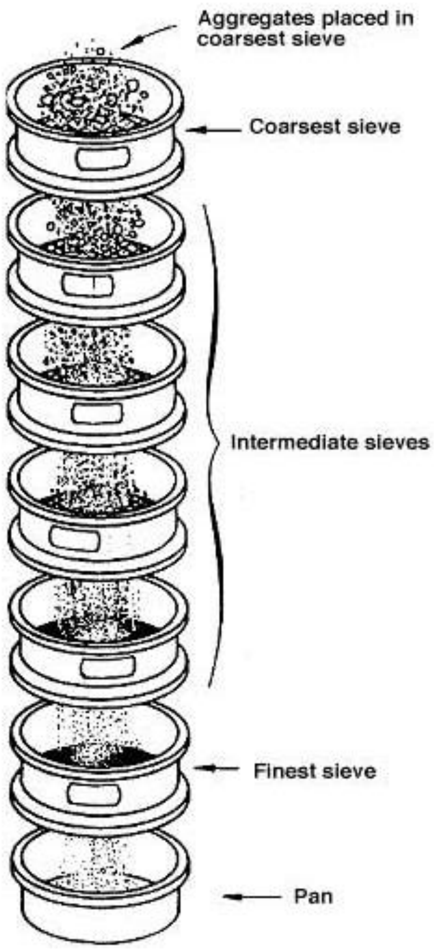

Figure 8: Sieve analysis of crumb rubber

5.4 Tests on Bitumen and Modified Bitumen

5.4.1 PENETRATION TEST

1. Apparatus/Equipments required:

1. Container
2. Needle
3. Water bath
4. Penetrometer
5. Transfer tray

2. Theory:

This test is applied almost exclusive bitumen. For tars, cutback and emulsions other consistency are used. This test determines the hardness or softness of bitumen by measuring the depth in millimetre to which a standard loaded needle will penetrate vertically in 5 seconds while the temperature of the bitumen sample is maintained at 25°C.

3. Procedure:

1. The bitumen is softening to a pouring consistency, stirred well and poured into the test containers.
2. The depth of bitumen in containers is kept at least 15 mm more than the excepted penetration.
3. The sample now the sample containers are placed in a temperature controlled water bath at a temperature of 25°C for one hour.
4. At the end of one hour, the sample is taken out of water bath and needle is brought in contact with the surface of bitumen sample and the reading of dial is set at zero or the reading of dial noted, when the needle is in contact with the surface of the sample.
5. Now the needle is released and the needle is allowed to penetrate for 5 seconds and the final reading is recorded on the same sample at least three penetration observations should be taken at distances at least 10 mm apart.
6. The mean value of three measurements is reported as penetration test.

7. The accuracy of the test depends upon pouring temperature, size of needle, weight placed on needle, and test temperature.

8. The grade of bitumen is specified in terms of penetration value. 30/40 grade bitumen indicates the penetration value of the bitumen in the range of 30 to 40 at standard test conditions. Penetration test is applied exclusively to bitumen. Tars being soft, penetration test on these materials cannot be carried out.

Figure 9: Penetration test for bitumen

4.4.2 DUCTILITY TEST IS: 1208 – 1978

1. Theory:

Ductility is a measure of elasticity of adhesiveness of bitumen. It is expressed as the distance in centimetres to which a standard briquette of bitumen can be stretched before the thread breaks. As per I.S. 1208-1958, the test should be conducted at 27° C and the pull should be applied at the rate of 50 mm per minute. The minimum width of cross-section should be 10×10 mm.

2. Apparatus /Equipments required:

1. Briquette of standard dimensions.
2. Pulling device with distance measuring dial.
3. Water bath arrangement.
4. Knife.
5. Heating metal.
6. Thermometer.
7. Glycerine.

3. Procedure:

1. The bitumen sample is heated to bring it in fluid state and poured in the briquette assembly and placed on a brass plate.
2. The whole assembly including bitumen briquette along with brass plate is allowed to cool in air.
3. The excess bitumen is cut and surface is levelled with the help of a hot knife.
4. The whole assembly now is kept in a water bath maintained at 27°C for about 85 to 95 minutes.
5. The side of the mould removed ,the clips hooked on the machine and the pointer adjusted to zero value or initial reading noted.

6. Now the clips are pulled apart horizontally at the rate of 50 mm per min. and the distance up to the point of breaking of thread is noted. This distance in centimeter gives the value of ductility of bitumen.

7. The ductility of bitumen may vary from 5 to 100 for different bitumen grades, but for satisfactory performance it should not be less than 50.

8. Ductility of bitumen is influenced by pouring temperature, dimensions of briquette, test temperature, rate of pulling etc.

Figure 10: Ductility test for bitumen

5.4.3 SOFTENING POINT TEST (IS: 1205 – 1978)

1. Apparatus/Equipments required:

1. A brass ring and steel ball.
2. Water bath and stirrer.
3. Thermometer
4. Metallic support

2. Theory:

Softening point is defined as the temperature at which a substance attains a particular degree of softening under specified conditions of test. Usually softening point for different grades of bitumen used for pavements vary from 35°C to 70°C.

3. Procedure:

1. Sample material is heated to a temperature between 75 and 100°C above the approximate softening point until it is completely fluid.
2. The bitumen test sample is placed in the brass ring and the ring is suspended in water at a given temperature.
3. A steel ball is put on the bitumen and the water bath is heated such that the temperature of water bath rises by 5°C per minute.
4. The temperature at which the softened bitumen touches the metal plate placed at a specified distance below the ring is noted. This temperature is called the softening point of the bitumen. Higher the softening point, harder the grade of the bitumen.

Figure 11: Setup of ring and ball test

Figure 12: Bitumen sample reaching its softening point.

5.4.4 MARSHALL STABILITY TEST

Apparatus:
Marshall apparatus
Balance and water bath

Theory:
This test is done to determine the Marshall stability of bituminous mixture as per ASTM D 1559. The principle of this test is that Marshall stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at 60oC and is measured in kg.

Procedure:

i) Heat the weighed aggregates and the bitumen separately upto 170^{o}C and 163^{o}C respectively.

ii) Mix them thoroughly, transfer the mixed material to the compaction mould arranged on the compaction pedestal.

iii) Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg). Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.

iv) Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.

v) A series of specimens are prepared by a similar method with varying quantities of bitumen content.

vi) Before testing of the mould, keep the mould in the water bath having a temperature of 30^{o}C for half an hour.

vii) Check the stability of the mould on the Marshall stability apparatus.

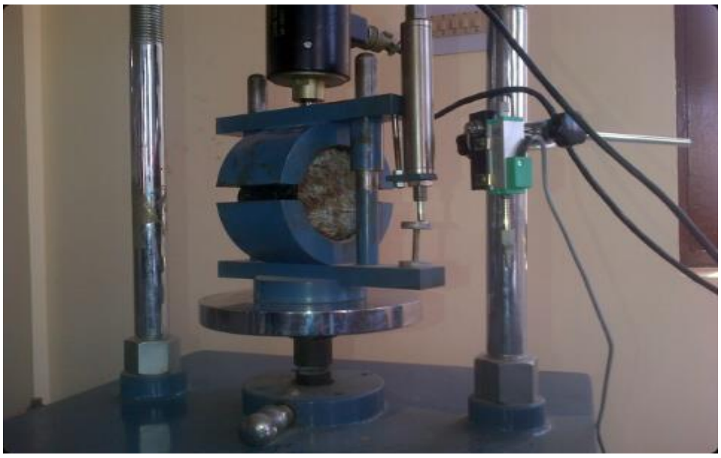

Figure 13: Marshall Mix Apparatus

CHAPTER 6

Observations and results

6.1 Test results of aggregates

6.1.1 Aggregate Crushing value test

Table 2: Observations of aggregate crushing value test

Serial No.	Details	Trial No.	
		1	2
1.	Total Weight of aggregate sample filling the Cylindrical measure = W_1 g	2500	2500
2.	Weight of aggregate passing 2.36 mm sieve after the test = W_2 g	502	497
3.	Weight of aggregate retained on 2.36 mm sieve after the test = W_3 g	1998	2003

