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Experimental Study on Utilisation of Plastic Waste in Bituminous Pavement

Mr. Sandip Vinod Hotey[1], Dr. M. R. Vyawahare[2], Prof. A. R. Bijwe[3]
[1]M.E Student, Dr. Rajendra Gode Institute of Technology and Research, Amravati (MS), India.
[2]Professor, Dr. Rajendra Gode Institute of Technology and Research, Amravati (MS), India.
[3]Professor, Dr. Rajendra Gode Institute of Technology and Research, Amravati (MS), India.

I. Abstract: The waste plastic and its disposal are a major threat to the environment, which results in pollution and global warming. The utilization of plastic waste in bituminous mixes enhances its properties and also its strength. In addition, it will also be a solution to plastic disposal. Reuse of wastes material is a very simple but powerful concept.

This innovative technology of Waste plastic use in road making will be boon for Indian hot-humid climate. It's economical. Disposal of waste materials including waste plastic bags has become a serious problem, especially in urban areas, in terms of its misuse, its dumping in the dustbins, clogging of drains, reduced soil fertility and aesthetic problem etc. Waste plastics are also burnt for apparent disposal, causing environmental pollution.

Utilization of waste plastic including bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Plastic waste which is cleaned is cut into a size such that it passes through 2-3mm sieve using shredding machine. When mixed with hot Bitumen & aggregate, plastics melt to form an oily coat over the aggregate and the resulted mix is used for road construction. The use of the innovative technology will not only strengthen the road construction but also increase the road life as well as will help to improve the environment. In my research work I have done a thorough study on the methodology of using plastic waste in bituminous mixes and presented the various tests performed on aggregates and bitumen.

Keywords: - Plastic Waste, Bitumen, Aggregates.

II. Content:

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LIST OF ABBREVIATIONS

\ASTHO	\merican Association of State Highway and Transportation Officials
\STM	\merican Society for Testing Materials
3C	3ituminous Concrete
:I	:longation Index
:I	:lakiness Index
Gm	3ulk Density of Mix
Gt	'heoretical Density of Mix
HMA	Hot Mix Asphalt
S	ndian Standard
MORTH	Ministry of Road Transport and Highways
DBC	Dptimum Binder Content
Sp. Gr.	Specific Gravity
/FB	/oids Filled with Bitumen
/G	/iscosity Grade
/MA	/oids in Mineral Aggregates
/v	/olume of Voids
'CA	plastic coated aggregate
'W	'lastic Waste
'emp	'emperature

CHAPTER 1

INTRODUCTION

Most of the Highways in India constructed with flexible pavement having wearing course with bituminous concrete. This Bituminous Concrete should be constructed to satisfy the recommendation and requirements of MORTH Section 509. This clause specifies the construction of Bituminous Concrete, for use 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 25 mm to 100mm in thickness. As per MORTH Section 500 clause 509 BC should be made with Bitumen Grade 60/70(VG 30) for nominal aggregate size 19 mm with bitumen content 5-6% has layer thickness 50-65 mm and for nominal aggregate size 13 mm with bitumen content 5-7% having layer thickness 30-45 mm.

1.1 USE PLASTIC

Polymer have a number of very important properties which exploited along or together make a significance and expanding contribution to construction needs

1. Durable and corrosion resistant

2. Good insulation for cold heat and sound saving energy and reducing noise pollution

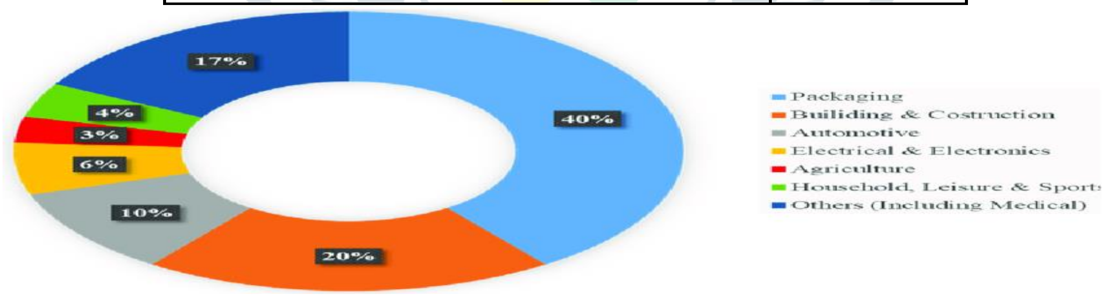
3. It is economical and longer life

4. Maintenance free

Plastic waste (Low Density Polyethylene) converted in the shredded form (2-8 mm and 300 micron) was used in this study as shown Fig 1.1. This type of plastic waste used my work and properties of shredded plastic waste are given in Table 1.1

Table1.1 - Properties of Plastic waste

operties	lue
ɔftening Temperature in ^{0}C	120 - 150
itial Decomposition Temperature in ^{0}C	270 - 350
elting Temperature in ^{0}C	>700



Sources of Plastic Waste

Plastic waste

Image No. 1.1

1.2 NEED OF STUDY

In present study Disposal of waste material (plastic) is a major problem. Plastic waste is a non-biodegradable. Burning of these waste plastic bags causes highly environmental pollution. It mainly consists of low-density polyethylene. To use of waste material in Bituminous Road construction really impressive job, this material dumped into land leads to wastage of land. In this study use of Aggregate as a filler material bituminous concrete and waste plastic as coating material. Find its utility in bituminous mixes for road construction. Improvement in properties of bituminous mix provides the solution for disposal in a useful way.

1.3 OBJECTIVES

Study has been carried out to satisfy following objectives:

1. To improve the volumetric properties of BC mix design.
2. To utilize waste plastic in bituminous mixes.
3. To evaluate laboratory performance of BC mix design.

1.4 SCOPE OF STUDY

This study will be conducted to explore the idea about use of waste material in bituminous concrete with detailed laboratory Investigation will be carry out to find whether it is viable to use or not in terms of suitability, economically and environmentally.

The present study will focus basically on these following points:

1. To study the basic physical and mechanical properties of waste plastic in order to contribute a better knowledge of its properties.

2. To study the effect on Marshall Stability of bituminous mix with the addition of waste plastic.

3. To reduce the bitumen content by the addition of Waste plastic in bituminous mix.

The laboratory investigation on the bituminous mix has been carried out as per the Indian Standards used for the road construction.

1.5 OVERVIEW

Chapter 1 : This chapter consist of introduction included background of waste plastic in which included properties of waste plastic use of material in road construction, also include need of study, objective and scope.

Chapter 2 : This chapter consist the background study and Literature Review.

Chapter 3: This chapter consist of methodology for Waste Plastic used in Bituminous Pavement.

Chapter 4 : This chapter consist of various Laborites test on Aggregate

Chapter 5 : This chapter consist of various Laborites test on bitumen test.

Chapter 6 : This chapter consist of various test for Marshall Mix Design.

Chapter 7 : This chapter consist of analysis of test and discuss results of the entire test carried out as per chapter 4, 5 and 6.

Chapter 8 : This chapter consist of Conclusion and future scope for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Indian population grows, so do the amount and types of wastes (plastic waste) being generated. Indian states each day plastic waste generated more than 12 million tons. Source of Waste plastic generated for house hold, health and Medicare, hotel and catering, respectively as follows carry bag, bottles, containers, mineral waste bottles.

Plastic Waste (PW) are abundantly available waste materials with several good characteristics Plastics waste can find its use in this process and this can help solving problem of pollution. The studies on the thermal behaviour and binding property of molten plastics promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction. An alternate method to use higher percentage of plastic waste in flexible pavement is by using plastic coated aggregate (PCA). This method is known widely as dry process. The aggregate coated with plastic was used as the raw material.

Research in to new and innovative use of waste material being under taken worldwide and innovative ideas that are expressed are worthy of this important subject many highway agencies, private organization and individuals have completed or are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmentally suitability and performance of using waste plastic in high way construction thesis studies try to match societal need for safe and economic disposal of waste material with the help of environmental friendly highway industries, which needs better and cost –effective construction material.

2.2 PAVEMENT MATERIAL: PLASTIC WASTE

Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Today, in India nearly 4 million tones of plastics are used and it is hoped to reach 12 million tons by 2014 and estimated that production is likely reach to 600 million tons in 2030. Their visibility has been perceived as a serious problem and made plastics a target in the management of solid waste. Plastics are non-biodegradable.

They also have very long lifetime and the burning of plastics waste under uncontrolled conditions could also lead to generation of many hazardous air pollutants (HAPs) depending upon the type of polymers and additives used. However, the end-of-life plastics can be recycled into a second life application but after every thermal treatment, degradation of plastics takes place to a certain extent.

1. "Use of Plastic Waste Along with Bitumen in Construction of Flexible Pavements" by Rajneesh Kumar, Lucknow Institute of Technology (2020).

Main objectives of this project work are: • To coat the aggregates with waste plastic materials. • Check the properties of various bitumen mixes. • Check the properties of bitumen mix after the coating the waste plastic materials. • Compare the bituminous mixes with plastic waste coating and conventional ones.

2. "Utilization of Plastic waste in Bitumen Mixes for Flexible Pavement" by Dr. S L Hake, Dr. R M Damgir, P R Awsarmal (2019)

In the present research work created procedures to utilize plastic waste for development motivation behind adaptable asphalts will be survey. In regular Street making process bitumen is utilized as folio. Such bitumen can be adjusted with squander plastic pieces and bitumen blend is made which can be utilized as a best layer of adaptable asphalt. The plastics from PET jugs to be utilized in blends for examine work. The measurements of plastic of 5 %, 7.5%, 10 %, 12.5% and 15 % utilized as substitution of bitumen. The advance plastics content is 10% with 5.25 % of bitumen content. In this paper concentrated on Marshall Test and extreme execution of hot blend black-top. In this examination work it is explored that the general cost of plastic blends bitumen spared 5.18 % cost as contrast with customary bitumen. Subsequently it is efficient and earth advantageous for development of plastic blend bituminous street.

3. "Plastic Waste Utilization as Asphalt Binder Modifier in Asphalt Concrete Pavement" by H. Naghawi, R. Al-Ajarmeh, R. Allouzi, A. Alklub, K. Masarwah, A. AL-Quraini, M. Abu-Sarhan (2018)

The main objective of this paper is to study the ability of using recycled plastic waste as a low-cost asphalt binder modifier to improve performance of asphalt roads as well as to extend their service life. For the purpose of this study Organic Polyethylene Terephthalate (PET) materials in the form of plastic cups and plastic bottles were used as an asphalt binder modifier. The PWM asphalt mixture was tested and compared to a conventional asphalt mixture using Marshall mix design procedure. Also, the IDT was determined for all mixtures using the splitting tensile test. It was found that the PWM asphalt mixture outperformed the conventional asphalt mixture.

4. "Use of waste plastic coated aggregates in bituminous road construction" by Prof. Dawale S. A., Lecturer, Plastic and Polymer Engineering, Institute of Petrochemical Engineering, Br. Babasaheb Ambedkar Technological University, Lonere, Raigad, Maharashtra, India (2016)

This paper presents the use of plastic which is collected from municipal solid waste for coating aggregates in bituminous road construction. Marshall properties, impact values, specific gravity, abrasion test, water absorption, soundness and stripping value of the waste plastic coated aggregates were determined.

5. "Plastic Waste Modified Bituminous surfacing for rural Roads" by *Dr. P. K. Jain, (2012)*

In this paper carried out study which deals with current imperatives for use of plastic waste in bituminous road construction. Are view of the available and usable plastic waste in bituminous road constructions is given. The findings of R & D conducted in India and countries abroad are summarized. The pilot studies/projects done on the use of plastic waste are discussed. It is found that shredded plastic waste of the size 2-8 mm may be incorporated conveniently in bituminous mixes used for road constructions. The optimum dose is 0.4-0.5 % by weight of bituminous mix and 6-8% by weight of bitumen. Plastic waste may also be used for up gradations of fly ash for its use as fine aggregate and filler in bituminous road construction.

6. "Use of Waste Plastic & Waste Rubber Tyres in Flexible Highway Pavements" (2012) *by Rokade S (2012)*

In this Paper Included Plastics is user friendly but not eco-friendly as they are non-biodegradable. Generally it is disposed by way of land filling or incineration of materials which are hazardous. The better binding property of plastics in its molten state has helped in finding out a method of safe disposal of waste plastics, by using them in road laying. The Semi Dense Bituminous Concrete (SDBC) mix was prepared using Marshall Method of bituminous mix Design. The SDBC mix was prepared with 4.5 to 6%incrementof 0.5% bitumen. This study used LDPE Low Density Polyethylene and CRMB Crumb rubber modified bitumen3% increment of the (LDPE) for 3%, 6%, 9% and CRMB used for 8%, 10% ,12%

respectively by weight of bitumen. The study on the use of LDPE and CRMB reveals that the Marshal Stability value, which is the strength parameter of SDBC, has shown increasing trend and the maximum values have increased by about 25 % by addition of LDPE and CRMB. The density of the mix has also increased in both the cases of LDPE and CRMB when compared with 60/70 grade bitumen.

7. "Effect of waste polymer modifier on the properties of bituminous concrete mixes" ***Sangita, Tabrez Alam Khan, Sabina, D.K. Sharma (2011)***

In this paper study of Disposal of waste materials including waste plastic bags is a menace and has become a serious problem, especially in urban areas, in terms of its misuse, its dumping in the dustbins, clogging of drains, reduced soil fertility and aesthetic problem etc. Waste plastics are also burnt for apparent disposal, causing environmental pollution. In the present study, the effect of waste polymer (nitrite rubber and polyethylene in 1:4 ratios) modifier (WPM) on various mechanical properties such as Marshall Stability, flow, Marshall Quotient (stability to flow ratio), resilient modulus and permanent deformation potential of bituminous concrete overlays has been evaluated. The Marshall tests of the waste polymer modified bituminous concrete (WPMB) mixes, prepared through dry process, indicated the optimum waste polymer modifier content to be 8% (by weight of optimum bitumen content). The waste polymer modified bituminous mix containing 8%WPM showed considerable improvement in various mechanical properties of the mix compared to the conventional bituminous concrete mix.

8. "Use of plastic waste in Bitumen Roads" ***P Sreejith (2010)***

In this paper carried out Polymer modified bitumen is emerging as one of the important construction of flexible pavements. The polymer modified bitumen show better properties for road construction and plastics waste can find its use in this process and this can help solving problem of pollution. The studies on the thermal behavior and binding property of molten plastics promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction.

This paper are represented alternate method to use higher percentage of plastic waste in flexible pavement is by using plastic coated aggregate (PCA). This method is known widely as dry process. The aggregate coated with plastic was used as the raw material. The bitumen was not blended with plastic waste. Plastic waste was dissolved in bitumen and the blend was coated over aggregate. It was tested by immersing in water. Even after 72 hours, there was no stripping. This shows that the blend has better resistance towards water. This may be due to better binding property of the plastic waste-bitumen blend. This paper of three types plastic waste are use Polyethylene (PE), Polypropylene (PP), Polystyrene(PS)in which % of waste plastic used in 0 to 1.5 increment of 0.5% by weight of bitumen. Decrement of Preparation of test value Softening Point value, Penetration Test value, Ductility value and % of one by one add the plastic contain increase Marshall stability value.

