A Project Report on

EXPERIMENTAL INVESTIGATION OF RAP MODIFIED ASPHALT BINDER AND CRUSHED RAP AGGREGATES

Submitted in partial fulfilment of the requirements

for the degree of

Bachelor of Engineering

by

Kadir Ahmed Abdul Qayum Rukhsana (12CE23)

Shaikh Asgar Ali Gaffar Ali Jannatunnisa (14CE54)

Khan Salman Mehboob (14CE31)

Ansari Tahir Ahmad Khurshid Ahmad (14CE11)

Under the guidance of

Prof.Tehsin A Kazi

Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

New Panvel, Navi Mumbai-410206

2017-2018

CERTIFICATE

This is to certify that the project entitled **"Experimental Investigation of RAP Modified Asphalt Binder And Crushed RAP Aggregates "**is a bonafide work of**" KADIR AHMED, SHAIKH ASGAR ALI, KHAN SALMAN AND ANSARI TAHIR "**submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

Prof. Tehsin A Kazi

(Guided By)

Dr. R. B. Magar
(Head of Department)

Dr. Abdul Razak Honnutagi
(Director, AIKTC)

APPROVAL SHEET

This dissertation report entitled **"Experimental Investigation of RAP Modified Asphalt Binder And Crushed RAP Aggregates"** by **"KADIR AHMED, SHAIKH ASGAR ALI, KHAN SALMAN AND ANSARI TAHIR"** is approved for the degree of "Civil Engineering"

Examiners

…………………………

…………………………

Supervisors:

…………………………

…………………………

Date:

Place: Panvel

DECLARATION

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

Kadir Ahmed Abdul Qayum	**(12CE23)**
Shaikh Asgar Ali Gaffar Ali	**(14CE54)**
Ansari Tahir Ahmad Khurshid	**(14CE11)**
Khan Salman Mehboob	**(14CE31)**

Date:

ABSTRACT

With the increase of the environmental awareness of people and the cost for petroleum based Asphalt as the binder of asphalt concrete, use of RAP has been the common construction practice for several decades in some countries. Since it gives the better performance over other material. To stimulate the reasonable use of RAP, it is necessary to research the ageing behavior asphalt under high temperature and oxidative condition. RAP is the term that has been given to removed or reprocessed pavement materials that contain asphalt and aggregates.

The study shows the physical characteristics of bitumen grade VG30 when mixed with RAP in various proportion i.e (10% , 20% , 30% , 40% , 50%) and the effects of these percentage on the physical characteristics like (Penetration, Softening point, Ductility and Specific gravity) Study also shows the recycling of RAP material and to minimize the problem of waste disposal into landfill up to some extent.

For the present study, the RAP was collected from Mumbai International Taxiway. The age of RAP is 8 years. The various test such as Crushing test, Impact test, Los Angeles Abrasion test and Shape test on crushed and virgin aggregates were also carried out. The summarizing results of RAP in various proportions with virgin bitumen and crushed aggregates are discussed.

KEYWORD: Reclaimed Asphalt Pavement, Physical Characteristics of Bitumen and Aggregate

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction

1.1 General

Despite asphalt being an integral part of human society for over 6,000 years and modern society for over a century, many complexities of asphalt pavement still elude researchers. In particular, this research focuses on the ability to recycle spent asphalt pavement and aggregates into new pavements. When old asphalt pavement is in need of maintenance or replacing, the old material can be mechanically ground and then reused as a substitute for raw materials in new roads. This old, recyclable material is known as reclaimed asphalt pavement (RAP). Nowadays the use of RAP as secondary material in the production of asphalt mixes has become a norm and a cost effective method of pavement construction and rehabilitation. Utilizing reclaimed asphalt pavement is found to be very beneficial from the technical, economical, and environmental perspectives. Some of the advantages include reduced waste, preservation of the existing pavement geometric, conservation of energy and reduction in life-cycle cost. Many laboratory and field studies have shown that asphalt mixtures containing RAP performed similar if not better than conventional asphalt materials in terms of indirect tensile strength, moisture susceptibility, permanent deformation and fatigue. However, research has also shown that RAP inclusion can have a negative effect on the fatigue resistance of the mixture.