Calculation

Aggregate crushing value = percent fines = $\frac{W_2}{W_1} \times 100$

(i) For sample 1 = 20.08%

(ii) For sample 2 =19.88%

Result:

For test sample = 19.98 %

As per the code the sample is suitable for both base course and surface course

6.1.2 Water absorption

Observations:

Table 3: Observations of water absorption test

S.No.	Determination No.	I	II
1	Weight of saturated surface dried sample in grams (A)	1007.5	1008
2	Weight of oven dried sample in grams (B)	1000.2	1000.5

Calculations:

$$\text{Water absorption} = \frac{A - B}{B} \times 100\%$$

(i) For sample 1 = .73%

(ii) For sample 2 = .75%

Result:

For test sample = .74%

As per the code the sample has marginally higher value of water absorption

6.1.3 Abrasion value test

Observation:

1. Type of aggregate = Grade B Aggregate
2. Grading = 12.5 mm passing and 10 mm retained, 2500gm
   20 mm passing and 12.5 mm retained, 2500gm
3. Number of spheres used = 11
4. Weight of charge = 390-445 gm
5. Number of revolution = 500

Table 4: Observations of abrasion value test

Observations	**Sample 1**	**Sample 2**
Let the original weight of aggregate = W_1 g	5000	5000
Weight of aggregate retained on 1.7 mm IS sieve after the test = W_2 g	3690	3696
Loss in weight due to wear = W_1 - W_2 g	1310	1304
Percentage wear = $\frac{(W_1 - W_2)}{W_1} \times 100$	26.2 %	26.08%
Average Value = 26.14%		

Calculation

Percentage wear = $\frac{(W_1 - W_2)}{W_1} \times 100$

Los Angles abrasion value, % = 26.14%

Result

For test sample = 26.14 %

6.1.4 Impact value test

Observation:

Table 5: observations of impact value test

S.No.	Details	Trial No.	
		1	2
1.	Total weight of aggregate sample filling the cylindrical measure = W_1 g	400	400
2.	Weight of aggregate passing 2.36 mm sieve after the test = W_2 g	76	78
3.	Weight of aggregate retained on 2.36 mm sieve after the test = W_3 g	334	322

Calculation

Aggregate impact value = percent fines = $\frac{W_2}{W_1} \times 100$

(i) For sample 1 = 19 %

(ii) For sample 2 = 19.5 %

Result

For test sample (average value) = 19.25%

As per the recommended values the sample is **strong** for road surfacing.

6.1.5 Shape test

Table 6: Observations for shape test

Size of Aggregate		Weight of the Fraction (gm)	Thickness Gauge Size (mm)	Weight of aggregates passing gauge (gm)	Length gauge size (mm)	Weight of aggregate retained (gm)
Passing Throu IS sieve	Retained on IS sieve					
1	**2**	**3**	**4**	**5**	**6**	**7**
63	50	W1 =	33.9	w1 = --	--	--
50	40	W2 =	27	w2 = --	81.0	x1 = --
40	31.5	W3 =154	21.45	w3 = 6	64.35	x2 = 42
31.5	25	W4 =485	16.95	w4 = 31	--	x3 = 107
25	20	W5 = --	13.5	w5 = --	40.5	--
20	16	W6 =234.5	10.8	w6 = 47	32.4	x4 = 31.5
16	12.5	W7 =151	8.55	w7 = 60	25.6	x5 = 22
12.5	10	W8 =21	6.75	w8 = 43	20.2	x6 =6
10	6.3	W9 =13.5	4.89	w9 = 7	14.7	x7 = 3.5
W =1059			w =194		x = 212	

Calculations:

Flakiness index = $\frac{(w_1 + w_2 + w_3 + ...)}{(W_1 + W_2 + W_3 + ...)} 100\, percent = \frac{100w}{W}\, percent$

Elongation index = $\frac{(x_{11} + x_2 + x_3 + ...)}{(W_1 + W_2 + W_3 + ...)} 100\, percent = \frac{100x}{W}\, percent$

Result:

Flakiness index = 18.31
Elongation index = 20.01

6.2 Test results of crumb rubber

6.2.1 SPECIFIC GRAVITY TEST

Table7: Observation for specific gravity test for crumb rubber

S. No.	DETERMINATION	SAMPLE-I	SAMPLE-II
1	Mass of density bottle in gm (m1)	**33.5**	**33.5**
2	Mass of bottle + crumb rubber in gm(m2)	**48.75**	**49.35**
3	Mass of bottle +crumb rubber + water Temperature 25 ^{0} C (m3)	**91**	**91.6**
4	Mass of bottle + water at temperature 25^0 C (m4)	**91.5**	**92.1**

Calculations:

$$G = \frac{(m2-m1)}{(m4 - m1)-(m3 - m2)}$$

Result:

Specific gravity of crumb rubber = 1.011

As per the code the specific gravity of crumb rubber to be used as a modifier should be between .97- 1.02. Therefore the crumb rubber can be used as a modifier.

6.2.2 SIEVE ANALYSIS

Weight of sample taken = 200gm

Table 8: Observation of sieve analysis of crumb rubber

I.S sieve No. or size	Wt. Retained in each sieve (gm)	Percentage on each sieve	Cumulative %age retained on each sieve	% Finer
2.36 mm	**0**	0	0	100
1 mm	0.5	0.25	0.25	99.75
600 micron	5	2.5	2.75	97.25
300 micron	55.5	27.75	30.5	69.5
150 micron	100.5	50.25	80.75	19.75
75 micron	28.5	14.25	95	5
Pan	5.5	2.75	97.75	2.5

Result: The following test shows a satisfactory result and crumb rubber can be used to modify bitumen.

6.2.3 SEPERATION TEST

Result:

Softening point of upper part of sample = 45℃

Softening point of lower part of sample =44℃

As per the code a variation of 3° is allowed. Hence the crumb rubber gets uniformly mixed in the bitumen

6.3 TEST RESULTS OF CRUMB RUBBER MODIFIED BITUMEN (CRMB)

Table 9: Results of crumb rubber modified bitumen

%CRUMB RUBBER	PENETRATION(in mm)	Softening point (in Celsius)	Ductility (in cm)
0	48	51	56
2.5	41.8	50	23.5
5	38	52	19
7.5	36.5	54	22
10	30.9	53	28
12.5	21.66	64.75	25
15	20.4	65	27

6.3.1 PENETRATION TEST

1. Pouring temperature, °C = 210 °C
2. Period of cooling in atmosphere, minutes = 60 minutes
3. Room temperature, °C = 20 °C
4. Period of cooling in water bath, minutes = 60 minutes

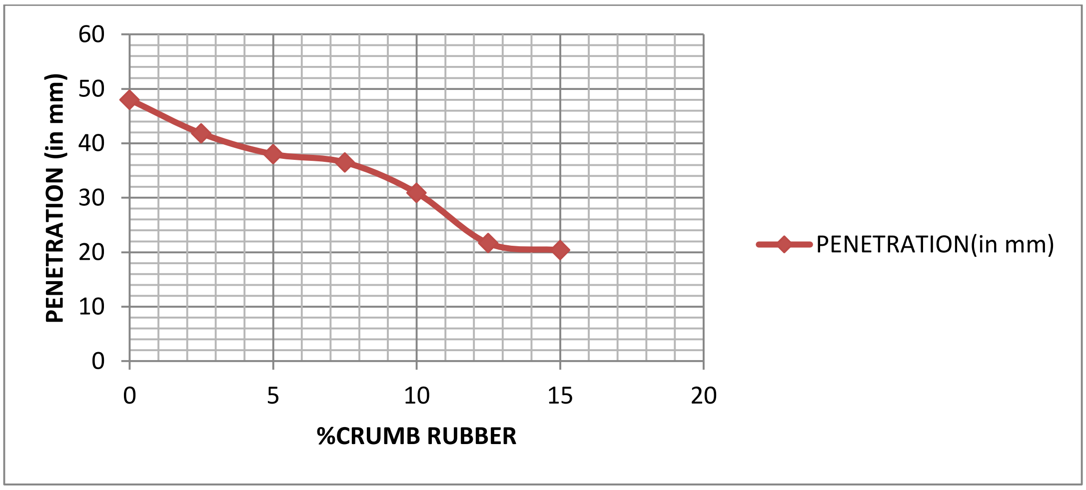

Figure 14: Change in penetration value with increase in crumb rubber %

6.3.2 DUCTILITY TEST

Observation:

1. Test temperature = 27 °C

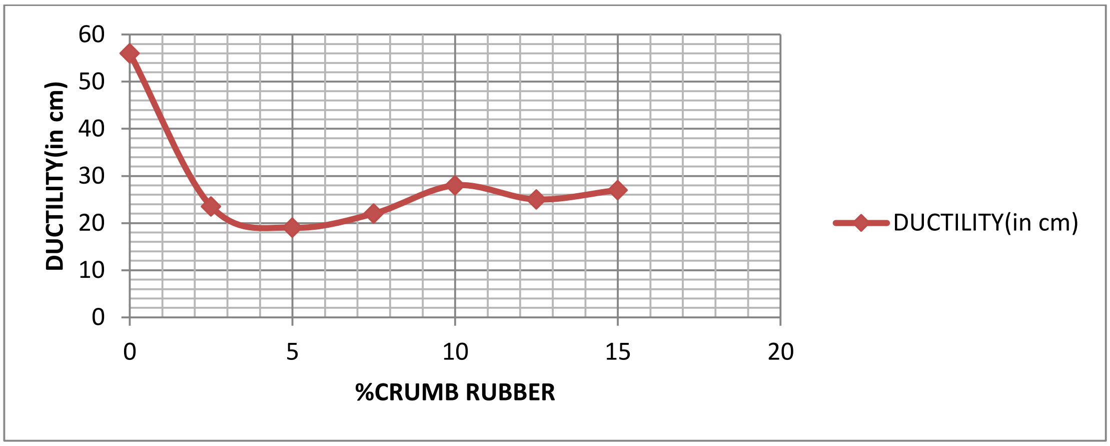

Figure 15: Change in ductility with increase in crumb rubber %

6.3.3 SOFTENING POINT TEST

1. Liquid used in the bath: Water
2. Period of air cooling, minutes: 60 minutes
3. Period of cooling in water bath, minutes = 60 minutes

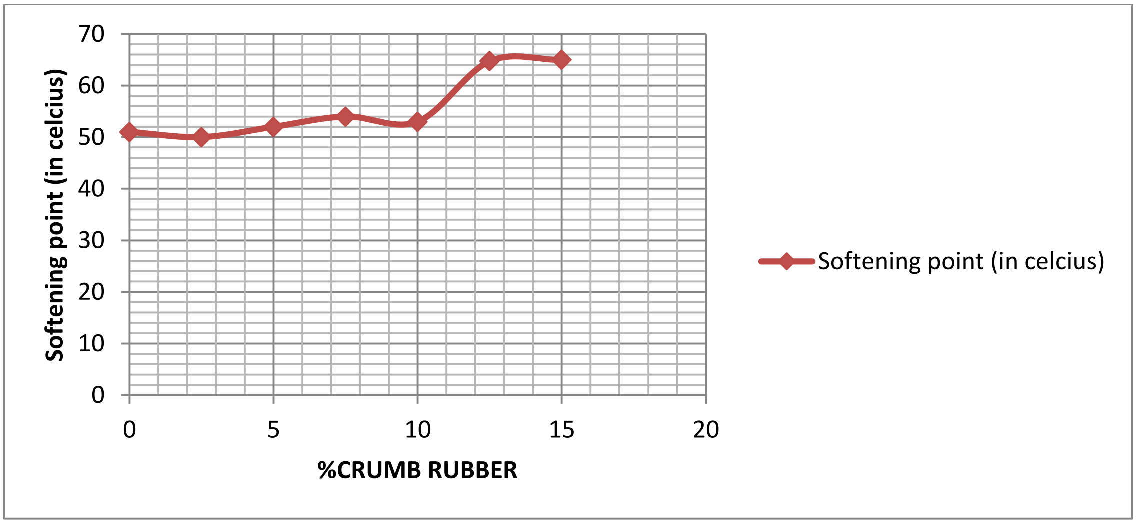

Figure16: Change in Softening point with increase in crumb rubber %

6.4 TEST RESULTS OF EVA (ETHYL-VINYL ACETATE) MODIFED BITUMEN

Table 10: Results of EVA modified bitumen

%EVA	PENETRATION(mm)	Softening point (Celsius)	Ductility (cm)
0	48	51	58
1	40	57	48
2	34	59	43
3	29	63	40
4	26	67	37
5	24	71	28
6	22	74	24

6.4.1 PENETRATION TEST

1. Pouring temperature, °C = 210 °C
2. Period of cooling in atmosphere, minutes = 60 minutes
3. Room temperature, °C = 20 °C
4. Period of cooling in water bath, minutes = 60 minutes