9. "Utilization of Waste Plastic In Bituminous Mixes For Road construction" ***Pada Sabtu, (2010)***

In this paper represent 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. The softening point of the modified bitumen increased with the addition of plastic additive, up to 8.0 %by weight. Studies were carried out on Bituminous mixes using 60/70 grade bitumen having average Marshall Stability Value (MSV) of 1300 kg at optimum bitumen content of 5.0 % by weight of the mix. Further studies on mixes were carried out using the modified binder obtained by the addition of varying proportions of processed plastic bags (percentage by weight of bitumen) with the conventional 80 /100 grade bitumen. The optimum modified binder content fulfilling the Marshall Mix design criteria was found to be 5.0 % by weight of the mix, consisting of 8.0 % by weight of processed plastic added to the bitumen. The average MSV of the mix using the modified binder was found to be as high as 1750 kg at this optimum binder content, resulting in about three fold increase in stability of the BC mix, which contains 4.6 % bitumen plus 8 % processed plastic by weight of bitumen, i.e.0.4 % processed plastic by weight of the mix.

10. "*The use of Polyethylene in hot Asphalt mixtures*" Mohammad T. Awwad and Sheeb Lina. (2007)

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

11. "Utilization of Waste Polymers Coated Aggregate for Flexible Pavement and Easy Disposal of Waste Polymers" Dr. *R. Vasudevan, S.K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar, B. Sundarakannan (2006)*

This paper is representing Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Disposal of a variety of plastic wastes in an ecofriendly way is the thrust area of today s research. The authors' innovative techniques to use the waste plastics and the tyre waste for the construction of flexible pavement, for making pathway blocks, and for making laminated roofing sheets form a good solution for the waste disposal problem of both plastic waste and municipal solid waste. The major polymers namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state. The generation of waste plastics is increasing day by day. The coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value, Compression Strength, Bending Strength, and decreases the impact value, abrasion value. Properties of Polymer Modified Bitumen in which add the % of Plastics reduces Ductility, Penetration and high Softening Point.

The crumb rubber blended bitumen is subjected to different tests like penetration point, Ductility, softening point. Here we have taken 80/100 bitumen and it is modified with different percentage of crumb rubber powders starting from 1% to 5% increment of 1%Reduce the bituminous like properties penetration point, ductility and high softening point.

12. "Study on the Characterization and Utilization of Waste Plastics-Green Technology" (2006)

This paper represent coating of molten plastic over the surface of aggregate reduces water absorption. Generally, voids should be less than 2 per cent. Lesser the voids better the quality of aggregate. Air voids with plastic waste 2.2 and nil and without plastic waste 4 and 1 hence, the aggregate with lesser voids is considered to be good for the purpose of road construction. The coating improves Soundness. The coating of plastics also improves the quality of aggregate. 1) By decreasing Aggregate Impact Value (AIV) value is 25.4 to 21.20, 18.50 to 17, with plastic waste and without plastic waste respectively 2) By decreasing Aggregate Crushing Value (ACV) value is 26 to 21, 20 to18 with plastic waste and without plastic waste respectively and 3) By decreasing Los Angeles Abrasion Value (LAAV) value is 37 to 32, 29to26 with plastic waste and without plastic waste respectively. These observations help to conclude that plastics waste coated aggregate can be considered more suitable for flexible pavement construction. Marshall Stability values (MSV) are higher and there is no stripping. This shows that the mix is much better for use in flexible pavement. The Marshall Stability values are fairly high and Marshall Quotient (MQ) is around 500.Flow value is in the expected range. Voids filled with bitumen (VFB) are expected to be around65 per cent.

13. "Waste Plastic for Road Construction" Narayan P. V., Bandopadhyay T. K., 2004

In this paper, crumb rubber cannot be considered a waste material. It is a valuable commodity with ongoing expansion and growth in diversified markets. Its use in asphalt is not making a highway into a linear landfill. Crumb rubber has proven to be one of the only additives to hot mix asphalt derived from a waste material that has a beneficial impact and actually improves performance. Some conclusions from studying this market may include:

1. Crumb rubber production is an environmentally economical sound method of waste tire reduction,

2. Asphalt Rubber has proven long term performance, cost effectiveness, and sustainable market growth, and

3. Asphalt Rubber paving programs are key components to acceptable and successful waste tire management programs.

All options must be considered to reduce the buildup of waste tires. It is far better to remove tires from the waste stream, regardless of disposal method than to allow the continuation of uncontrollable and disastrous waste tire stockpile fires throughout the world. Without question, the emissions from equipment and facilities that process waste tires will always be lower than the emissions from a waste tire fire burning out of control in the open demonstrated.

14. "Utilization of Waste Plastic Bags in Bituminous Mix for Improved Performance of Roads" ***C.E.G. Justo, Veeraragavan (2002)***

This paper represent processed plastic was used as an additive with heated bitumen in different proportions (ranging from zero to 12 % by weight of bitumen) and mixed well by hand, to obtain the modified bitumen. 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. The softening point of the modified bitumen increased with the addition of plastic additive, up to 8.0 % by weight.

Studies were carried out on Bituminous Concrete (BC) mixes using 80/100 grade bitumen having average Marshall stability value (MSV) of 1100 kg at optimum bitumen content of 5.0 % by weight of the mix. Further studies on BC mixes were carried out using the modified binder obtained by the addition of varying proportions of processed plastic bags (percentage by weight of bitumen) with the conventional 80 /100 grade bitumen. The optimum modified binder content fulfilling the Marshall Mix design criteria was found to be 5.0 % by weight of the mix, consisting of 8.0 % by weight of processed plastic added to the bitumen.

The average MSV of the BC mix using the modified binder was found to be as high as 3312 kg at this optimum binder content, resulting in about three-fold increase in stability of the BC mix, which contains 4.6 % bitumen plus 8 % processed plastic by weight of bitumen, i.e., 0.4 % processed plastic by weight of the mix.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this study Bituminous concrete mix has been design for 19 mm nominal size of aggregate. The Aggregate used in the study is crusher Aggregate from Quarry and VG30 60/70 grade of Bitumen used as binder.

First, Laboratory testing has been carried out to find the physical properties of Aggregate by conducting tests like Grain size analysis, Aggregate Impact value, Abrasion Test, Crushing value test, Flakiness and elongation Index (combined), Water absorption, Specific Gravity etc. Also, by sieve analysis the Gradation of Aggregate has been decided which satisfied the requirement of Gradation of 19 mm nominal size of aggregate for BC design as per MORTH section 509.

Similarly, The Bitumen test for 60/70 grade has been done including Penetration test at 25 °C, Softening Point test, Ductility test at 27 °C, Viscosity at 150 °C, Specific Gravity etc. which satisfied the requirement of IS:73-2006.

Secondly, sample will be prepared for Marshall Mix design and determine the Optimum bitumen content for 60/70 grade. After determining the OBC prepare sample at different % of waste plastic like 0.25%, 0.5%, 0.75%, and 1% and based on this the Optimum waste plastic content has been determined. The study Methodology shown in Figure3.1

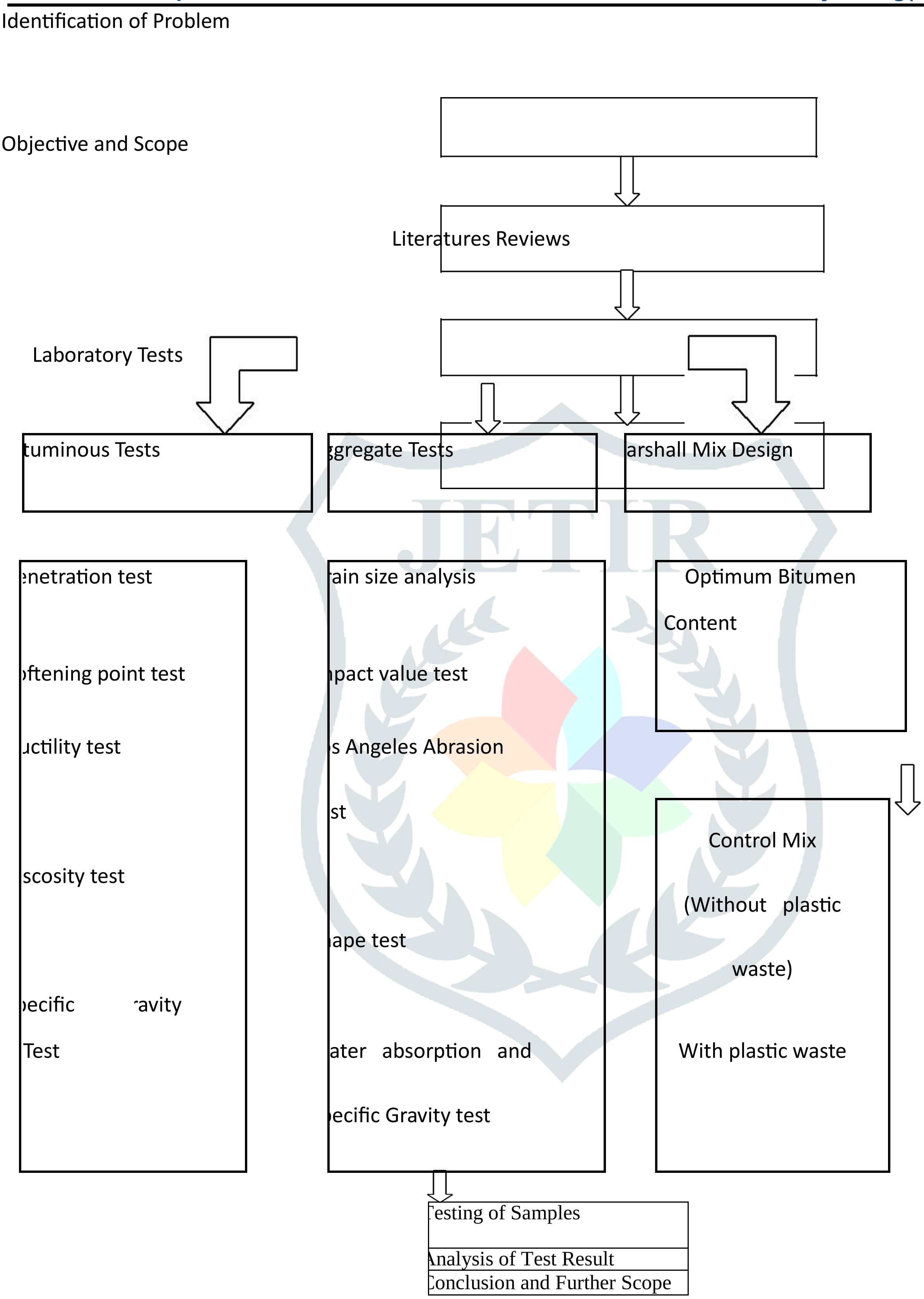


Figure 3.1 Flow chart of methodology

CHAPTER 4

LABORATORY INVESTIGATIONS: AGGREGATE TESTS

4.1. DESIGN OF EXPERIMENT

Design of Bituminous mixes start with Laboratory tests commence by finding Physical properties of Aggregate which must satisfied the requirement as per relevant IS codes. After that Marshall Stability test for Mix Design has been carried to determine the OBC as well as Optimum plastic waste contain design of BC. Finely, to check certain engineering properties of with and without plastic contain Aggregate used in the design of BC is crusher aggregate collected from quarry. Before use of aggregate in design mix it has been tested for their physical properties consist of Hardness, Toughness, Cleanliness, Particle shape, Water absorption, Stripping etc. All these tests should be performed as per procedure in relevant IS codes. The tests to be performed are enlisted as follows

1. Grain size analysis
2. Impact value test, IS:2386 (Part 4)-1963
3. Abrasion test, IS:2386 (Part 4)-1963
4. Shape test, IS:2386 (Part 1)-1963
5. Water absorption and Specific Gravity test, IS: 2386 (Part 3)-1963
6. Stripping value test, IS: (6421-1974)

4.2. GRAIN SIZE ANALYSIS

This test has been carried out to determine the particle shape distribution of fine and coarse aggregate by sieving or screening.

Apparatus

The following apparatus are used

1. Sieves- 26.5, 19, 13.2, 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.075 mm
2. Balance- accuracy of 0.1 percent of the weight of the test sample.

Procedure: -

The sample shall be brought to an air-dry condition before weighing and sieving. This may be achieved either by drying at room temperature or by heating at a temperature of 100 to 110°C. The air-dried sample shall be weighed and sieved successively on the appropriate sieves starting with the largest. Care shall be taken to that the sieves are clean before use.

1. Each sieve shall be shaken separately over a clean tray until not more than a trace passes, but in any case, for a period of not less than two minutes. The shaking shall be done with a varied motion, backwards and forwards, left to right, circular clockwise and anti-clockwise, and with frequent jarring, so that the material is kept moving over the sieve

surface in frequently changing directions. Material shall not be forced through the sieve by hand pressure, but on sieves coarser than 20 mm, placing of particles is permitted. Lumps of fine material, if present, may be broken by gentle pressure with fingers against the side of the sieve. Light brushing with a soft brush on the underside of the sieve may be used to clear the sieve openings.

2. Light brushing with a fine camel hair brush may be used on the 150-micron and 75-micron IS Sieves to prevent aggregation of powder and blinding of apertures. Stiff or worn-out brushes shall not be used for this purpose and pressure shall not be applied to the surface of the sieve to force particles through the mesh.

3. On completion of sieving, the material retained on each sieve, together with any material cleaned from the mesh, shall be weighed.

Reporting of Result

1. The cumulative percentage by weight of the total sample passing each of the sieves, to the nearest whole number, and

2. The percentages by weight of the total sample passing one sieve and retained on the next smaller sieve, to the nearest 0.1 percent.

4.3. IMPACT VALUE TEST, IS: 2386 (PART 4)-1963

Toughness is the property of a material to resist impact. Due to traffic loads the road stone are subjected to the pounding action of impact and there is possibility of breaking into smaller pieces. The road stone should therefore be tough enough to resists fracture under impact. A test designed to evaluate the toughness of stones i.e. the resistance of the stones to fracture under repeated impacts may be called an impact test for road stones.

The aggregate impact value indicates a relative measure of the resistance of an aggregate to a sudden shock or an impact, which differs from its resistance to a slow gradually increasing compressive load. The method of test covers the procedure for determining the aggregate impact value of course aggregate.

Image No. 4.1 Impact Value Test Apparatus

Apparatus

The following apparatus are used

1. Impact testing Machine (Image No. 4.1).

2. Cylindrical metal measure- internal diameter 7.5 cm and depth 5 cm.

3. Tamping rod- circular cross section 1 cm diameter and 25 cm long, rounded at one end.

4. IS a sieve- size 12.5 mm, 10 mm, and 2.36 mm for sieving the aggregate.

5. Oven- thermostatically controlled drying capable of maintaining constant temperature between 100° C and 110° C.

6. Balance- capacity not less than 500 gm to weight accurate to 0.1 gm.

Procedure

1. The test sample consists of aggregates passing 12.5 mm sieve and retained on 10 mm sieve and dried in an oven for four hours at a temperature 100° C to 110° C, and cooled.