Using RAP in hot mix asphalt applications could possibly present a lower performance due to the behaviour of the aged binder, which loses its lighter fractions with time. In order to improve the mixture properties, a binder could be used. This allows the modification of the aged binder, restoring some of its original properties and promoting an adequate performance of the mixture.

The use of RAP and its effects on the performance of the new pavement is well documented and the use of RAP without modification is known to produce an overall stiffer asphalt pavement.

The main concern is the efficiency of RAP binder blended with virgin binder and rejuvenating agent in a paving mixture and the stripping of the binder from the aggregate.

1.2 Rationale for taking up the proposed project work

Asphalt is produced by fractional distillation of crude oil. Crude oil originates from the remains of marine organisms and vegetable matter deposited with mud and fragments of the rock on the ocean bed. Cost is an important factor in terms of recyclability and reuse of material and can be an incentive to use such material. The construction industry will certainly recognize the economic benefits of using recycled materials, such as crushed RAP aggregates for base courses of the pavements. The cost-effectiveness of substituting conventional aggregate with recycled materials is highly dependent on the location, the quality and cost of local aggregates. Recycling versus tipping fees and distances to landfills are other important aspects for the feasibility of recycling. In some urban areas recycling can be more profitable than in rural areas. In rural areas recycling can be expensive and impractical due to high transportation cost and the lack of nearby materials. On the other hand, if materials are available, reuse of materials that otherwise have to be transported can be very cost effective

1.3 Impact of Waste Bitumen

In India, the recycling of pavement materials and studies related to the performance of the recycled materials have not been to the extent that it should have been. Bitumen being a major binding material for paving has been given less importance. Fewer attempts have been made to study and understand the properties of the bitumen. Bitumen grading is practiced on the basis of penetration test which is conducted at a temperature of 25°C and does not indicate viscous/elastic behaviour of bitumen at this test temperature. The most common problem associated with the bitumen handling and recycling is the ageing effect, which in turn affects the binding property and the performance of bituminous pavements.

The production of demolition and construction waste has been increasing at a gradual rate in recent years. The amount of landfill available to contain this material has been decreasing, and the need to find appropriate disposal locations has been of increasing concern. Recycling programs offer a viable solution.

1.4 Aim of Research Work

This project has taken up to replace a small fraction of virgin aggregates with RAP, in base layers to promote RAP usage in the pavement industry.

Using RAP does not only help in minimizing the cost of project but also ensures proper utilization of resources.

1.5 Objectives

The experimental work is carried out to find the effect of varying proportions of RAP materials on Strength and Durability of Pavement, following objectives are proposed:

1.To use RAP as a recycle material and to solve the problem of waste disposal.

2.To evaluate the strength characteristics of Bitumen and Recycled Aggregates for different proportions of RAP in replacement of 10%, 20%, 30%,…. 50%.

3.To study the results of replacement and concentration on future use,&

4.Study the aging effect on RAP hot mix asphalt.

Chapter 2

Literature Review

2.1 Introduction

Bitumen is sometimes called asphalt, but to be clear asphalt denotes the impure form of generic material, whereas the bitumen, the basic mixture of heavy hydrocarbons free of inorganic impurities. Bitumen is a non-volatile hydrocarbon soluble in carbon disulfide having a very complex material structure. It bears the properties same as those of asphalt, except that the asphalt occurs naturally in lake form while bitumen is an extract of crude oil.