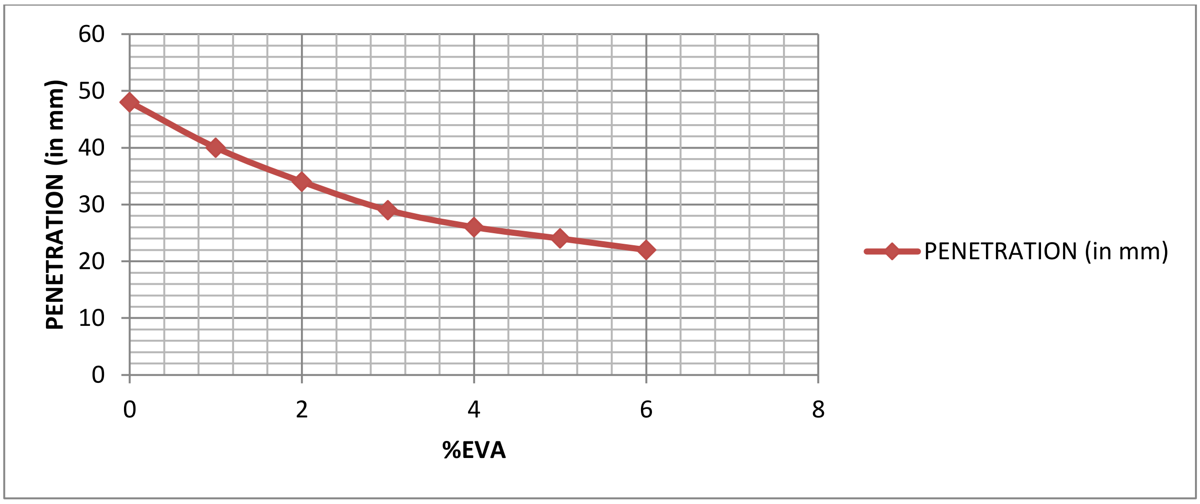

Figure 17: Change in penetration value with increase in EVA %

6.4.2 DUCTILITY TEST

Test temperature = 27 °C

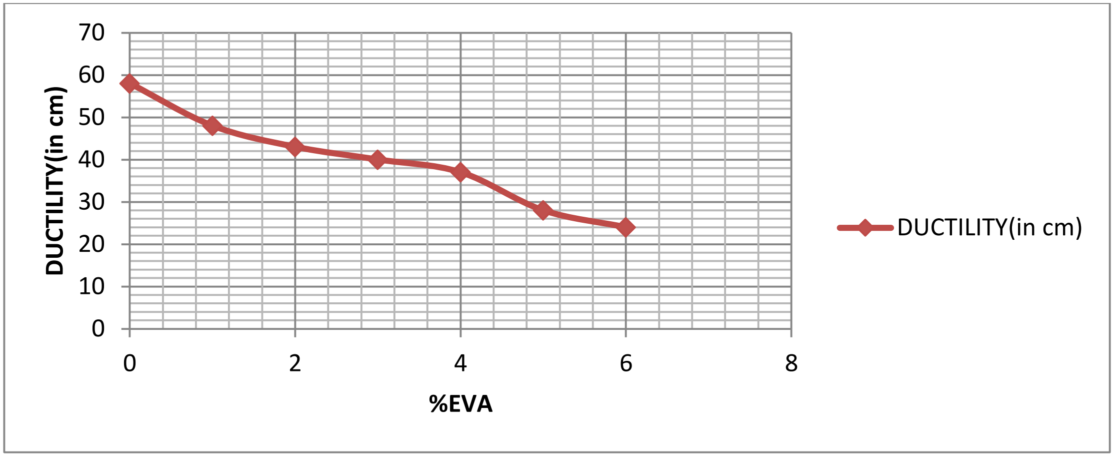

Figure 18: Change in ductility with increase in EVA %

6.4.3 SOFTENING POINT TEST

1. Liquid used in the bath: Water
2. Period of air cooling, minutes: 60 minutes
3. Period of cooling in water bath, minutes = 60 minutes

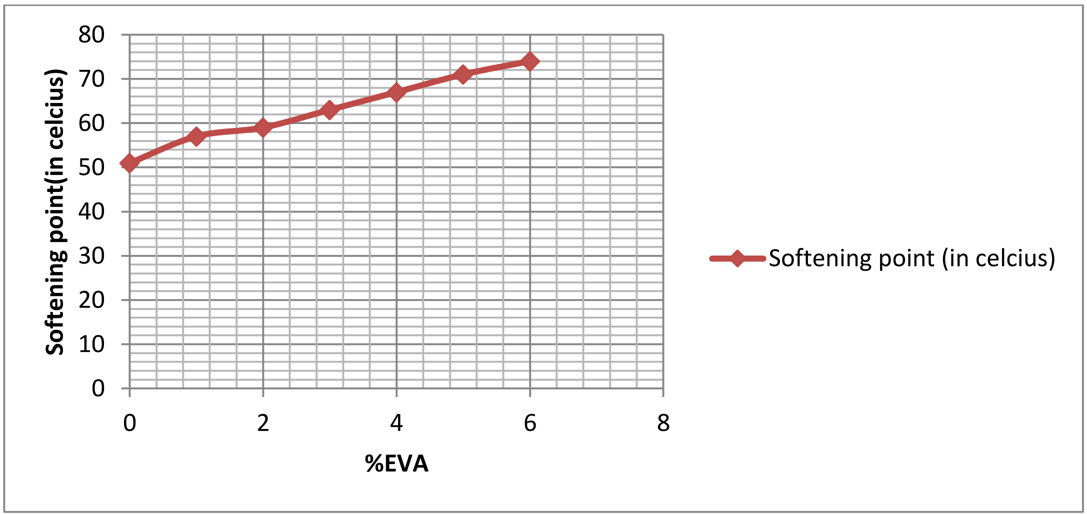

Figure 19: Change in softening point with increase in EVA %

6.5 TEST RESULT OF SBS (STYRENE BUTADIENE STYRENE) MODIFIED BITUMEN

Table 11: Results of SBS modified bitumen

%SBS	PENETRATION(mm)	Softening point (Celsius)	Ductility (cm)
0	48	51	58
2	44	52	61
4	41	58	64
6	39	64	66
8	34	73	67

6.5.1 PENETRATION TEST

1. Pouring temperature, °C = 210 °C
2. Period of cooling in atmosphere, minutes = 60 minutes
3. Room temperature, °C = 20 °C
4. Period of cooling in water bath, minutes = 60 minutes

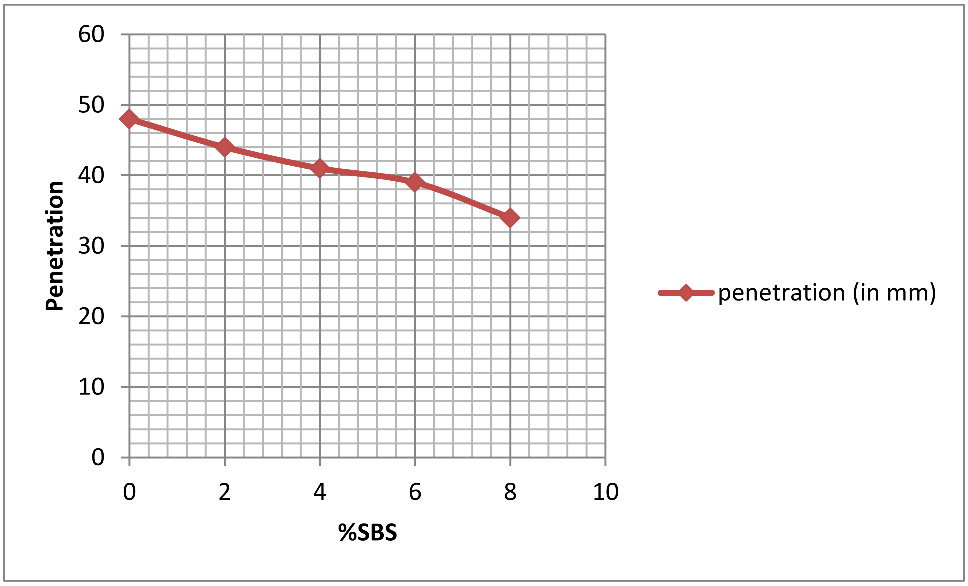

Figure 20: Change in penetration value with increase in SBS

6.5.2 DUCTILITY TEST

Test temperature = 27 °C

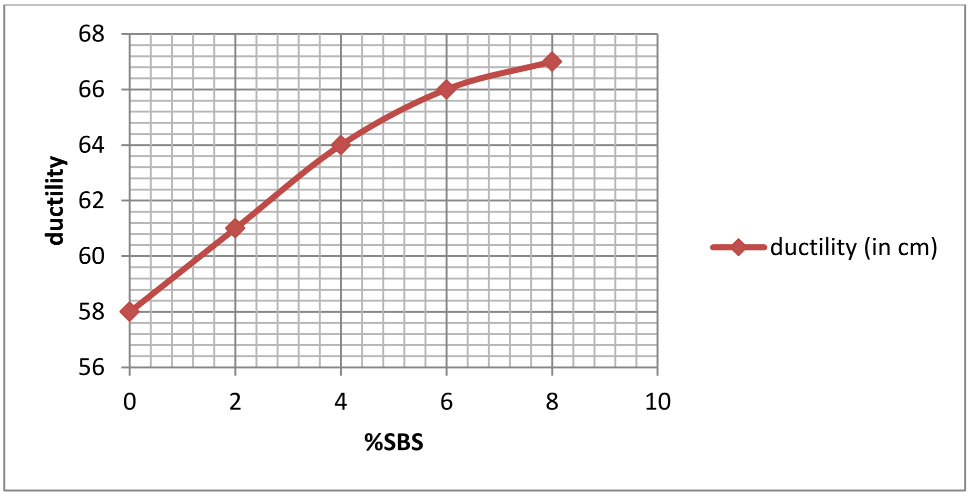

Figure 21: Change in ductility with increase in SBS %

6.5.3 SOFTENING POINT TEST

1. Liquid used in the bath: Water
2. Period of air cooling, minutes: 60 minutes
3. Period of cooling in water bath, minutes = 60 minutes