2. Test aggregates are filled up to about one third full in the cylindrical measure and tamped 25 times with rounded end of the tamping rod. Further, quantity of aggregates then added up to about two third full m the cylinder and 25 stroked of the tamping rod are given. The measure is now filled with the aggregates to over flow, tamped 25 times.

3. The surplus aggregates are struck off using the tamping rod as straight edge. The net weight of the aggregates in the measure is determined to the nearest gram.

4. The Impact machine (Image No. 4.1) is placed with its bottom plate flat on the floor so that the hammer guides columns are vertical. The cup is fixed firmly in position of the base of the machine and the whole of the test sample from the cylindrical measure is transferred to the cup and compacted by tamping rod with 25 strokes.

5. The hammer is raised until its lower face is 38 cm above the upper surface of the aggregates in the cup, and allowed to fall freely on the aggregates. The test sample is subjected to a total of 15 such blows, each being delivered at an interval of not less than one second.

6. The crushed aggregates are than removed from the cup and the whole of its sieved on the 2.36 mm sieve until on further significant amount passes. The fraction passing the sieve is weighted accurate to 0.1 g. The fraction weight of the fractions passing and retained on the sieve is added is should not be less than the original weight of the specimen by more than one gram, if the total weight is less than original by over one gram the result should be discarded and a fresh test made.

Reporting of Result

Aggregate Impact value = W2 / W1%

Where,

W1= Original weight of the aggregate passing through 12.5 mm IS sieve and retained on 10 mm IS sieve

W2= Weight of the aggregate passing through 2.36 mm IS sieve

4.4. ABRASION TEST IS: 2386 (PART 4)-1963

Due to the movement of traffic, the road stones and used in the surfacing course are subjected to wearing action at the top Resistance to wear or hardness is hence an essential property of road aggregate, especially when used in wearing course. Thus, road stones should be hard enough to resist the abrasion due the traffic. When fast moving traffic fitted with pneumatic tyres move on the road, the sod particles present between the wheel and road surface causes abrasion on the road stone. Steel tyres of the animal drawn vehicles which rub against the stones can cause considerable abrasion of the stones on the road surface Hence in order to tests are carried out in the laboratory. Table 4.1 shows the specification of grading for different size of aggregate.

Table 4.1 - Grading Specification for LOS Angeles Test

Grading	Weight in grams of each least sample in the size range mm (passing and retained on square holes)										No. of sphere	Weight of charge (gm)
	80-63	63-50	50-40	40-25	25-20	20-12.5	12.5-10	10-6.3	6.3-4.75	4.75-2.36		
A	-	-	-	1250	1250	1250	1250	-	-	-	12	5000 ± 25
B	-	-	-	-	-	2500	2500	-	-	-	11	584 ± 25
C	-	-	-	-	-	-	-	2500	2500	-	8	330 ± 25
D	-	-	-	-	-	-	-	-	-	5000	6	500 ± 25
E	2500*	2500*	5000*	-	-	-	-	-	-	-	12	000 ± 25
F	-	-	5000*	5000*	-	-	-	-	-	-	12	000 ± 25
G	-	-	-	5000*	5000*	-	-	-	-	-	12	000 ± 25

Source: MORTH section 500 clause 509 *Tolerance of ± 2 percent permitted

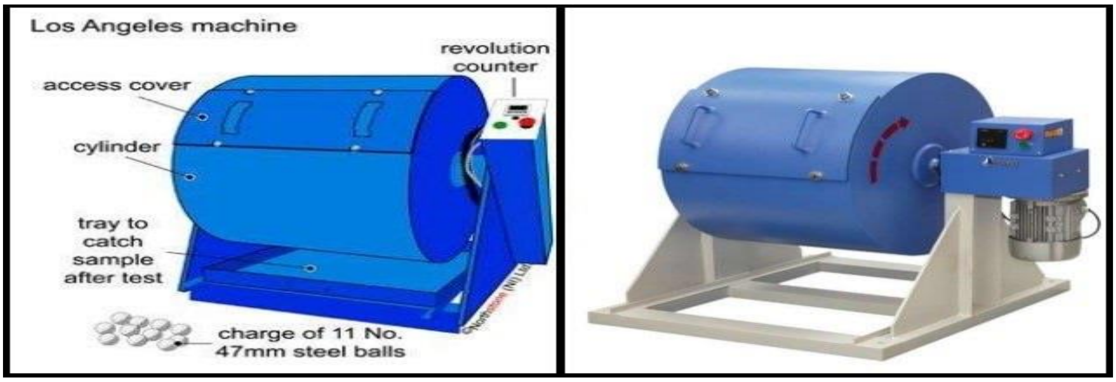


Image No. 4.2 Abrasion Test Apparatus

Apparatus

The following apparatus are used

1. Los Angeles Machine-(Image No. 4.2) the machine has hollow steel cylinder 700 mm in dia. and 500 mm in side length. A steel self-88 x 25 x 500 mm is projecting radically. It can be mounted on inside of the cover plate.

2. Sieve- 1.70 mm and as given in Table 4.1 for different grades of aggregates

3. Abrasive charge- consists of cast iron spheres or steel sphere app 48 mm in dia. and weighing 390 to 446 gm No of spheres are chosen from Table 4.1 as per the grade of aggregates.

4. Oven- thermostatically controlled drying capable of maintaining constant temperature between 100° C and 110° C.

5. Balance- capacity not less than 500 gm to weight accurate to 0.1 gm

Procedure

1. The test sample and the abrasive charge shall be placed in the Los Angeles abrasion testing machine and the machine rotated at a speed of 20 to 33 revolution /min.

2. For grading A, B, C and D, the machine shall be rotated for 500 revolutions for grading E, F and G; it shall be rotated for 1000 revolutions. The machine shall be so driven and so counter-balanced as to maintain a substantially uniform peripheral speed.

3. If an angle is used as the shelf, the machine shall be rotated in such a direction that the charge is caught on the outside surface of the angle.

4. At the completion of the test, the material shall be discharged from the machine and a preliminary separation of the sample made on a sieve coarser than the l-70-mm IS Sieve. The finer portion shall then be sieved on a 1.70 mm IS Sieve.

5. The material coarser than the 1.70 mm IS Sieve shall be washed dried in an oven

6. at 105 to 110°C to a substantially constant weight, and accurately weighed to the nearest gram.

Reporting of Result

Abrasion value = W2/W1 %

Where, W1= Total weight of aggregate as per grading

W2= Weight of the aggregate passing through 1.7 mm IS sieve

4.5. SHAPE TEST, IS: 2386 (PART 1)-1963

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 mixes, the presence of flaky and elongated particles are considered undesirable as they may cause inherent weakness with possibilities of breaking down under heavy loads. Angular shape of particles is desirable for granular base course due to increased stability derived from the better interlocking. Thus, evaluation of shape of the particles, particularly with reference to flakiness and elongation is necessary. Table 4.2 shows the dimension of thickness and length gauge.

Table 4.2 - Dimensions of Thickness and Length Gauge

Sr. No.	Size of Aggregate		Thickness Gauge* (mm)	Length Gauge+ (mm)
	Passing through IS sieve (mm)	Retained on IS sieve (mm)		
1	63.0	50.0	33.90	-
2	50.0	40.0	27.00	81.00
3	40.0	31.5	19.50	58.50
4	31.5	25.0	16.95	-
5	25.0	20.0	13.50	40.50
6	20.0	16.0	10.80	32.40
7	16.0	13.5	8.55	25.60
8	13.5	10.0	6.75	20.20
9	10.0	6.3	4.89	14.70

Source: MORTH section 500 clause 509

*This dimension is equal to 0.6 times mean sieve sizes

+ This dimension is equal to 1.8 times sieve sizes the mean the

Image No. 4.3 Thicknesses and Length Gauge Apparatus

Apparatus

The following apparatus are used

1. Thickness Gauge
2. Length Gauge
3. Balance- capacity not less than 500 gm to weight accurate to 0.1 gm

Procedure

A) Determine Flakiness Index

1. The sample shall be sieved in accordance with the method described in sieve analysis with the sieves specified in Table 4.2.

2. Each fraction shall be gauged in turn for thickness on a metal gauge of the pattern shown in Image No. 4.3 or in bulk on sieves having elongated slots. The width of the slot used in the gauge or sieve shall be of the dimensions specified in Table 4.2 for the appropriate size of material.

3. The total amount passing the gauge shall be weighed to an accuracy of at least 0.1 percent of the weight of the test sample.

B) Determine Elongation Index

1. The sample shall be sieved in accordance with the method described in sieve analysis with the sieves specified in Table 4.2.

2. Each fraction shall be gauged individually for length on a metal length gauge of the pattern shown in Image No. 4.3 the gauge length used shall be that specified in Table 4.2 for the appropriate size of material.

3. The total amount passing the gauge shall be weighed to an accuracy of at least 0.1 percent of the weight of the test sample.

Reporting of Result

1. The flakiness index is the total weight of the material passing the various thickness gauges or sieves, expressed as a percentage of the total weight of the sample gauged.

2. The elongation index is the total weight of the material retained on the various length gauges, expressed as a percentage of the total weight of the sample gauged.

4.6. SPECIFIC GRAVITY AND WATER ABSORPTION TEST

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregates may contain water permeable voids, so two measures of specific gravity of aggregates are used apparent specific gravity and bulk specific gravity.

Water absorption the difference between the apparent and bulk specific gravities is nothing but the water permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a saturated, surface dry condition, with all permeable voids filled with water.

Apparatus

The following apparatus are used

1. Balance - capacity not less than 3 kg, readable and accurate to 0.5 gm and of such a type and shape as to permit the basket containing the sample to be suspended from the beam and weighed in water.

2. Oven - thermostatically controlled, to maintain a temperature of 100 to 110ºC.

3. Wire basket of not more than 6-3 mm mesh or a perforated container of convenient size, preferably chromium plated and polished, with wire hangers not thicker than one millimeter for suspending it from the balance.

4. Stout watertight container in which the basket may be freely suspended.

5. Two dry soft absorbent cloths each not less than 75 x 45 cm.

6. Shallow tray of area not less than 650 elms.

7. Airtight container of capacity similar to that of the basket.

Procedure

1. A sample of not less than 2000 gm of the aggregate shall be tested. Aggregates which have been artificially heated shall not normally be used.

2. The sample shall be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22°C and 32°C with a cover of at least 5 cm of water above the top of the basket.

3. Immediately. after immersion the entrapped air shall be removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second. The basket and aggregate shall remain completely immersed during the operation and for a period of 24± l/2 hours afterwards.

4. The basket and the sample shall then be jolted and weighed in water at a temperature of 22 to 32% if it is necessary for them to be transferred to a different tank for weighing, they shall be jolted 25 times as described above in the new tank before weighing (weight A1).

5. The basket and the aggregate shall then be removed from the water and allowed to drain for a few minutes, after which the, aggregate shall be gently emptied from the basket on to one of the dry clothes, and the empty basket shall be returned to the water, jolted 25 times and weighed in titer (weight A2).

6. The aggregate placed on the dry cloth shall be gently surface dried with the cloth, transferring it to the second dry cloth when the first will remove no further moisture. It shall then be spread out not more than one stone deep on the second cloth, and lest exposed to the atmosphere away from direct sunlight or any other source of heat for not less than 10 minutes, or until it appears to be completely surface dry (which with some aggregates may take an hour or more). The aggregate shall be turned over at least once during this period and a gentle current of unheated air may be used after the first ten minutes to accelerate the drying of difficult aggregates. The aggregate shall then be weighed (weight B).

7. The aggregate shall then be placed in the oven in the shallow tray, at a temperature of 100 to 110°C and maintained at this temperature for 24± l/2 hours. It shall then be removed from the oven, cooled in the airtight container and weighed (weight C).

Reporting of Result

Specific gravity, apparent specific gravity and water absorption shall be calculated as follows:

1. Specific Gravity = C/(B-A)

2. Water Absorption =(B-C)/C× 100

Where,

A= Weight of saturated aggregate in water, (A1 – A2), in gm.

B= Weight of saturated surface-dry aggregate in air, in gm.

C= Weight of oven dried aggregate in air, in gm.

4.7. STRIPPING VALUE TEST

Bitumen adheres well to all normal types of road aggregates provided they are dry and free from dust. In the absence of water there is practically no adhesion problem of bituminous construction. Adhesion problem occurs when the aggregate is wet and cold. This problem can be dealt with by removing moisture from the aggregate by drying and increasing the mixing temperature. Further, the presence of water causes stripping of binder from the coated aggregates. This problem occurs when bitumen mixture is permeable to water. Several laboratory tests are conducted to arbitrarily determine the adhesion of bitumen binder to an aggregate in the presence of water.

Image No. 4.4 Stripping Value Test Apparatus

Apparatus

The following apparatus are used

1. Beaker- 500 ml capacity
2. Oven - thermostatically controlled, to maintain a temperature of 100 to 110ºC
3. Sieve- 20 and 12.5 mm
4. Water Bath

Procedure

1. Take 200 gm aggregate sample passing through 20 mm and retained on 12.5 mm IS sieve.
2. Oven dried and clean aggregate mixed with 5% bitumen at temperature of 160 ºC.
3. The aggregates are also to be heated prior to mixing to a temperature of 150 ºC.
4. After complete coating the mixture is transferred to a 500 ml beaker and allowed to cool at the room temperature for about two hours.
5. Distilled water is then added to immerse the coated aggregates. The beaker is covered and kept in a water bath maintained at 40ºC, taking care that the level of water in the water bath comes up to at least half the height of the beaker.
6. After the expire of 24 hours the beaker is taken out, cooled at room temperature and the extent of stripping is estimated visually while specimen is still under water.
7. The stripping value shall be the ratio of the uncovered area observed visually to the total area of the aggregates in each test expressed as a percentage.

Reporting of Result

The mean of the three results shall be reported as stripping value of the tested material and shall be expressed nearest to whole number.

The required physical properties of aggregate as per MORTH section 500 clauses 509 Table 500-17 shown in Table 4.3.

Table 4.3 - Required Physical Properties of Aggregate

Sr. No	Property	Test	Recommended Value as per MORTH section 500 clause 509
1	eanliness ust)	ain size analysis	ax 5% passing 0.75 mm eve
2	ughness	ggregate Impact value	% max
3	ardness	s Angeles Abrasion value	% max
4	rticle Shape	akiness and elongation Index (combined)	% max
5	ater Absorption	ater absorption	max
6	ecific Gravity	ecific Gravity	5- 3.0
7	ripping	ating and stripping of bitumen aggregate ixture	% min

Source: MORTH section 500 clause 509

CHAPTER 5

LABORATORY INVESTIGATION: BITUMEN TESTS

5.1. DESIGN OF EXPERIMENTS

Bitumen used in the design of BC is VG30 (60/70). Before use of bitumen in design mix it has been tested for their physical properties. All these tests should be performed as per procedure in relevant IS codes. The tests to be performed are enlisted as follows

1. Penetration test at 25 °C, IS:1203-1978
2. Softening test Point °C, IS:1205-1978
3. Ductility test at 27 °C, IS:1208-1978
4. Viscosity test at 150°C, IS:1206-1978
5. Specific Gravity test, IS:1202-1978

5.2. PENETRATION TEST

Bituminous materials are available in variety of types and grades. The penetration test determines the hardness of these materials by measuring the depth in tenth of a millimeter to which a standard needle will penetrate vertically under specified conditions of standard load, time and temperature the sample is maintained at the standard temperature of 25 °C. The total load on needle is l00 gm. The penetration test set-up is illustrated in fig. 5.1. The softer the bitumen, the greater will be its number of penetration unit. Penetration test is widely used world ever for classifying the bituminous materials into different grades.