Asphalt is produced by fractional distillation of crude oil. Crude oil originates from the remains of marine organisms and vegetable matter deposited with mud and fragments of the rock on the ocean bed. Conversion of organism and vegetable matter into hydrocarbons of crude oil is thought to be the result of application of heat within the earth's crust and pressure applied by the upper layer of the sediments, possibly aided by the effect of bacterial action and radioactive bombardment. As further layers are deposited on the sedimentary rock, where the oil has formed, the additional pressure squeezes the oil sideways and upwards through the porous rocks, where the oil seeps through the surface. Fortunately, the majority of the oil and gas will be trapped in porous rock which was overlaid by impermeable rock, thus forming gas and oil reservoirs. The oil remains here until its presence is detected by seismic surveys and recovered by drilling through the impermeable rock.

Use of bitumen in the construction industry has various applications like paving, waterproofing, painting etc. Various forms of bitumen have come into form namely - bituminous emulsions, cutbacks, hot mix asphalts etc. to serve the purpose. The ageing of bitumen is important factor governing the performance of bitumen.

2.2 Review of Literature

Dharmesh Kumar, Dr. R.K Pandey,(2016) carried out A Reappraisal Paper on Reclaimed Asphalt Pavement (Rap).

Reclaimed Asphalt Pavement is a new technology of construction work with the help of which bituminous pavements can be constructed at a decreased cost as it involves the utilize of old bituminous pavement materials. Also it ensures accumulation of resources and supports sustainable development. Optimal percentage of Reclaimed Asphalt Pavement Depends upon the mixture of reclaimed bituminous material and type of payment layer in which it is to be used. Though 25%- 55% are mostly adopted.

Brajesh Mishra,(2015) studied Use of Reclaimed Asphalt Pavement (RAP) Materials in Flexible Pavement

It was observed that the RAP materials can be successfully used in granular sub base layer of flexible pavements after blending to match the required grading as per MORTH specifications for sub base material.

It was also observed that the RAP materials in combination to natural aggregate in various proportions can be easily used after blending to match the required grading as per MORTH specifications in the base courses of flexible pavements.

It is clear from the above investigation results that 30% replacement of natural aggregate can be successfully done in base course of flexible pavements, resulting in a savings of around 25-30% in construction cost.

Above all the problem of disposal of RAP wastes can be easily solved and adverse effect on environment may be avoided by using the RAP materials in flexible pavement construction.

Jaspreet Singh, *et al.*,(2015) Studied Reclaimed Asphalt Pavement(RAP)

RAP is a new technology with the help of which bituminous pavements can be constructed at a reduced cost as it involves the usage of old bituminous pavement materials. Also it ensures optimization of resources and supports sustainable development. Optimal percentage of RAP depends upon the composition of reclaimed bituminous material and type of layer in which it is to be used. Though 20%- 50% are mostly adopted.

Edward J. Hoppe, *et al.*,(2015) evaluated Feasibility of Reclaimed Asphalt Pavement (RAP) Use As Road Base and Sub base Material.

The use of RAP in road base and sub base layers is technically viable.

Numerous transportation agencies have been recycling RAP in unbound base and sub base layers for many years; however, there is a lack of literature on actual field performance.

Because of concerns related to lower shear strengths and excessive permanent deformations resulting from large strains as RAP content increases, there is a general trend of using up to 50% RAP content by weight in virgin aggregate base and sub base layers.

There is a general lack of uniformity among the RAP use specifications adopted by various transportation agencies.

When the nuclear density gauge is used for wet/dry density measurements, the compaction acceptance criteria need to be modified to account for the RAP content.

Current pavement design procedures do not account for RAP material properties.

There do not appear to be substantive leaching concerns related to unstabilized RAP used as base or sub base material.

Use of chemical stabilization agents may require environmental assessment on a case-bycase basis.

Ahmed Mohamady, *et al.*,(2014) studied Effect of Using Reclaimed Asphalt Pavement on Asphalt Mix Performance The optimum asphalt content is decreased as the RAP percent increase. Mix stability decreases as the recycled aggregate percent increases. This may due to the fatigue of such materials by aging.