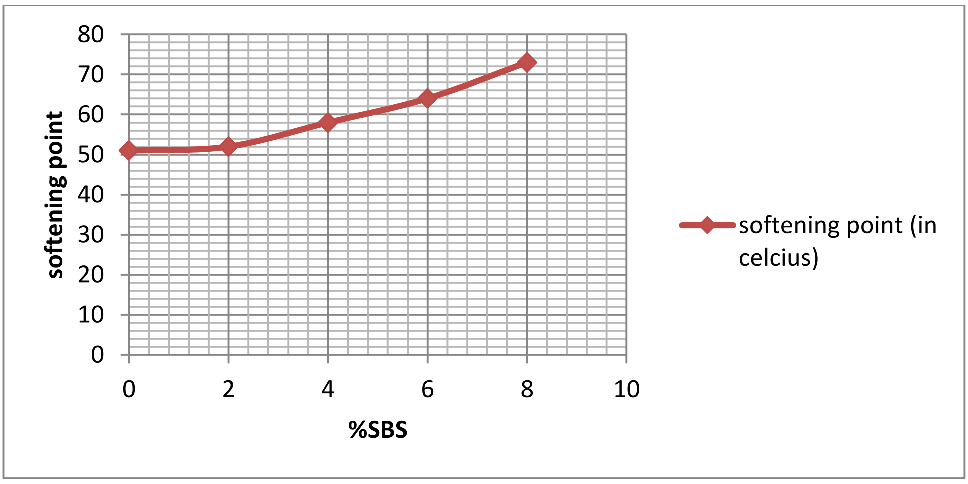

Figure 22: Change in softening point with increase in SBS %

6.6 TEST RESULTS OF STABLIZED BLACK COTTON SOIL

Table 12 : Test results of stabilized black cotton soil

S.NO	TYPES OF SOIL	LIQUID LIMIT TEST	PLASTIC LIMIT TEST	PLASTICITY INDEX (LL – PL)	COMPACTION TEST		CBR TEST
					OMC	MDD	IN SOAKED CONDITION
1	B.C SOIL	65.67%	38.2	27.47	15.6%	1.796g/cc	3.2%
2	B.C SOIL+9%LIME	58%	31.91	26.09			
3	B.C SOIL +12% LIME	46.63%	28.5	17.53	5.3%	2.07g/cc	6.9%
4	B.C SOIL+15% LIME	46%	26.08	19.92			

6.6.1 LIQUID LIMIT TEST

Table 13 a : observations of liquid limit test at varying % of lime

NO of drops (at 0%)	Water content (at 0%)	NO of drops (at 9%)	Water content (at 9%)
36	46.7	28	53.8
28	64.5	33	51
22	68.6	24	59.88

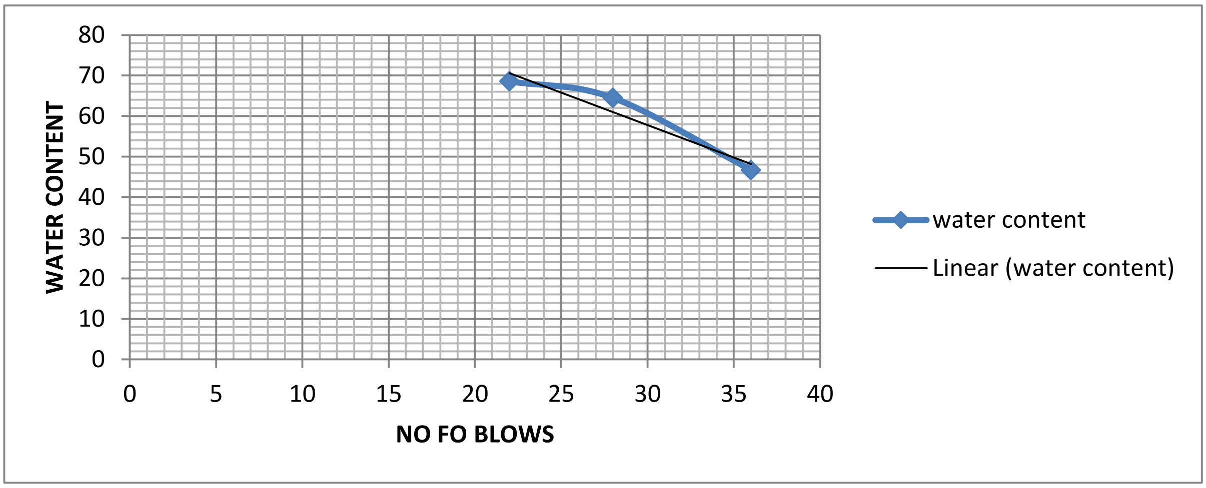

Figure 23: flow curve at 0% lime content

Result:
Liquid limit water content corresponding to 25 number of blows = 65.67

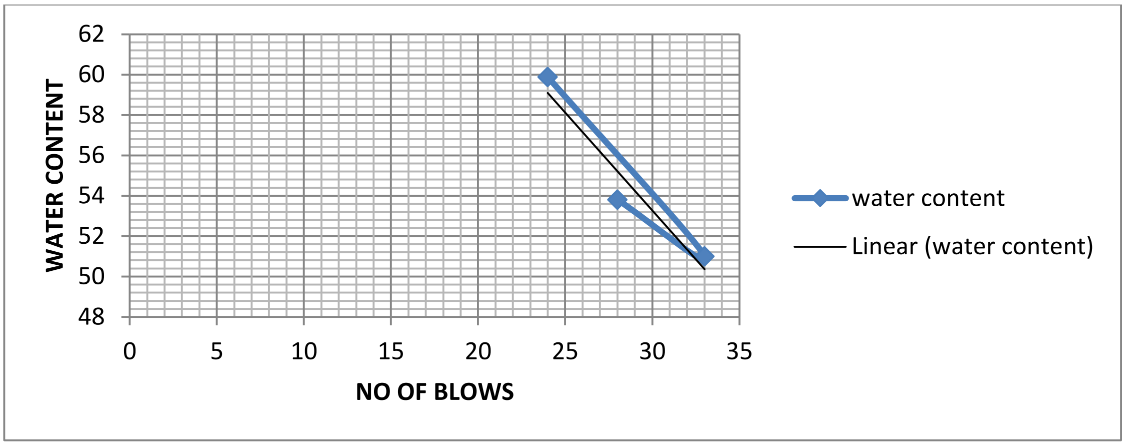

Figure 24: flow curve at 9% lime content

Result:

Liquid limit water content corresponding to 25 number of blows = 58 %

Table 13 b: observations of liquid limit at varying % of lime content

NO of drops (at 12%)	Water content(at 12%)	NO of drops (at 15%)	Water content (at 15%)
33	38.42	36	38.42
29	42.32	28	42.44
22	50.12	22	49.12

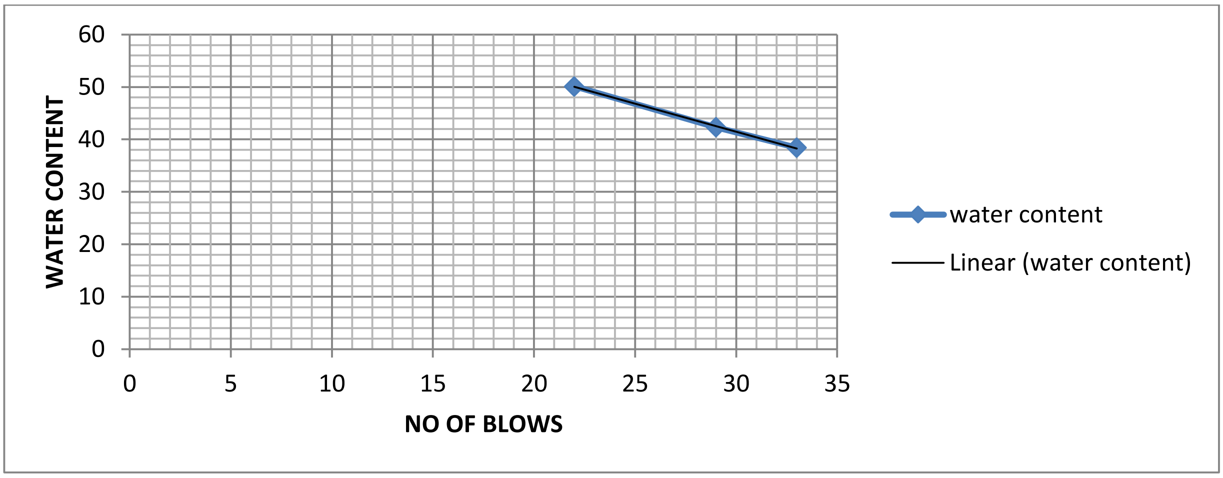

Figure 25: flow curve at 12% lime content

Result:

Liquid limit water content corresponding to 25 number of blows = 46.63 %

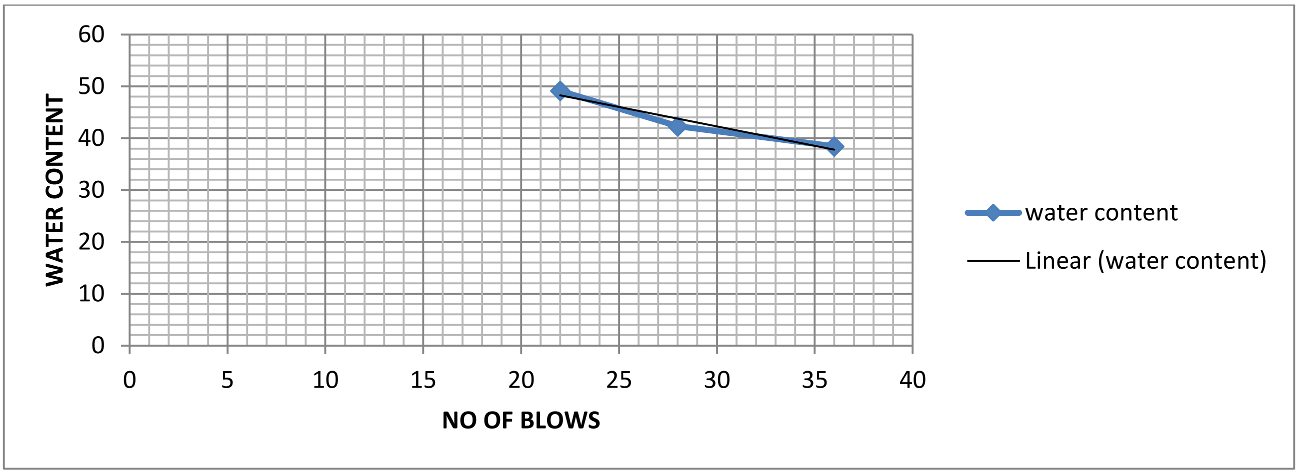

Figure 26: flow curve at 15% lime content

Result:

Liquid limit water content corresponding to 25 number of blows = 46.0 %

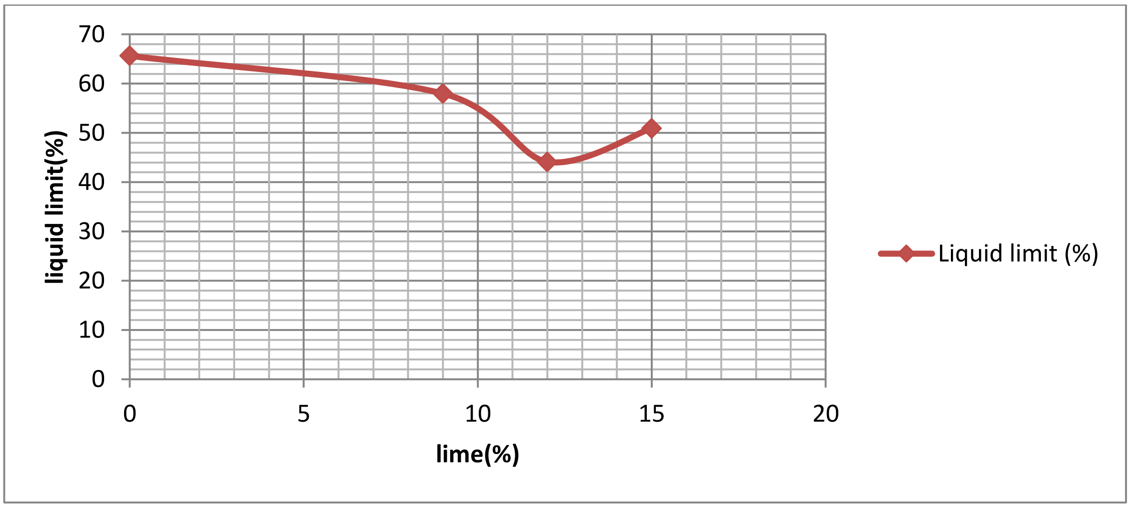

Figure 27: Change in liquid limit with increase in lime %

6.6.2 PLASTIC LIMIT TEST

Table 14: Observations of Plastic limit test

	B.C soil	B.C soil +9% lime content	B.C soil + 12% lime content	B.C soil + 15% lime content
Wt of container ,W1 (gm)	8.8	8.2	10.6	7.9
WT of container + wet soil sample , W2 (gm)	15.3	14.4	16.9	13.7
WT of container + dry soil sample , W3 (gm)	13.5	12.9	15.5	12.5
Plastic limit (%) ={(W2-W3)/(W3-W1)}*100	38.2	31.91	28.5	26.08

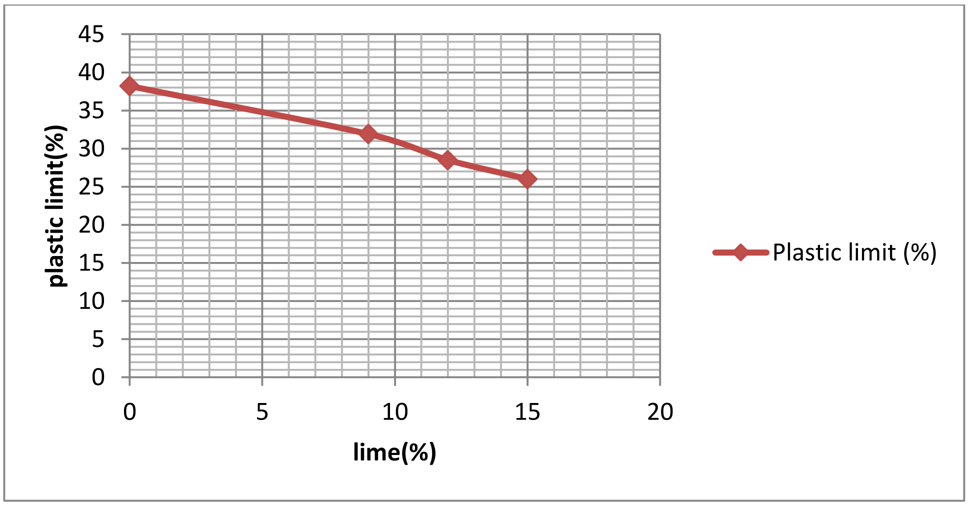

Figure 28: Change in Plastic limit with increase in lime %

6.6.3 STANDARD PROCTOR TEST

1. Mould volume : 997cc

2. Mould weight : 2057gm

Table 15 : Observations of Standard proctor test at 12 % lime content

S.NO	Mould+sample wt (gm)	Wet density (gm/cc)	Empty dish wt (gm)	Dish + wet sample(gm)	Dish+ dry sample(gm)	Water content(%)	Dry density(gm/cc)
1	4141	2.09	44.97	102.82	101.48	2.32	2.045
2	4147	2.10	54.9	91.72	90.73	2.69	2.04
3	4200	2.15	44.16	84.34	82.83	3.76	2.07
4	4272	2.22	47.7	96.37	93.59	5.71	2.10
5	4331	2.28	76.17	76.17	73.3	11.20	2.05