Image No. 5.1 Penetration Test Apparatus

Apparatus

The following apparatus are used

1. Container- A flat bottomed cylindrical metallic container 55 mm in diameter and 35 mm or 57 mm in ht.

2. Needle- A straight, highly polished cylindrical hard steel needle with conical end. Needle is provided with a shank appropriately 3 mm in diameter into which it is immovably fixed.

3. Water Bath- A water bath is maintained at 25 + 1°C containing not less than 10 liters of water, the sample is immersed to depth not less than 100 mm from top and supported on a perforated shelf not less than 50 mm from the bottom of the bath.

4. Penetrometer- It is an apparatus which allows the needle to penetrate without appreciable friction. It is accurately calibrated to yield results in hundreds of centimeters "These days automatic penetrometers (eclectically operated) are also available.

5. Transfer Tray- A small tray which can keep the container fully immersed in water during the test.

Procedure

1. The bitumen is softened to a pouring consistency between 75°C and 100°C above the approximated temperature at which bitumen softens.

2. The sample material is thoroughly stirred to make it homogenous and free from air bubbles and water. The sample material is then poured into the container to a depth at least 15 mm more than the expected penetration.

3. The sample containers are cooled in atmosphere of temperature not lower than 18°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.

4. The sample container is placed in the transfer tray with water from the water bath and is placed under the needle of the penetrometer.

5. The weight of needle, shaft and additional weight are checked. The needle is now arranged to make contact with the sample surface.

6. Zero reading of the penetrometer dial is taken before releasing the needle. The needle is released for 5 seconds and the final reading is taken on the dial. At least three measurements are made on this sample by testing at distance not less than 10 mm apart.

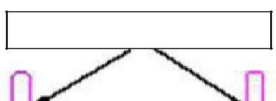
7. After each test, the needle is disengaged and wiped with benzene and carefully dried.

Reporting of Results

Based on penetration of needle in tenth of mm determine the penetration value of bitumen i.e., 60-70, 80-100 etc.

5.3. SOFTENING TEST POINT

Bitumen does not suddenly change from solid to liquid state, but as the temperature increases, it gradually becomes softer until it flows readily. All semi-solid state bitumen grades need sufficient fluidity before they are used for application with the aggregate mix. The common procedure however is to liquefy the bitumen by heating. 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. A brass ring containing the test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen and liquid medium is then heated at a specified rate. The temperature at which the soften bitumen touches the metal plate placed at a specified distance below the ring is recorded as the softening point of a particular bitumen. The apparatus and test procedure are standardized by BIS. It is obvious that harder grade bitumen possesses higher softening point than softer grade bitumen.



Thermometer

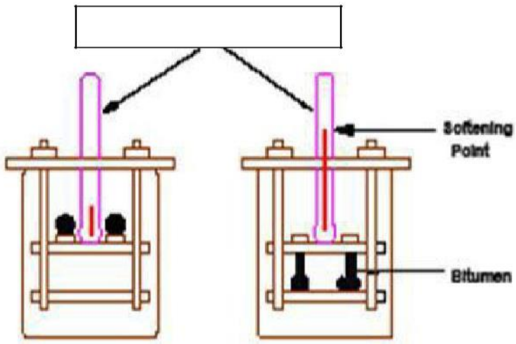


Image No. 5.2 Bitumen Softening Point Test Apparatus

Apparatus

The following apparatus are used

1. Steel Balls- They is two in number. Each has a diameter 9.5 mm and weighs 2.5+0.5 gm.
2. Brass Rings- There are two rings of the following dimension:

   Depth: 6.4 mm

   Inside diameter at bottom: 15.9mm

   Inside diameter at top: 17.5 mm

   Outside diameter: 20.6mm

3. Support- The metallic support is used for placing pair of ring. The upper surface of the rings is adjusted to be

50mm below the surface of water or liquid contained in the bath. A distance of 25 mm between the bottom of the rings and top surface of the bottom plate of support is provided. It has housing for suitable thermometer.

4. Bath and Stirrer- A heat resistant glass container of 85 mm diameter and 120 mm depth is used. Bath liquid is water for materials having softening point above 80°C, and glycerin for materials having softening point above 80°C. Mechanical stirrer is used for ensuring uniform heat distribution at all times throughout the bath.

Procedure

1. Sample material is heated to a temperature between 75°C to 100°C above the approximate softening point until it is completely fluid and is poured in heated rings placed on metal plate. As show in fig 5.2
2. To avoid sticking of the bitumen to metal plate, coating is done to this with a solution of glycerin and dextrin.
3. After cooling the rings in air for 30 minutes, the excess bitumen is trimmed and rings are placed in the support. 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.
4. The temperature of water is raised at a uniform rate of 5°C per minute with a controlled bottom plate by sinking of balls. At least two observations are made. For material whose softening point is above 80°C glycerin is used in heating medium and the starting temperature is 35°C instead of 5°C.

Reporting of Result

The mean values at which soften bitumen touches bottom plate is reported as softening point.

5.4. DUCTILITY TEST

The ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when a briquette specimen in fig 5.3.

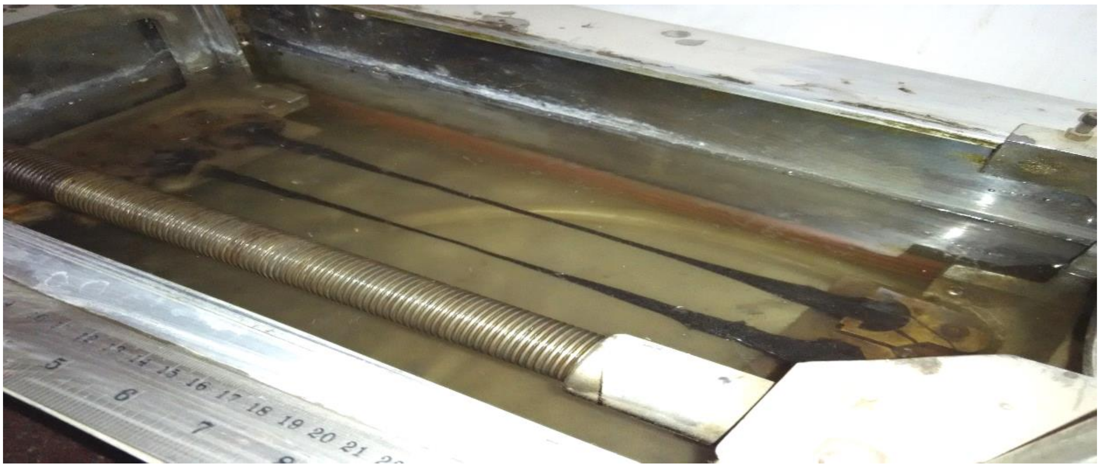


Image No. 5.3 Ductility Testing Mould Apparatus

Apparatus

The following apparatus are used

1. Ductility Machine and Moulds.
2. Thermometer- standard thermometer of equivalent range and accuracy shall be used.
3. Water Bath.
4. Scale- Any transparent scale of measuring up to 25 cm with ± 1mm accuracy.

Procedure:

The bitumen sample is melted and poured in the mould assembly and placed on a brass plate, (after a solution of glycerin and dextrin is applied at all surfaces of the mould exposed to bitumen).

After 30 to 40 minutes, the sample mould is placed in water bath maintained at 27^0C for 30 minutes. The excess bitumen is removed with hot knife.

1. The sample and mould assembly is placed in the water bath of the ductility machine maintained at 27^0 C for 85 to 95 minutes.
2. The sides of the mould are removed, the clips hooked on the machine and the pointer is adjusted to zero.
3. The machine is started and the two clips are thus pulled apart horizontally at the rate of 50 mm per minute.
4. The distance at which the bitumen thread of each specimen breaks, is recorded (in cm) to report as ductility value.

5.5. VISCOSITY TEST

The degree of fluidity at the application of temperature greatly influences the strength character of the resulting paving mixes. At high fluidity i.e. low viscosity the bituminous material lubricates the aggregate instead of providing binding action and at low i.e. high viscosity it results in high the compactive efforts for in heterogeneous mix.

One of the methods by which viscosity is measured is by determining the time taken by 50ml. of the material to flow from a cup though specified orifice at a given temperature. The standard orifice viscometer test results are useful to classify the grades of tars and cutbacks.

Image No. 5.4 Bitumen Viscosity Test Apparatus

Apparatus

The following apparatus are used

1. The viscometer: - It consists of a brass cup with circular hole of 10 mm diameter at its bottom. The cup is fixed in to the water bath of about 160 mm diameter and 105 mm depth. The water bath is mounted on a tripod stand and provided with a run off cock. A sleeve which is a brass tube of 42 mm, internal diameter and 105 mm height holds the cup in position with an easy sliding. A stirrer with vertical vanes slips on the sleeve. The curved shield fitted to the upper edge of the cylinder carries an insulated hand for rotating the stirrer, A support for a thermometer and a swelled support for the valve. The valve is a ball fitted at one end of a rod. A leveling peg is provided on the rod at a predetermined point.
2. Receiver: - It is a 100 ml measuring cylinder having an internal diameter of not more than 29 mm.
3. Thermometer: - Two standard thermometers, one for the bath and other for the cup.
4. Stop Watch.
5. Heating Stove.
6. A Stirring rod.

Procedure:

The tar sample is heated to a temperature 20^{0}C above the specified test temperature (i.e., 35^{0}C, 40^{0}C, 45^{0}C and 50^{0}C for RT-1, RT-2, RT-3 and RT-4 respectively), and is allowed to cool, while stirring is continued. When the temperature has fallen too slightly above the specified temperature, the material is poured in the tar cup until the leveling peg on the Valve is just immersed. In the graduated receiver, 20 ml of mineral oil or a one percent by weight solution of soft soap is poured and the receiver is placed under the orifice of the tar cup. Water in the bath is heated to the temperature specified for the test and is maintain throughout the test and stirring is continued. When the receiver records 25 ml, the stop watch is started and is stopped when tar flows up to 75 ml mark. Thus, the time of flow of 50 ml of the sample through a 10 mm orifice is determined. If the values of tests in the sample differ from the mean by more than 4%, the test is to be repeated.

Reporting of Result

1. Material :
2. Specified test temperature :
3. Size of orifice :
4. Actual test temperature :
a) Initial :
b) Final :
c) Average :

Test Property	Test run		
	1 (sec)	2 (sec)	3 (sec)
Viscosity			
Mean value of Viscosity: - Sec.			

Result: -

The time in seconds for 50ml of the test sample to flow through the orifice is defined as the viscosity at a given test temperature.

5.6. SPECIFIC GRAVITY TEST

The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known content to the mass of equal volume of water at 27ºC. The specific gravity can be measured using either pycnometer or preparing a cube specimen of bitumen in semi solid or solid state.

Image No. 5.5 Specific Gravity Test Apparatus

Apparatus

The following apparatus are used

1. Specific gravity bottle 50 ml capacity

2. Constant temperature bath- having depth greater than that of pycnometer capable of being maintained within 0.2ºC of desired temperature.

3. Bath thermometer- range 0-44ºC, graduation 0.2ºC, immersion 65 mm

Procedure

1. Clean, dry and weigh the specific gravity bottle together with the stopper (A). Fill it with freshly boiled and cooled distilled water and inert the stopper firmly. Keep the bottle up to its neck for not less than half an hour in a beaker of distilled water maintained at a temperature of 27± 0.1ºC or any other temperature at which specific gravity is to be determined, wipe all surplus moisture from the surface with a clean, dry cloth and weigh again (B). After weighing the bottle and water together the bottle shall be dried again.

2. In the case of solids and semisolids, bring a small amount of the material to a fluid condition by gentle application of heat, care being taken to prevent loss by evaporation. When the material is sufficiently fluid, pour a quantity into the clean, dry specific gravity bottle to fill at least half. Slightly warm the bottle before filling. Keep the material away from touching the sides above the final level of the bottle and avoid the inclusion of air bubbles. The use of a small funnel will prevent contamination of the neck of the bottle. To permit escape of entangled air bubbles, allow the partly filled bottle to stand for half an hour at a suitable temperature, then cool to the specified temperature and weigh with the stopper (C).

3. Fill the specific gravity bottle containing the asphalt with freshly boiled distilled water placing the stopper loosely in the specific gravity bottle. Do not allow any air bubble to remain in the specific gravity bottle. Place the specific gravity bottle in the water bath and press the stopper firmly in place. Allow the specific gravity bottle to remain in the water bath for a period of not less than 30 minutes. Remove the specific gravity bottle from the water bath, wipe all surplus moisture from the surface with a clean dry cloth and weigh it along with the stopper.

4. In the case of liquids such as creosote and anthracites oil, fill the bottle up to the brim and insert the stopper firmly. Keep the filled bottle for not less than half an hour in a beaker of distilled water maintained at a temperature of 27± 0.1ºC, remove the bottle from the beaker, wipe all surplus water from the surface with a clean, dry cloth and weigh again.

Reporting of Result

Specific gravity = (C-A) / (B-A) - (D-C)

Where,

A = mass of the specific gravity bottle

B = mass of the specific gravity bottle filled with distilled water

C = mass of the specific gravity bottle about half filled with the material

D = mass of the specific gravity bottle about half filled with the material and the rest with distilled water, and

Table 5.1 - Standard Test Result of 60-70(VG30) Grade of Bitumen

Sr. No	Tests	Recommendation as per Code 73- 2006
	ːnetration at 25 °C, 0.1 mm, 5 sec	) to 70
	›ftening Point, °C, min	in. 47
	›ecific Gravity	in. 0.99
	ıctility, 27 °C, cm	in. 75
	scosity Test, , 150 °C	in. 300

Source: IS Code 73 - 2006

CHAPTER 6

MARSHALL MIX DESIGN

6.1. INTRODUCTION

The mix design should aim at an economical blend, with proper gradation of aggregate and adequate proportion of bitumen so as to fulfill the desired properties of the mix bituminous concrete is the one of the highest and costliest types of flexible pavement layer used in surface course the desirable properties of a good bituminous mix are stability, flexibility, skid resistance, durability, workability.

Marshall Stability test Carrey out find the stability, flow value, air voids, voids fill with bitumen, density. Finally consist of an OBC& optimum plastic content.

6.2. GRADUATION REQUIREMENT OF AGGREGATE

Grading of aggregate has been carried out before mix design. For this purpose sieve analysis of aggregate has been done having size 20mm, 10mm, 6mm, and cement as filler. Grading requirement of BC for this study should satisfy the MORTH section 509 Table 500-18 for 19 mm nominal size of aggregate. The aggregate has been sieved and final blend of aggregate has to be obtained by Heat and Trial. Grading requirement of aggregate shown in Table 6.1

Table 6.1 - Grading Requirements of Aggregate

Grading	1	2
lominal Aggregate size	19mm	13mm
.ater Thickness	50-65mm	30-45mm
S Sieve (mm)	Cumulative % by weight of total aggregate passing	
5	---	---
7.5	---	---
6.5	100	---
.9	79-100	---
.3.2	59-79	100
).5	52-72	90-100
.75	35-55	35-51
.36	28-44	24-39
..18	20-34	15-30
).6	15-27	---
).3	10-20	9-19
)..15	5-13	---
).075	2-8	---
itumen content % by mass of total mix	5.0-6.0	5.0-7.0
itumen grade (pen)	65	65

Source: MORTH section 500 clause 509

Gradation requirement for Bituminous concrete (BC) as per MORTH specification which are given in Table 6.1This table also consist the gradation which is using in the mix. Here Mix design of bituminous concrete has done of 19 mm nominal aggregate size.

6.3. MARSHALL STABILITY TEST

This test has been carried out to determine the Optimum Binder content for BC mixes. The properties incorporate with the test are stability, flow value, Bulk specific gravity, Air voids, Voids filled with bitumen and Voids in mineral aggregate. Marshall Requirement of bituminous mixes shown in Table 6.2 the Voids in mineral aggregate must satisfied the requirement as shown in Table 6.3

Theoretical Specific Gravity

It is the ratio of total weight of sample and sum of volume of each fraction used in the mix.

: = W1+W2+W3+W4

1+w2+w3+w4

[redacted]

1 G2 3 G4

'here,

: = Theoretical specific gravity

1	Sp.gr. of course, aggregate	'1	Weight of coarse aggregate in total mix
2	Sp.gr. of fine aggregate	'2	Weight of fine aggregate in total mix
3	Sp.gr. of filler material	'3 =	Weight of filler material in total mix
4	Sp.gr. of bitumen	'4 =	Weight of bitumen in total mix

Bulk Density of mix

It is the ratio of weight in air of sample to difference in weight of sample in air and water and is denoted by Gm.

Air Voids

It is the total volume of the small pockets of air between coated aggregate particles throughout a compacted paving mixture, expressed as percentage of the total volume of the compacted paving mixture.

$$Vv = \frac{Gt - Gm}{Gt} \times 100$$

Where,

Vv = Air voids (%)

Gt = Theoretical specific gravity

Gm = Bulk density of mix (g/cc)

Voids in Mineral Aggregate

It is the volume of inter granular void space between the uncoated aggregate particles of a compacted paving mixture that includes the air voids and effective bitumen content. VMA is expressed as percentage of the total volume of the compacted paving mixture.

VMA = Vv + Vb

Where,

Vv= Air voids (%)

Vb= Volume of bitumen

Voids Filled with Bitumen

It is the percentage of VMA that is occupied by the effective bitumen.

VFB = Vb / VMA × 100

Where,

Vb = Volume of bitumen

VMA = Voids in mineral aggregate

Table 6.2 - Marshall Requirements of Bituminous concrete

Properties	Requirement
Minimum stability (KN at 60^0 C)	9.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Percent air voids	3-6
Percent voids filled with bitumen (VFB)	65-75
Loss of stability on immersion in water at 60^0 C (ASTM D 1075)	Min. 75 percent retained strength

Source: MORTH section 500 clauses 509, Table 500-19

Table 6.3 - Requirement of Voids in Mineral Aggregate

Nominal Maximum Particle size (mm)	Minimum VMA, Percent Related to Design Air Voids, (%)		
	3.0	4.0	5.0
9.50	14.0	15.0	16.0
12.5	13.0	14.0	15.0
19.0	12.0	13.0	14.0
25.0	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Source: MORTH section 500 clauses 509, Table 500-12

6.3.1. Determination of Optimum Binder Content

Apparatus

The following apparatus are used

1. Marshall Stability testing machine
2. Cylindrical mould – 10 cm. diameter and 7.5 cm. height
3. Rammer – 4.5 kg. weight with free fall of 45.7 cm
4. Compacting Machine
5. Oven
6. Thermometer
7. IS Sieves

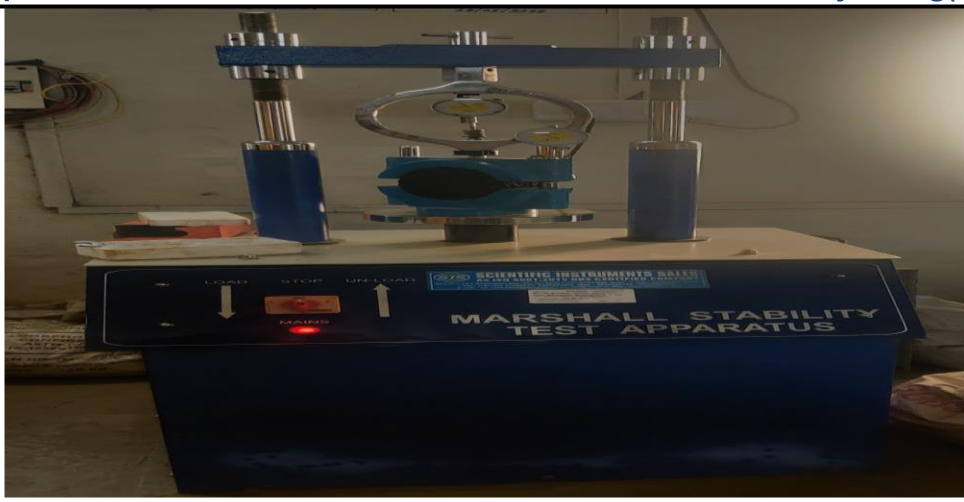


Image No. 6.1 Marshall and Compactor Apparatus

Procedure

1. Take about 1200 gm of aggregate sample from design Gradation and kept in oven until dried.

2. The aggregate should be heated to 135°C temperature before addition of bitumen.

3. For BC mix bitumen should be added in the aggregate varying from 5-6% at an increment of 0.5% by weight of total mix.

4. Three samples should be prepared for each binder content by compacting 75 blows on both side of sample in Marshall Compactor (fig 6.1).

5. After 24 hrs. Sample should be de-molded and noted down the weight of sample in Air and in water to determine the bulk density of mix.

6. The sample should be immersed in water bath at 60°C for 40 minutes prior of testing and tested on Marshall Apparatus (fig 6.1) which gives the Stability and Flow value for each sample.

At each bitumen content and from the volumetric properties of the mix plot the Graph of followings:

1. Binder content versus corrected Marshall stability

2. Binder content versus Flow Value

3. Binder content versus Air void (Vv) in the total mix

4. Binder content versus voids filled with Bitumen (VFB)

5. Binder content versus Unit weight or Bulk Density (Gm)

Optimum Binder Content for mix should be determining by average of this three:

1. Binder content corresponding to maximum stability
2. Binder content corresponding to maximum Unit weight or Bulk Density (Gm)
3. Binder content corresponding to 4.5% Air voids (Vv) in the total m

6.3.2. Optimum Waste Plastic Content

Plastic contains added to 0% to 1% by increment of 0.25%. Varying percentages of waste plastic by weight of total mix was added into the heated aggregates.

1. Marshall specimen with varying waste plastic content was tested for bulk density and stability.
2. Finally, Avg. of max Maximum value of stability and 4% of air voids was considered as criteria for optimum waste plastic Content.
3. Avg. Optimum Waste Plastic Content value.

CHAPTER 7

ANALYSIS OF TEST RESULTS AND DISCUSSION

7.1. INTRODUCTION

Laboratory test results has been evaluated to predict the behavior of with plastic waste as well as Control mix (without plastic waste) and to determine the use of Waste plastic in bituminous mixes has superior over control mix (without plastic waste). Analysis of test results start from the analysis of aggregate and bitumen test results, which satisfied all the recommendation of MORTH section 500 clause 509 and IS:15462-2004 respectively. Analysis

Secondly, volumetric properties of Marshall mix design has been analyzed Also, results of a Optimum waste plastic content has been analyzed while comparing with stability, bulk density and Air voids, flow value, voids fill with bitumen Finally, analyzed the results of all performance evaluation tests in terms of their mechanical properties.

7.2. AGGREGATE TESTS

Aggregate used in this study was crusher aggregate from Quarry. The sizes of aggregate used are 20 mm, 10mm, 6mm as per recommendation of MORTH Section 509 for nominal size of aggregate 19 mm. The physical properties of aggregate are shown in Table7.8

1. Grain size analysis
2. Impact value test, IS:2386 (Part 4)-1963
3. Los Angeles Abrasion Test, IS:2386 (Part 5)-1963
4. Shape test, IS:2386 (Part 1)-1963
5. Water absorption and Specific Gravity test, IS:2386 (Part 3)-1963

AGGREGATE TEST (WITH AND WITHOUT PLASTIC)

Table 7.1 - Impact Value Test Result, IS: 2386 (Part 4)-1963

IMPACT VALUE TEST						
Sr. No	Description	Impact Value Test for without Plastic Sample	Impact Value Test for With Plastic Sample			
			0.25%	0.50%	0.75%	1.0%
1	otal wt. of surface dry sample assing through 12.5 mm sieve & etained on 10 mm in gms….A	584	609	597	575	604
2	Vt. of fraction passing 2.36 mm sieve fter 15 blows in gms….B	52	55	53	48	55
3	mpact Value = (B/A)X100	8.90	9.03	8.88	8.34	9.10

Table 7.2 - Shape Test, IS: 2386 (Part 1)-1963

FLAKINESS INDEX				**ELONGATION INDEX**			
Sr. No	**Sieve Set**	**Material Retained on Sieve, (gm), X**	**Weight of particle retain of sieve, (gm), Y**	**Sr. No**	**Sieve Set**	**Material passing Through Thickness Gauge, (gm), W = Xn-Yn**	**Material Retained on Length Gauge, (gm), Z**
1	20-16	109.3	22.7	1	20-16	90.8	3.6
2	16-12.5	511.2	51.6	2	16-12.5	603.8	81.1
3	12.5-10	193.1	21.4	3	12.5-10	179.9	29.1
4	10-6.3	9.2	0	4	10-6.3	9.2	3.3
Total		822.8	95.7	Total		883.7	117.1
ALCULATION akiness Index = 100*Y/X, (%) = 11.63				ALCULATION Elongation Index = 100*Z/W, (%) = 13.25			
Combined Index = F.I + F.I = 11.63 +13.25 = 24.88							

Table 7.3 - Water Absorption and Specific Gravity Test, IS: 2386 (Part 3)-1963 (Without Plastic)

;r. No	Description	20mm aggregate	10m aggregate	6mm aggregate
1	/t. of saturated aggregate suspended in water with asket in gms - A1	2920	2910	2900
2	/t. of Basket in water in gms - A2	1575	1575	1575
3	/t. of saturated aggregate in water in gms A = \1-A2)	1345	1335	1325
4	/t. of saturated surface dry aggregate in gm - B	2060	2045	2030
5	/t. of oven dried aggregate - C	2035	2020	2010
	PECIFIC GRAVITY = C/ (B-A)	2.84	2.84	2.85
	/ATER ABSORPTION = (B-C) X 100/C	1.22	1.23	0.99

Table 7.4 - Water Absorption and Specific Gravity Test Result, IS: 2386 (Part 3) -1963 (With Plastic)

Sr. No	Description	20mm aggregate	10mm aggregate
1	Nt. of saturated aggregate suspended in water with Basket in gms … \1	2942	2930
2	Nt. of Basket in water in gms - A2	1575	1575
3	Nt. of saturated aggregate in water in gms - A = (A1-A2)	1367	1355
4	Nt. of saturated surface dry aggregate in gms - B	2060	2044
5	Nt. of oven dried aggregate - C	2059	2042
	;PECIFIC GRAVITY = C/ (B-A)	2.96	2.96
	NATER ABSORPTION = (B-C) X 100/C	0.14	0.09

Table 7.5 - Specific Gravity Test Result IS: 2386 (Part 3)-1963 (DUST)

Sr. No	Description	Dust
1	Vt. of empty pycnometer (gms) - A	440
2	Wt. of pycnometer + Water) (gms) - B	1430
3	Wt. of pycnometer + Dust) (gms) - C	965
4	Wt. of pycnometer + Dust + Water) gms - D	1772
5	Vt. of Dust (gms) - E	527
;PECIFIC GRAVITY = E / (E-(D-B))		2.85 ·

Table 7.6 - Abrasion test Result, IS:2386 (Part 4)-1963

Sr. No	Description	Without Plastic	With Plastic
1	nitail Weight, W_1 (gm)	5000	5000
2	Veight retained after test on 1.70 mm Sieve, W_2 gm)	4210	4270
3	.os Angles Abrasion Value = $\{(W_1-W_2)/W_1\}$x 100	15.80	14.60

Table 7.7 - Stripping Value Test Result (IS 6421-1974)

Sr. No	Description	1	2
1	Veight of Aggregate Passing IS Sieve 20mm but etained on IS Sieve 12.5mm (gm)	200	200
2	Veight of Bitumen added (gm)	10	10
3	'ercentage of retained coating on aggregate bserved after 24 hours immersion in distilled vater at 40^0C	99	99
\verage percentage of stripping		99%	

Table 7.8 - Physical Properties of Aggregate (with and without Plastic)

Sr. No	Property	Test	Result		Recommended Value
			Without Plastic	With Plastic	
1	oughness	ggregate Impact value	14%	13.82 %	24% Max
2	article shape	akiness and elongation Index ombined)	24.88%	-	30% Max
3	Vater absorption	Vater absorption	1.23% 1.22% 0.99%	0.14% 0.09%	2% Max
4	pecific ravity	pecific ravity	2.84% 2.84% 2.85%	2.96% 2.96%	2.4-3.0
5	ardness	os Angles Abrasion Test	15.90%	14.40%	30%
6	tripping	oating and Stripping of bitumen ggregate mixture	99%	99%	Min 95%

7.3. BITUMEN TESTS

Bitumen used in the study are VG30 (60/70) which has been tested as per procedure given in relevant IS codes. All the tests must satisfy the requirement of physical properties of Binders as per IS: 73-2006. The test results of binder used in the study shown in Table7.13

1. Penetration test at 25 °C, IS:1203-1978
2. Softening test Point °C, IS:1205-1978
3. Ductility test at 27 °C, IS:1208-1978
4. Viscosity test at 150°C, IS:1206-1978
5. Specific Gravity test, IS:1202-1978

Table 7.9 - Penetration Test at 25 °C, Is: 1203-1978 (with and without Plastic)

PENETRATION TEST (mm)					
Sr. No	Penetration Value for without Plastic Sample	Penetration Value for With Plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	65	63	64	66	67
2	70	61	65	65	62
3	66	62	63	61	60
Avg.	67	62	64	64	63

Table 7.10 - Softening Test Point °C, IS: 1205-1978 (with and without Plastic)