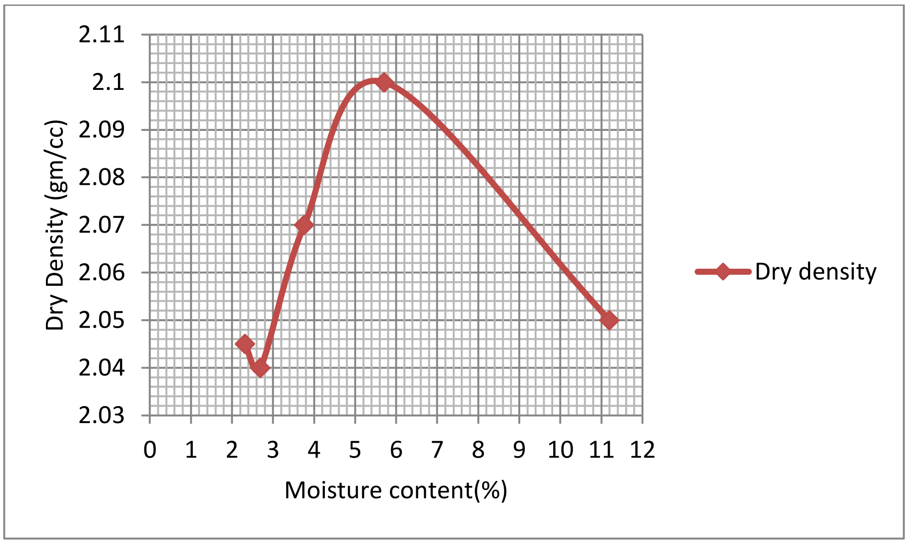

Figure 29: Compaction curve at 12 % lime content

Result:
OMC = 5.3 %
MDD = 2.07 gm/cc

Table 16: Observations of Standard proctor test at 0% lime content

Water content	**Dry density (gm/cc)**
11	1.715
12.9	1.75
14.9	1.795
17.5	1.78
21.9	1.7

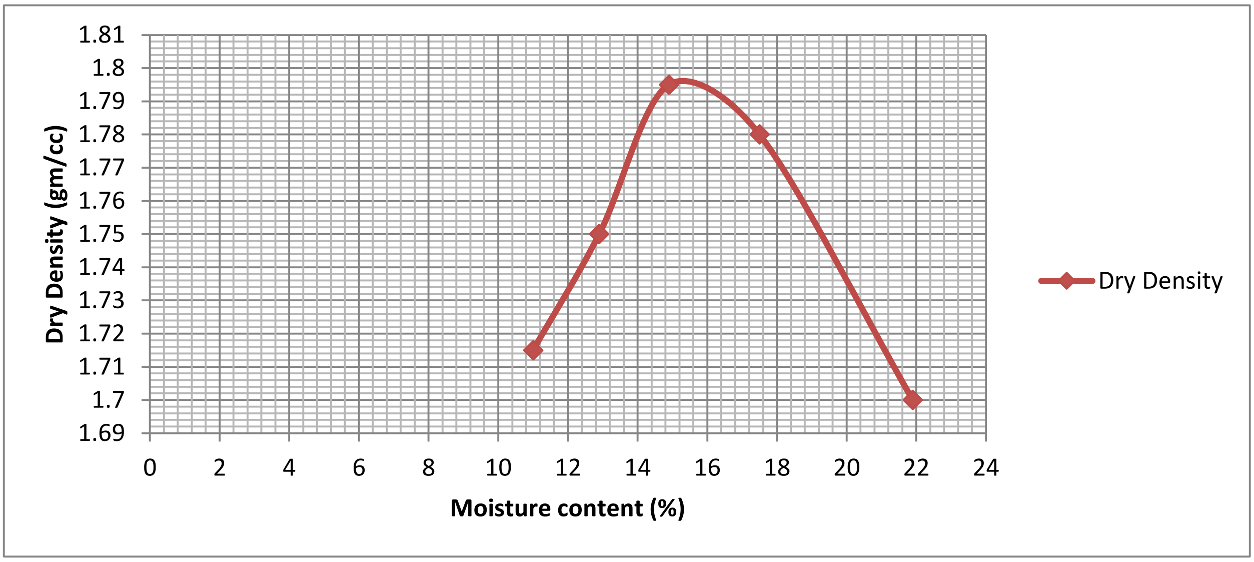

Figure 30: Compaction curve at 0 % lime content

Result:
OMC = 15.6 %
MDD = 1.796 gm

6.6.4 CALIFORNIA BEARING RATIO TEST

Table 17 : Observations of CBR test at 0% lime content

(at OMC=15.6% and MDD=1.796gm/cc)

Penetration (mm)	Load (kg)
0.5	15
1	30
2	40
2.5	45
5	65
5.5	85

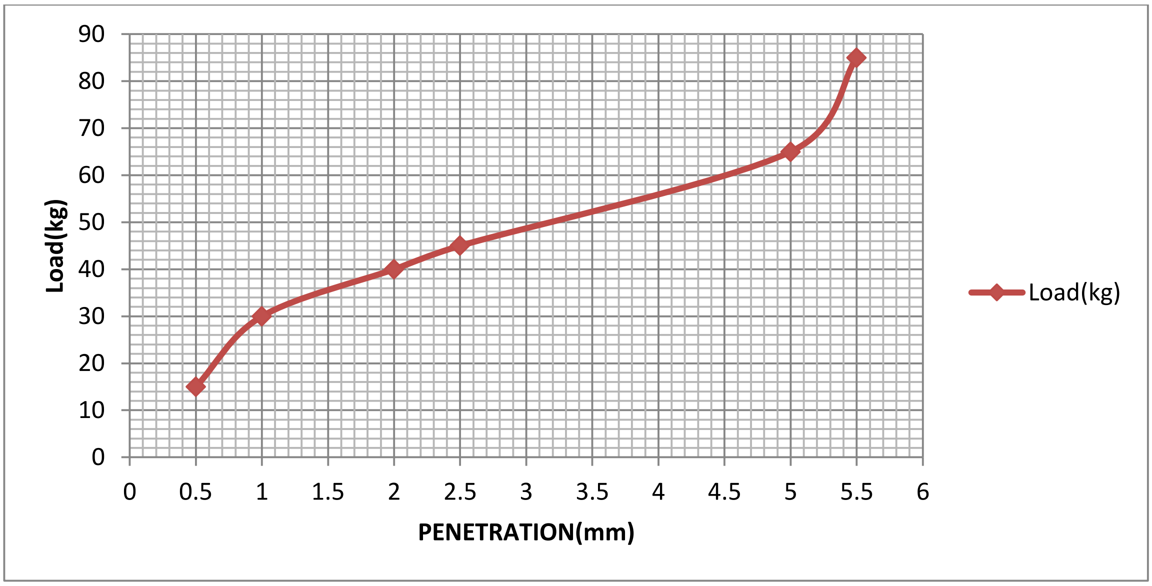

Figure 31 : Load vs penetration at 0 % lime content

CBR at 2.5 mm penetration= (45/1370)*100 = 3.28

CBR at 5 mm penetration= (65/2055)*100 = 3.16

Table 18: Observations of CBR test at 12 % lime content

(at OMC=5.3% and MDD=2.07gm/cc)