SOFTENING POINT TEST (Sec Tem.^{0}C)					
Sr. No	Softening Point Test for without Plastic Sample	Softening Point Test for With Plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	46	45	47	48	45
2	48	41	43	46	47
Avg.	47	43	45	47	46

Table 7.11 - Ductility Test at 27 °C, IS: 1208-1978 (with and without Plastic)

DUCTILITY TEST (27^{0}C) Cm					
Sr. No.	Ductility test value for without plastic	Ductility test value for with plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	78	72	76	74	78
2	80	74	78	72	79
Avg.	79	73	77	73	78.5

Table 7.12 - Viscosity test at 150°C, IS: 1206-1978 (with and without Plastic)

VISCOSITY TEST Sec					
Sr. No.	Viscosity test value for without plastic	Viscosity test value for with plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	210	167	178	211	186
2	385	365	376	369	378
3	296	285	296	290	288
Avg.	297	272.4	283.4	290	284

Table 7.13 - Specific Gravity Test, IS: 1202-1978

Specific Gravity of Bitumen

Observations		
1	mpty Weight of Beaker, A (gm)	46.6
2	Veight of Water + Beaker, B (gm)	101.9
3	Veight of Beaker + Half-filled Bitumen, C (gm)	78.5
4	Veight of Beaker + Half-filled Bitumen, + water D (gm)	104.5
5	ottle completely filled with Bitumen, E (gm)	98.4
Calculations	Specific gravity, (C-A)/(B-A) - (D-C) =1.089	

Table 7.14 - Standard Test Result of 60-70 (VG30) Grade of Bitumen

Sr. No	**Tests**	**Recommendation as per Code 73- 2006**
	enetration at 25 °C, 0.1 mm, 5 sec	to 70
	ftening Point, °C, min	in 47
	ecific Gravity	in0.99
	uctility, 27 °C, cm	in75
	scosity Test, , 150 °C	in 300

Source: IS Code 73 - 2006

7.4. GRADATION OF AGGREGATE

Sieve analysis has been carried out for the aggregate to be tested for their physical properties and Grading of aggregate is to be determining for Mix design which must satisfied the MORTH requirement for 19 mm nominal size of aggregate. The final obtained Gradation for aggregate used in the study shown in Table 7.15

Table 7.15 - Typical Gradation of aggregate

Sr. No	Size of sieve in mm	20mm	10mm	6mm	Dust	Filter	Combined gradation	Norms
		15%	45%	25%	12%	3%		
1	19	15	45	25	12	3	100	100%
2	13.2	13.05	45	25	12	3	98.05	79-100%
3	9.5	3.60	40.50	25	12	3	84.10	70-88%
4	4.75	1.65	31.95	21.75	12	3	70.35	53-71%
5	2.36	1.20	20.25	19.50	11.88	3	55.83	42-58%
6	1.18	-	12.60	12.25	8.76	3	36.61	34-48%
7	0.6	-	9.0	9.0	7.68	3	28.68	26-38%
8	0.3	-	5.40	7.0	6.36	2.88	21.64	18-28%
9	0.15	-	2.70	4.75	4.44	2.73	14.62	12-20%
10	0.075	-	-	1.25	2.88	2.61	6.74	4-10%

From Table 7.15 it has been clearly seen that Final Gradation of aggregate is within limit of 19 mm nominal size of aggregate. Now, the entire sample should be prepared by adopting this Gradation of aggregate.

7.5. MARSHALL MIX DESIGN

7.5.1. Optimum Bitumen content

Then after will perform Marshall Test include Preparation of sample at bitumen (60/70 VG30 Grade) content ranges from 5 - 6.0% at 0.5% increment, three samples will prepare at each bitumen content and find out OBC. As shown in Table 7.17

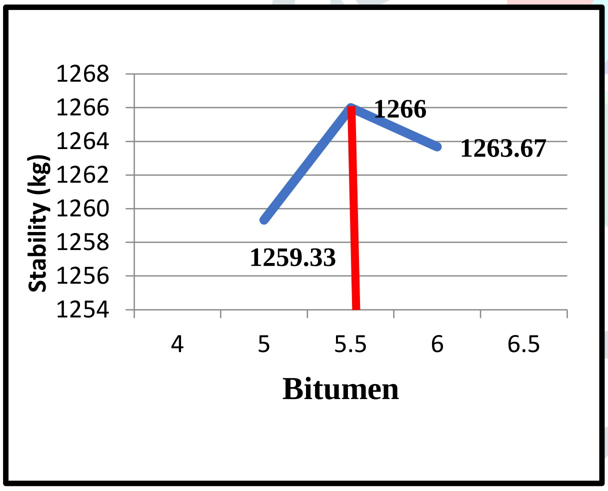
Table 7.16 - Bitumen Content

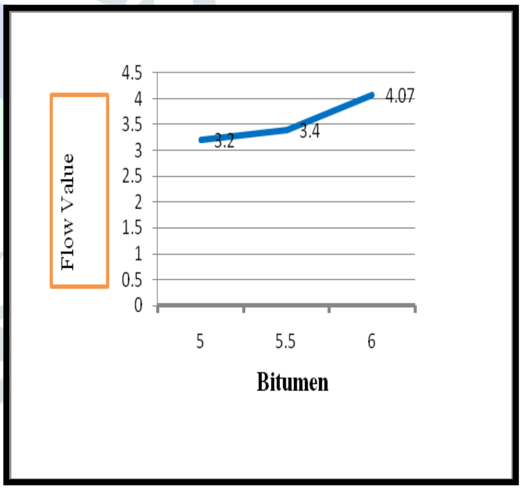
Sr. No	Sample %	Wt. in Air	Wt. in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)	Flow Value (mm)
1	5.00	1260	724.5	535.5	2.35	2.45	4.0	11.099	15.08	73.57	998	3.1
2	5.00	1259	722	537	2.34	2.45	4.3	11.06	15.32	72.23	991	3.3
3	5.00	1259	725.2	533.8	2.36	2.45	3.7	11.13	14.81	75.15	995	3.2
4	5.5	1266	735	531	2.38	2.43	2.1	12.31	14.36	85.70	1175	3.4
5	5.5	1266	733	533	2.38	2.43	2.4	12.26	14.68	83.51	1178	3.5
6	5.5	1266	732	534	2.37	2.43	2.6	12.24	14.84	82.46	1176	3.3

7	6.00	1264	733	538	2.36	2.42	2.2	13.25	15.47	85.63	933	4.1
8	6.00	1264	734	538	2.36	2.42	2.2	13.25	15.47	85.63	931	3.9
9	6.00	1263	732	540	2.36	2.42	2.6	13.20	15.79	83.62	935	4.2

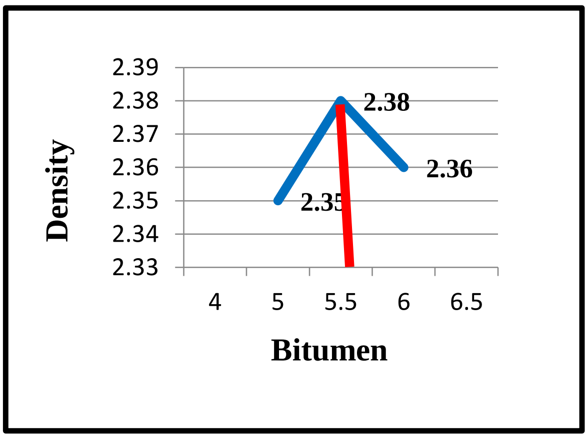
Table 7.17 - Optimum Bitumen Content

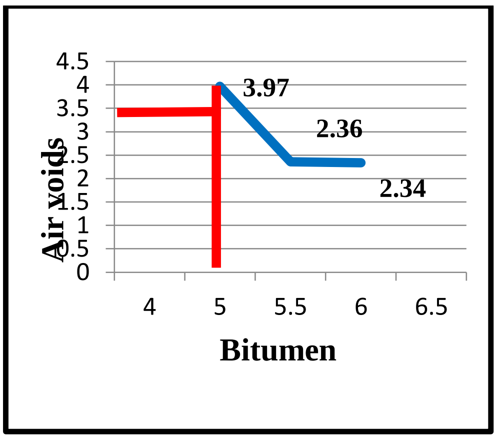
Sr. No	ample in %	Wt. in Air	Wt. in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)	Flow Value (mm)
1	5.00	259.33	723.90	535.43	2.35	2.45	.97	11.09	15.07	73.65	994.67	3.20
2	5.50	266.00	733.33	533.93	2.38	2.43	.36	12.27	14.63	83.89	1176.33	3.40
3	6.00	263.67	733.00	532.60	2.36	2.42	.34	13.23	15.58	84.96	933.00	4.07



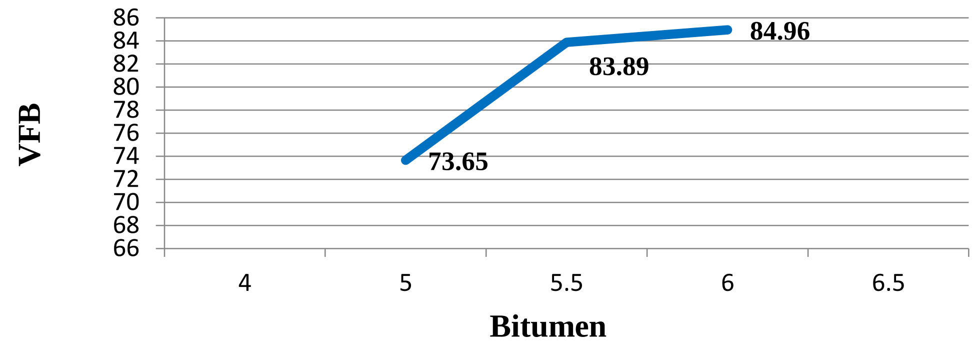


Graph 7.1 Bitumen Vs StabilityGraph7.2Bitumen Vs Flow value





Graph 7.3 Bitumen vs Density **Graph 7.4 Bitumen vs Air Voids**



Graph 7.5 Bitumen vs Voids filling Bitumen

Studies were carried out on Bituminous mixes using 60/70(VG30) grade bitumen having max value of Marshall Stability, density and 4% air voids average at optimum bitumen content of (Table 7.18) 5.33 % by weight of the mix. Fig 7.1, 7.2, 7.3, 7.4,7.5.

Table 7.18 - Optimum Bitumen Content of Bitumen Concrete mix-

Sr. No.	Description	Bitumen (%)
1	Binder content corresponding to maximum Stability	5.5
2	Binder content corresponding to maximum Bulk Density of mix (Gm)	5.5
3	Binder content corresponding to 4.0% Air Voids (Vv) in the total mix	5.0
Average		5.33 ≈ **5.5**

7.5.2. Optimum Waste Plastic Content

Plastic contains added to 0% to 1% by increment of 0.25%. Varying percentages of waste plastic by weight of total mix was added into the heated aggregates.

1. Marshall specimen with varying waste plastic content was tested for bulk density and stability

2. Finally, Avg. of maximum value of stability and 4% of air voids was considered as criteria for optimum waste plastic Content.

3. Avg. Optimum Waste Plastic Content value 0.76% refer fig 7.6,7.7 and Table 7.21

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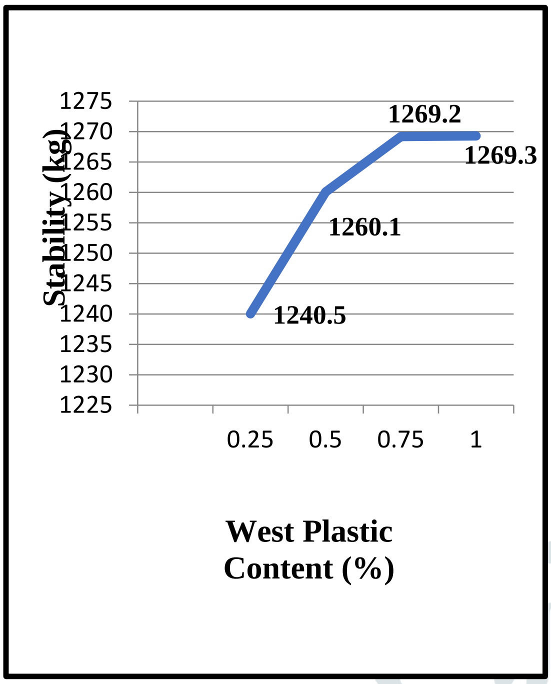
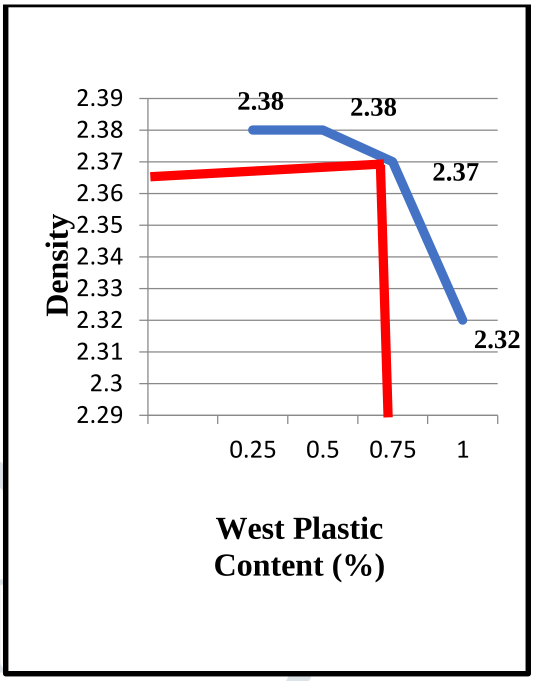
Table 7.19 - PLASTIC CONTENT

Sr. No	Sample	Wt in Air	Wt in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)
1	0.25%	1221.6	703.6	518	2.36	2.36	0.2	11.85	12.01	98.60	1146
2	0.25%	1259.4	734.4	525	2.40	2.44	1.5	11.49	12.99	88.46	927
Avg.	0.25	1240.5	719	521.5	2.38	2.4	0.85	11.67	12.5	93.53	1036.5
3	0.50%	1265.8	733.2	532.6	2.38	2.45	2.9	11.43	14.38	79.49	1313
4	0.50%	1254.4	728.2	526.2	2.38	2.43	1.8	11.54	13.31	86.70	1248
Avg.	0.50%	1260.1	730.7	729.4	2.38	2.44	2.4	11.48	13.84	83.09	1280.5
5	0.75%	1265	731.5	533.5	2.37	2.45	3.1	11.44	14.55	78.61	1334
6	0.75%	1273.5	731.5	538	2.37	2.46	3.9	11.36	15.29	74.33	1330
Avg.	0.75%	1269.2	733.5	535.75	2.37	2.45	3.5	11.4	14.92	76.47	1332
7	1%	1272.2	723.4	548.8	2.32	2.46	5.8	11.38	17.19	66.17	1608
8	1%	1266.4	721.4	545	2.32	2.45	5.2	11.43	16.38	68.90	1352
Avg.	1%	1269.3	722.4	546.9	2.32	2.45	5.5	11.6	16.88	67.53	1480