Penetration (mm)	**Load (kg)**
0.5	15
1	45
2	75
2.5	95
5	125
5.5	135

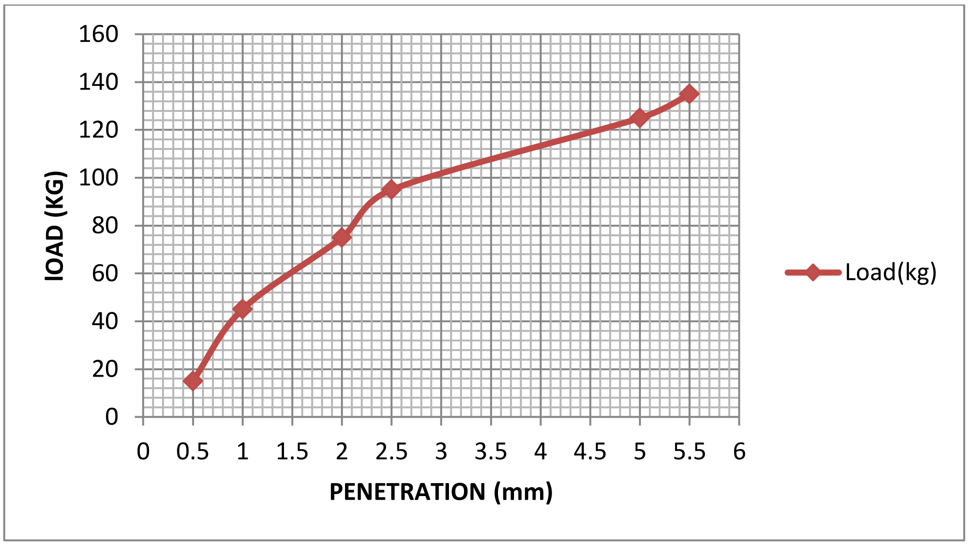

Figure 32: Load v/s penetration at 12 % lime content

CBR at 2.5 mm penetration= (95/1370)*100 = 6.93

CBR at 5 mm penetration= (125/2055)*100 = 6.08

6.7.1 DESIGN OF BITUMINOUS MIX FOR MARSHAL STABILITY

Table 19: Design of bituminous mix for marshal stability

NOMINAL AGGREGATE SIZE	19MM		
LAYER THICKNESS	50-65MM		
SIEVE SIZE, MM	% PASSING , BY WEIGHT	WEIGHT PASSING(gm)	WEIGHT RETAINED(gm)
26.5	100	1200	0
19	89.5	1072	128
13.2	69	829	243
9.5	62	749	80
4.75	45	500	249
2.36	36	438	102
1.18	27	329	109
0.6	21	250	79
0.3	15	177	73
0.15	9	109	68
0.075	5	63	46
		TOTAL	1177
BITUMEN CONTENT, % BY WEIGHT OF TOTAL MIX	6-7		
WEIGHT OF BITUMEN IN (gm)	60-78		

6.7.2 DISPLACEMENT VS LOAD DATA FOR SBS

Table 20: Displacement v/s Load values for SBS

	SBS at 0%	SBS at 4%	SBS at 6%	SBS at 8%
DISPLACEMENT	LOAD(KN)	LOAD(KN)	LOAD (KN)	LOAD (KN)
0.5	0.4	0.6	3.5	1.8
1	0.8	1.3	4.9	2.4
1.5	1.4	1.9	5.2	2.7
2	1.7	2.8	5.9	3.1
2.5	2.3	3.7	6.5	3.5
3	2.5	4.5	6.6	3.9
3.5	3	5.1	6.9	4.6
4	3.2	5.8	7.4	5.1
4.5	3.5	6.4	7.7	5.8
5	3.6	6.7	8	6.4
5.5	3.7	6.9	8.3	7.1
6	3.7	7.1	8.5	7.5
6.5	3.7	7.4	8.7	8
7	3.8	7.5	8.9	8.3
7.5	3.8	7.7	9.2	8.7
8	3.8	7.7	9.5	9.2
8.5	3.8	7.8	9.7	9.4
9		8	9.8	9.6
9.5		8.1	9.9	9.8
10		8.1	10	10.1
10.5			10.2	10.3
11			10.3	10.3
11.5			10.5	10.4
12			10.8	
12.5			11.2	
13			11.5	

13.5			11.8	
14			12	
14.5			12.2	
15			12.3	

6.7.3 MARSHAL STABILITY DATA FOR SBS

Table 21: Marshall Stability data for SBS

MARSHAL STABILITY(kN)				
S.No	% of Bitumen	% of SBS	Stability	Temp
1	7	0	3.8	30
2	7	4	8.1	30
3	7	6	12.3	30
4	7	8	10.4	30

CHAPTER 6

CONCLUSIONS

- Physical properties of bitumen such as penetration, softening point and elastic recovery are improved with addition of the polymers and crumb rubber.
- There is a significant decrease in penetration values and increase in softening point for modified blends, indicating the improvement in temperature susceptibility resistant characteristics. The improvement is governed by the swelling process of crumb rubber particles that interacted with bitumen.
- EVA modified binder also gives lower penetration value. The softening point increases with increase in percentage of modifier as the bitumen becomes increasingly viscous.
- Although with the addition of these modifiers, the ductility of the bitumen is reduced to a great extend. The properties of bitumen are highly influenced by the temperature at which the sample is prepared. This was the main reason for variations in the results obtained for crumb rubber modified bitumen.
- SBS modified bitumen gave the best results out of all the three modifiers used in the project as the ductility in its case gave good results the reason being at temperature above 160 degree celcius SBS is in melt condition and releases low molecular weight fraction into the bitumen.
- Liquid limit and plastic limit of black cotton soil decreases with increase in lime content. It is because on mixing lime with black cotton soil there is a immediate exothermic hydration reaction. It reduces water content with further reduced by aeration of soil. Water fall percentage varies by 2 to 3 % of added lime.
- Reduction in Plasticity Index (PI): It switches from being plastic to stiff and grainy.The optimum percentage of lime which gave the best result for sub grade black cotton soil is 12%.
- Compaction character for black cotton soil is also affected by varying % of lime. At 0% lime OMC of black cotton soil is 15.3% and MDD is 1.796 gm/cc but at 12% of lime content OMC decreases and MDD increases which indicates that soil has high strength
- The increase in strength of lime stabilised material is due to reactions between clay and lime particles and the clay-lime compound formed provide cemented material and reinforcement in the soil.

- CBR value of black cotton soil increases with lime content at 12% of lime content it gave the best result for sub grade soil. A 0% of lime content CBR value =3.2 and at 12% of lime content CBR value=6.9.

CBR VALUE	SUBGRADE STRENGTH	COMMENTS
3% and less	POOR	capping is required
3% -5%	NORMAL	Widely encountered cbr range Capping considered according to road category
5%-15%	GOOD	capping normally unnecessary except on very heavily trafficked roads.

- Marshall Stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The stability is derived mainly from internal friction and cohesion. Cohesion is the binding force of binder material while internal friction is the interlocking and frictional resistance of aggregates. As bituminous pavement is subjected to severe traffic loads from time to time, it is necessary to adopt bituminous material with good stability.
- Test results have illustrated that SBS as additive play a significant role in the properties of bituminous mixtures. Based on the Marshall test result an optimum content of 6% SBS is recommended for Styrene butadiene styrene modified bitumen AT 6-7% Bitumen content and 6 % SBS content the SBS modified bitumen exhibits the highest stability.

CHAPTER 8

FUTURE SCOPE:

- This test method covers measurement of resistance to plastic flow of 4 in. (102 mm) cylindrical specimens of asphalt paving mixture loaded in a direction perpendicular to the cylindrical axis by means of the Marshall apparatus. This test method is for use with dense graded asphalt mixtures prepared with asphalt cement (modified and unmodified), cutback asphalt, tar, and tar-rubber with maximum size aggregate up to 1 in. (25 mm) in size (passing 1 in. (25 mm) sieve).
- This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use
- Better capability to characterize material properties and assess existing pavement structural capacity (through laboratory testing, non destructive testing, and back calculation, or all three)
- Ability to evaluate and compare different design alternatives on a fair (defensible) basis.
- Ability to account rigorously for stochastic variability or uncertainty in the design process.
- A look to the near future (as discussed above) indicates that one key step in the improvement of flexible pavement design is already taking place, that is, development of the 2002 AASHTO Guide for Design of New and Rehabilitated Pavement Structures. This step will not only result in a major enhancement over the current 1993 AASHTO Guide, but will also help establish some badly needed credibility for the use of modern pavement design procedures by both state and local highway agencies.

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