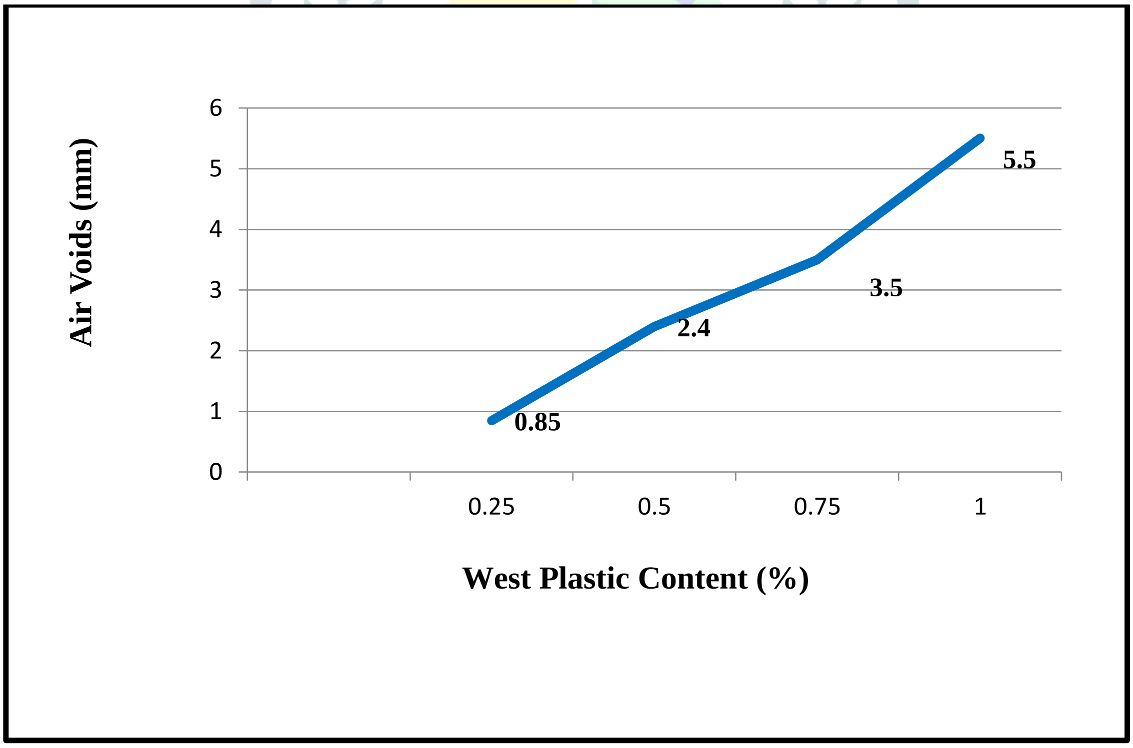
Table 7.20 - % IN PLASTIC CONTENT

Sr. No	% in plastic	Wt in Air	Wt in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)
1	0.25	1240.5	719.0	521.5	2.38	2.4	0.85	11.67	12.50	93.53	1036.5
2	0.50	1260.1	730.7	729.4	2.38	2.44	2.4	11.48	13.84	83.09	1280.5
3	0.75	1269.2	733.5	535.75	2.37	2.45	3.5	11.4	14.92	76.47	1332.0
4	1.0	1269.3	722.4	546.9	2.32	2.45	5.5	11.6	16.88	67.53	1480.0





Graph 7.6 Waste plastic content Vs Stability and Density



Graph 7.7 Waste plastic content Vs Volume of voids

Table 7.21 - Optimum Waste Plastic content

Sr. No	escription	. Contain (%)
1	aste pl content corresponding to maximum Stability	0.75
2	aste pl content corresponding to maximum ılk Density of mix (Gm)	0.75
3	aste pl content corresponding to 4.0 % Air ɔids (Vv) in the total mix	0.8
	Average	0.76 ≈ **0.75**

CHAPTER 8

CONCLUSION

8.1. CONCLUSIONS :

In this work, laboratory test results were assessed to anticipate the behaviors of bituminous pavements with and without plastic waste, and to determine if the use of waste plastic in bituminous mixes is superior than that without plastic waste. The examination of test findings begins with the evaluation of aggregate and bitumen test results.

Secondly, the volumetric properties of Marshall mix design have been investigated. Furthermore, the results of an optimal waste plastic content were analyzed in comparison to stability, bulk density, air voids, flow value, and void fill with bitumen.

Based on these findings, it may be possible to conclude that -

1.) Incorporating waste plastic in bitumen pavements improves the properties of aggregate and bitumen when compared to normal mixes.

2.) The binder content corresponding to optimal stability, the average optimum bitumen content of bitumen concrete mix is 5.33 ≈ **5.5**.

3.) The optimum Waste Plastic Content to added plastic, the waste plastic content that corresponds to maximum stability is 0.75, with an average of 0.76 ≈ **0.75**.

It has been noticed that adding plastic to a mixture boosts its resistance to moisture susceptibility. BC with plastic yields the maximum tensile strength ratio. In comparison to other materials, BC mixes with plastic cause the least amount of deformation. Based on the results presented above, it can be concluded that the use of waste plastic improved the engineering properties of bituminous mixes. As a result, this study investigates a potential chance to improve pavement material in wearing courses, hence increasing durability.

8.2. FUTURE SCOPE :

1. The study can be conducted with varying percentage of plastics in aggregate, percentage of bitumen, grade of bitumen.

2. The study can be conducted by substituting the binder (i.e. Plastic) used in this project by any other material such as rubber, fly-ash, slag furnace.

3. The study can be conducted with varying traffic, environmental and topographical conditions. Cost parameters can also be estimated.

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APPENDIX – 1 Laboratory testing reports

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CERTIFICATE

This is to certify that **Mr. Sandip Vinod Hotey** was performing all Aggregate, Bituminous and Marshall Stability test related to thesis in our organization. He is very sincere to his work.

Best Wishes for your future.

Authourized Signatory

Shree Testing Laboratory And Consultant

Mr. Krushna Jadubanshi
(Technical Manager)

Place:- Nagpur

Date:- 15/04/2023

Format No. STL/LAB/F231

CONDITION :
1) The result relate only to be item tested. the item tested are provided by customer.
2) This report in full or part shall not publish without written permission of laboratory.
3) Samples will be retained by us for specific period unless specified instructions to the contrary received.
4) All disputes are subject to Nagpur jurisdiction and and any correction to this report invalidates this report.

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1. Impact Value Test

IMPACT VALUE TEST						
Sr. No	Description	Impact Value Test for without Plastic Sample	Impact Value Test for With Plastic Sample			
			0.25 %	0.50 %	0.75 %	1.0 %
1	Total wt. of surface dry sample passing through 12.5 mm sieve & retained on 10 mm in gm - A	584	609	597	575	604
2	Wt. of fraction passing 2.36 mm sieve after 15 blows in gm - B	52	55	53	48	55
3	Impact Value = (B/A)X100	8.90	9.03	8.88	8.34	9.10

2. Shape Test

FLAKINESS INDEX				ELONGATION INDEX			
Sr. No	Sieve Set	Material Retained on Sieve, (gm), X	Material Retained on Thickness Gauge, (gm),, Y	Sr. No	Sieve Set	Material Retained on Sieve, (gm), W = Xn-Yn	Material Retained on Length Gauge, (gm), Z
1	20-16	109.3	22.7	1	20-16	90.8	3.6
2	16-12.5	511.2	51.6	2	16-12.5	603.8	81.1
3	12.5-10	193.1	21.4	3	12.5-10	179.9	29.1
4	10-6.3	9.2	0	4	10-6.3	9.2	3.3
Total		822.8	95.7	Total		883.7	117.1
CALCULATION Flakiness Index = 100*Y/X, (%) = 11.63				CALCULATION Elongation Index = 100*Z/W, (%) = 13.25			
Combined Index = F.I + F.I = 11.63 +13.25=24.88							

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Format No. STL/LAB/F231

CONDITION :
1) The result relate only to be item tested. the item tested are provided by customer.
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3. Water Absorption and Specific Gravity Test(Without Plastic)

Sr. No	Description	20mm aggregate	10mm aggregate	6mmaggregate
1	Wt. of saturated aggregate suspended in water with Basket in gms - A1	2920	2910	2900
2	Wt. of Basket in water in gms - A2	1575	1575	1575
3	Wt. of saturated aggregate in water in gms A = (A1-A2)	1345	1335	1325
4	Wt. of saturated surface dry aggregate in gm - B	2060	2045	2030
5	Wt. of oven dried aggregate - C	2035	2020	2010
	SPECIFIC GRAVITY = C/ (B-A)	2.84	2.84	2.85
	WATER ABSORPTION = (B-C)X 100/C	1.22	1.23	0.99

4. Water Absorption and Specific Gravity Test(With Plastic)

Sr. No	Description	20mm aggregate	10mmaggregate
1	Wt. of saturated aggregate suspended in water with Basket in gms … A1	2942	2930
2	Wt. of Basket in water in gms - A2	1575	1575
3	Wt. of saturated aggregate in water in gms - A = (A1-A2)	1367	1355
4	Wt. of saturated surface dry aggregate in gms - B	2060	2044
5	Wt. of oven dried aggregate - C	2059	2042
	SPECIFIC GRAVITY = C/ (B-A)	2.96	2.96

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5. Specific Gravity Test(DUST)

Sr. No	Description	Dust
1	Wt. of empty pycnometer(gms) - A	440
2	(Wt. of pycnometer + Water) (gms) - B	1430
3	(Wt. of pycnometer + Dust) (gms) - C	965
4	(Wt. of pycnometer + Dust + Water) gms - D	1772
5	Wt. of Dust (gms) - E	527
SPECIFIC GRAVITY = E / (E-(D-B))		2.85

6. Abrasion Test

Sr. No	Description	Without Plastic	With Plastic
1	Initial Weight, W_1 (gms)	5000	5000
2	Weight retained after test on 1.70 mm Sieve, W_2 (gms)	4210	4270
3	Los Angles Abrasion Value = $\{(W_1-W_2)/W_1\}$x 100	15.80	14.60

7. Stripping Value Test

Sr. No	Description	1	2
1	Weight of Aggregate Passing IS Sieve 20mm but retained on IS Sieve 12.5mm (gms)	200	200
2	Weight of Bitumen added (gms)	10	10
3	Percentage of retained coating on aggregate observed after 24 hours immersion in distilled water at 40^0C	99	99
Average percentage of stripping		99%	

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1. **Penetration Test**

PENETRATION TEST mm					
Sr. No	Penetration Value for without Plastic Sample	Penetration Value for With Plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	65	63	64	66	67
2	70	61	65	65	62
3	66	62	63	61	60
Avg.	67	62	64	64	63

2. **Softening Test Point**

SOFTENING POINT TEST					
Sr. No	Softening Point Test for without Plastic Sample	Softening Point Test for With Plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	46	45	47	48	45
2	48	41	43	46	47
Avg.	47	43	45	47	46

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3. Ductility Test

DUCTILITY TEST cm					
Sr. No.	Ductility test value for without plastic	Ductility test value for with plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	78	72	76	74	78
2	80	74	78	72	79
Avg.	79	73	77	73	78.5

4. Viscosity Test

VISCOSITY TEST sec					
Sr. No.	Viscosity test value for without plastic	Viscosity test value for with plastic Sample			
		0.25%	0.50%	0.75%	1.0%
1	210	167	178	211	186
2	385	365	376	369	378
3	296	285	296	290	288
Avg.	297	272.4	283.4	290	284

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5. Specific Gravity Test for Bitumen

Observations		
1	Empty Weight of Beaker, A (gm)	46.6
2	Weight of Water + Beaker, B (gm)	101.9
3	Weight of Beaker + Half-filled Bitumen, C (gm)	78.5
4	Weight of Beaker + Half-filled Bitumen, + water D (gm)	104.5
5	Bottle completely filled with Bitumen, E (gm)	98.4
Calculations	Specific gravity, (C-A)/(B-A)-(D-C)=1.089	

6. Typical Gradation of aggregate

Sr. No	Size of sieve in mm	20mm	10mm	6mm	Dust	Filter	Combined gradation	Norms
		15%	45%	25%	12%	3%		
1	19	15	45	25	12	3	100	100%
2	13.2	13.05	45	25	12	3	98.05	79-100%
3	9.5	3.60	40.50	25	12	3	84.10	70-88%
4	4.75	1.65	31.95	21.75	12	3	70.35	53-71%
5	2.36	1.20	20.25	19.50	11.88	3	55.83	42-58%
6	1.18	-	12.60	12.25	8.76	3	36.61	34-48%
7	0.6	-	9.0	9.0	7.68	3	28.68	26-38%
8	0.3	-	5.40	7.0	6.36	2.88	21.64	18-28%
9	0.15	-	2.70	4.75	4.44	2.73	14.62	12-20%
10	0.075	-	-	1.25	2.88	2.61	6.74	4-10%

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Marshall Mix design

1. Bitumen Content

Sr. No	Sample %	Wt. in Air	Wt. in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)	Flow Value mm
1	5.00	1260	724.5	535.5	2.35	2.45	4.0	11.099	15.08	73.57	998	3.1
2	5.00	1259	722	537	2.34	2.45	4.3	11.06	15.32	72.23	991	3.3
3	5.00	1259	725.2	533.8	2.36	2.45	3.7	11.13	14.81	75.15	995	3.2
4	5.5	1266	735	531	2.38	2.43	2.1	12.31	14.36	85.70	1175	3.4
5	5.5	1266	733	533	2.38	2.43	2.4	12.26	14.68	83.51	1178	3.5
6	5.5	1266	732	534	2.37	2.43	2.6	12.24	14.84	82.46	1176	3.3
7	6.00	1264	733	538	2.36	2.42	2.2	13.25	15.47	85.63	933	4.1
8	6.00	1264	734	538	2.36	2.42	2.2	13.25	15.47	85.63	931	3.9
9	6.00	1263	732	540	2.36	2.42	2.6	13.20	15.79	83.62	935	4.2

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2. Optimum Bitumen Content

Sr. No	Sample in %	Wt. in Air	Wt. in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)	Flow Value mm
1	5.00	1259.33	723.90	535.43	2.35	2.45	3.97	11.09	15.07	73.65	994.67	3.20
2	5.50	1266.00	733.33	533.93	2.38	2.43	2.36	12.27	14.63	83.89	1176.33	3.40
3	6.00	1263.67	733.00	532.60	2.36	2.42	2.34	13.23	15.58	84.96	933.00	4.07

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3. Optimum Bitumen Content of Bitumen Concrete mix

Sr. No	Description	Bitumen (%)
1	Binder content corresponding to maximum Stability	5.5
2	Binder content corresponding to maximum Bulk Density of mix (Gm)	5.5
3	Binder content corresponding to 4.0% Air Voids (Vv) in the total mix	5.0
Average		5.33

4. Plastic Content

Sr. No	Sample	Wt in Air	Wt in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)
1	0.25%	1221.6	703.6	518	2.36	2.36	0.2	11.85	12.01	98.60	1146
2	0.25%	1259.4	734.4	525	2.40	2.44	1.5	11.49	12.99	88.46	927
Avg.	0.25	1240.5	719	521.5	2.38	2.4	0.85	11.67	12.5	93.53	1036.5
3	0.50%	1265.8	733.2	532.6	2.38	2.45	2.9	11.43	14.38	79.49	1313
4	0.50%	1254.4	728.2	526.2	2.38	2.43	1.8	11.54	13.31	86.70	1248
Avg.	0.50%	1260.1	730.7	729.4	2.38	2.44	2.4	11.48	13.84	83.09	1280.5
5	0.75%	1265	731.5	533.5	2.37	2.45	3.1	11.44	14.55	78.61	1334
6	0.75%	1273.5	731.5	538	2.37	2.46	3.9	11.36	15.29	74.33	1330
Avg.	0.75%	1269.2	733.5	535.75	2.37	2.45	3.5	11.4	14.92	76.47	1332
7	1%	1272.2	723.4	548.8	2.32	2.46	5.8	11.38	17.19	66.17	1608
8	1%	1266.4	721.4	545	2.32	2.45	5.2	11.43	16.38	68.90	1352
Avg.	1%	1269.3	722.4	546.9	2.32	2.45	5.5	11.6	16.88	67.53	1480

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5. % in plastic content

Sr. No	% In plastic	Wt in Air	Wt in Water	Volume	Density	Gt	Vv	vb	VMA	VFB	Stability (kg)
1	0.25	1240.5	719	521.5	2.38	2.4	0.85	11.67	12.5	93.53	1036.5
2	0.50	1260.1	730.7	729.4	2.38	2.44	2.4	11.48	13.84	83.09	1280.5
3	0.75	1269.2	733.5	535.75	2.37	2.45	3.5	11.4	14.92	76.47	1332
4	1	1269.3	722.4	546.9	2.32	2.45	5.5	11.6	16.88	67.53	1480

6. Optimum Waste Plastic content

Sr. No	Description	PL Contain (%)
1	Waste pl content corresponding to maximum Stability	0.75
2	Waste pl content corresponding to maximum Bulk Density of mix (Gm)	0.75
3	Waste pl content corresponding to 4.0 % Air Voids (Vv) in the total mix	0.8
	Average	0.76

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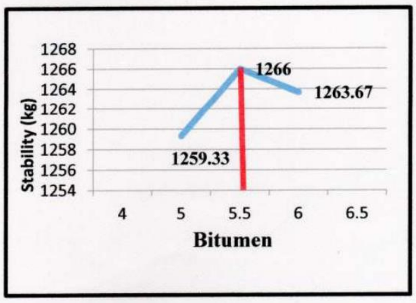
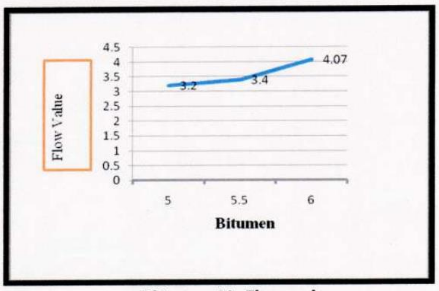
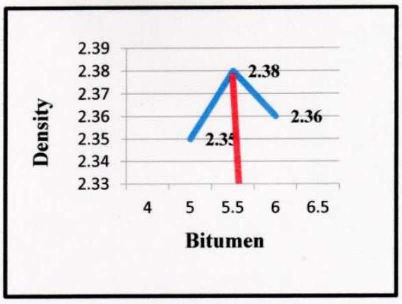


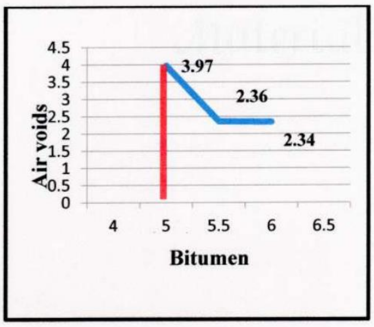
Bitumen Vs Stability



Bitumen Vs Flow value



Bitumen vs Density



Bitumen vs Air Voids

Format No. STL/LAB/F231

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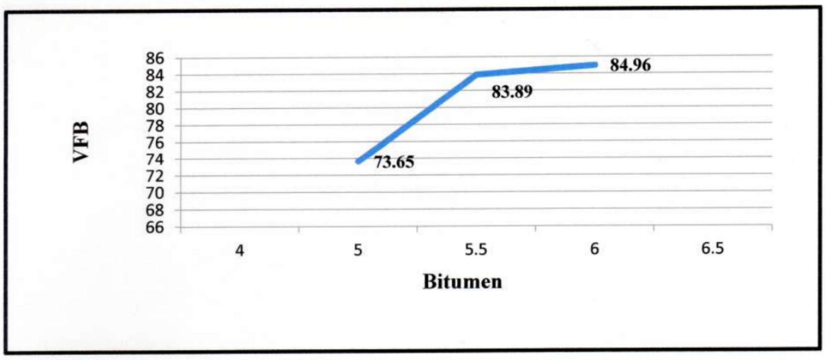

Bitumen vs Voids filling Bitumen

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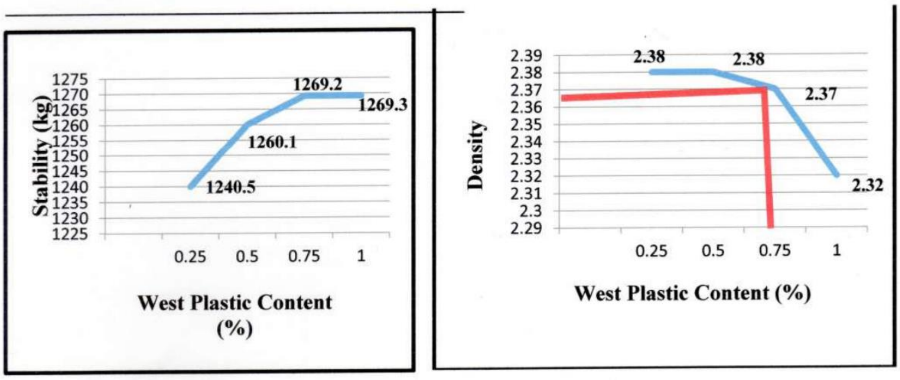
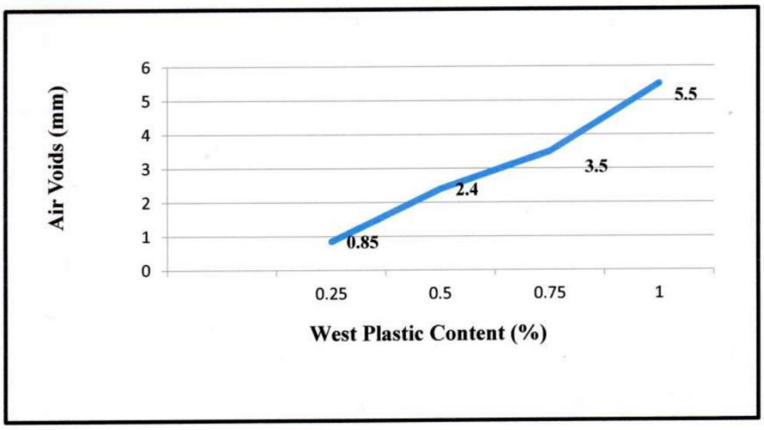


Waste plastic content Vs Stability and Density



Waste plastic content Vs Volume of voids

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APPENDIX – 2 Laboratory testing photoes

Material Testing Laboratory

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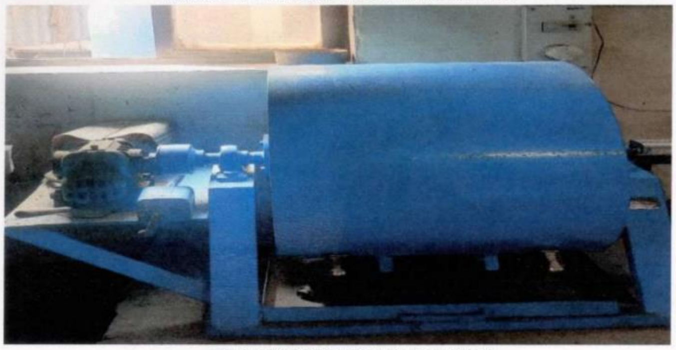
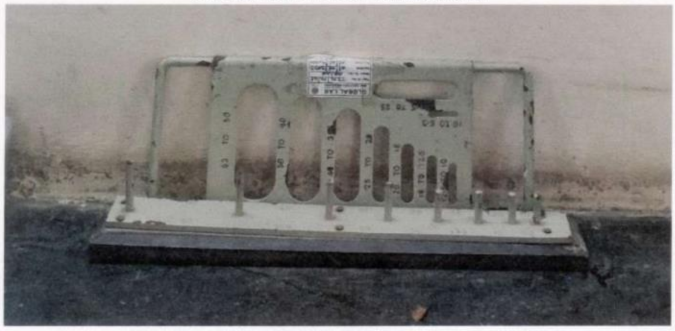
ISO / IEC 17025:2017 ACCREDITED TESTING LABORATORY BY NABL VIDE CERTIFICATE NO. TC-11925
Ground Floor, House No. - 1482, Ward No. - 4, Sonba nagar, Khadgaon Road,
Lawa Nagpur - 440023 (Maharashtra) INDIA, E-mail : shreetestinglab@gmail.com, Mobile : 9970078660, 9527028306

IMPACT VALUE TEST APPRATUS



ABRASION TEST MACHINE



FLAKINESS AND ELONGATION GAUGE

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Format No. STL/LAB/F231

CONDITION :
1) The result relate only to be item tested. the item tested are provided by customer.
2) This report in full or part shall not publish without written permission of laboratory.
3) Samples will be retained by us for specific period unless specified instructions to the contrary received.
4) All disputes are subject to Nagpur jurisdiction and and any correction to this report invalidates this report.

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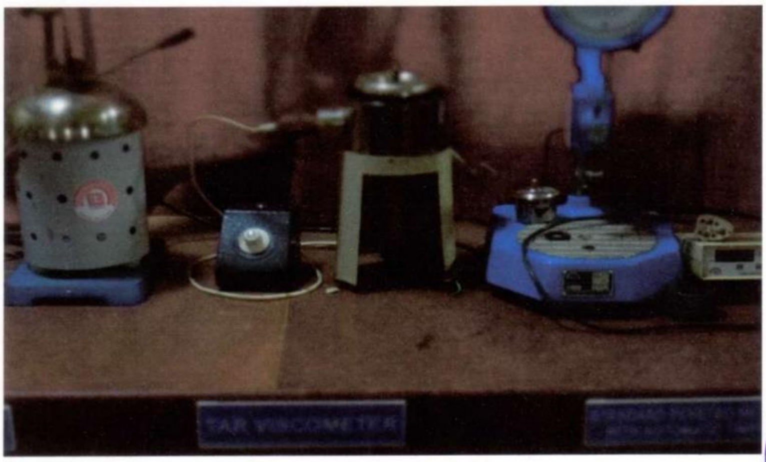
SPECIFIC GRAVITY AND WATER ABSORPTION TEST



VISCOSITY TEST

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PENETRATION TEST

SOFTENING TEST POINT

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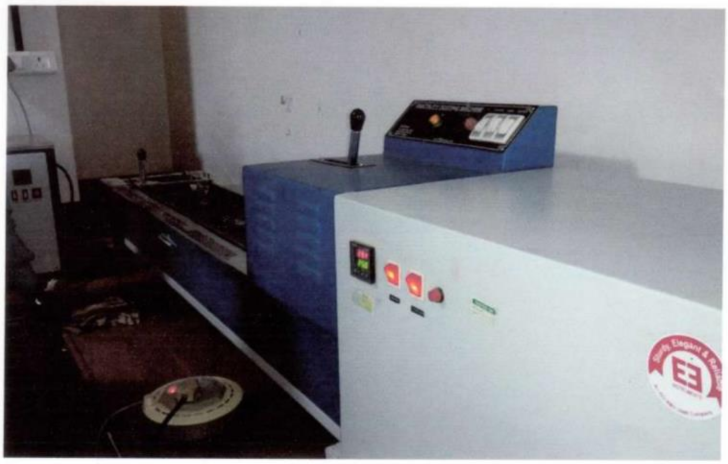

DUCTILITY TEST

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SAMPLE

MARSHAL MOULD RAMMER

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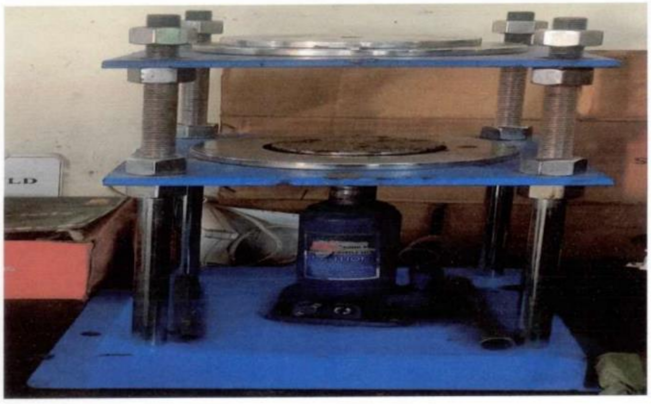
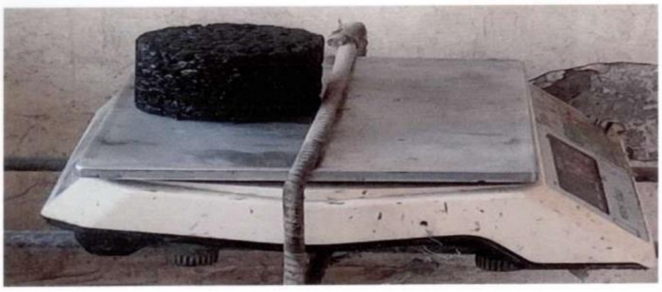


MARSHAL MOULD EXTRACTOR



SAMPLE MOULD

ASPHALT WATER BATH

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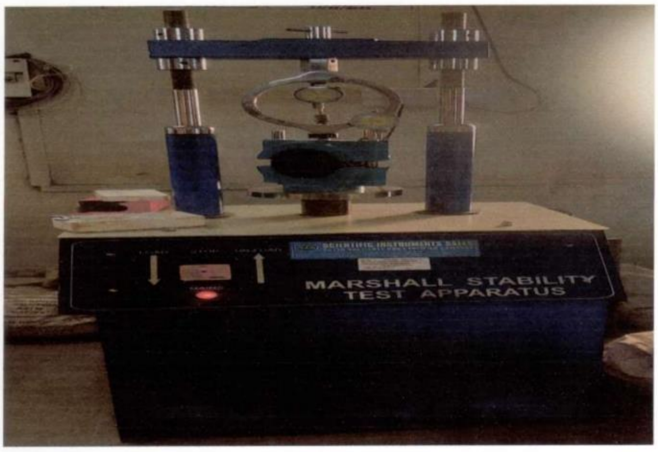

MARSHALL STABILITY TEST APPARATUS

BITUMEN EXTRACTOR

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APPENDIX – 3 Sample collection photo

SAMPLE COLLECTION PHOTO