Increasing RAP percent from zero to 30%, decreases the stability value by about 22%. However, this decrease reaches 31% when reclaimed percent reaches 40%.

Increasing the recycled aggregate percent in the asphalt mixes decreases the air voids percent which may leads to asphalt bleeding. Asphalt mix with RAP percent of 40% gives air voids percent of 2.5% which is out of the specification range.

Increasing of recycled material percent decreases the mix indirect tensile strength. However, the reduction in mix tensile strength is more significant when the percent of RAP is higher than 30 %.

Increasing of recycled material percent increases the loss of stability of asphalt mix. However, the increasing in loss of stability of asphalt mix is more significant when the percent of RAP is higher than 30 %.

S M Mhlongo, *et al.*, (2014) carried out the results of the indirect tensile strength (ITS) and stability tests are presented in Tables IV and V, as well as the mean of the volumetric properties of the tested specimens. The original asphalt material without additional bitumen i.e. 5.3% bitumen had high relative density (2528 kg/m3) and high air void ratio which is above the specification. The air voids at 5.9% bitumen was slightly higher than the maximum value recommended by specification (3 – 6%). The HMA fabricated with 50/70 bitumen, regardless of the percentage of the bitumen added, exhibited a higher ITS, which is higher than the minimum specified. It can be noticed that the relative density and air voids decreases with the increase in binder content.

Khushbu M. Vyas, Shruti B. Khara,(2013) Evaluated Technical Viability Of Using Reclaimed Asphalt Pavement In Ahmedabad Brts Corridor For Base Course.

The RAP aggregates did not meet the required gradation as per MORTH. We observed that the large size of aggregates were deficient in RAP mix due to the action of crushing & aging. So, to meet the required gradation numbers of trials are made with natural aggregate and by adding 60% of RAP mix, 30% of 40mm size of aggregates & 10 of % stone dust, we can achieve the passing limits of each sieve size of aggregates.

Aggregate Impact Value was 14.89% which is less than the 30 % maximum permissible limits as per MORTH for WMM. Hence the material is satisfied.

The Combined Flakiness & Elongation index was 27.64% which is less than the 30% maximum permissible limits as per MORTH for WMM. Hence the material is satisfied.

The specific gravity of aggregates was lying from 2.8 to 3.0 and the water absorption of aggregates ranges from 0.3 to 2.0 % which was between specifying limit so material is satisfied.

T. Anil Pradyumna, ***et al., (2013)*** carried out Characterization of Reclaimed Asphalt Pavement (RAP) for Use in Bituminous Road

Based on the laboratory testing work carried out on virgin mixes and mixes with 20 % RAP, it was found that addition of RAP improves all the properties of the bituminous mixes. This indicates that mixes with 20% RAP would perform better than the virgin mixes under similar conditions.

Based on the findings of the study, it is concluded that it is possible to design acceptable-quality bituminous

mixes with RAP that meets the required volumetric, mechanical properties and desired performance criteria.

However, for actual field performance evaluation of RAP mixes, Accelerated Pavement Testing Facility (APTF)

available at CSIR-CRRI may be put to use to get the results in a shorter time period.

H. Ziari ***et al*****., (2005**) Department of Civil Engineering Iran Science & Technology, Tehran - Economic and environmental considerations have prompted the recycling of steel, aluminium, plastic, and many materials. One of these recyclable materials is hot mix asphalt .This paper presents research findings from the Investigation of Recycled Asphalt Pavement mixtures project. The samples contained from 0 to 40 percent RAP from a road of Tehran. RAP material was blended with fresh aggregate such that all samples tested had approximately the same grading. Samples were examined for resilient modulus. The resilient modulus test provide a measure of the elastic properties of the mixture.

2.3 Summary of Literature Review

The addition of modifiers to the bitumen results in improving physical properties. The physical properties like softening point, penetration and elastic recovery improves. The value of complex modulus, elastic modulus and storage modulus increases and phase angle decreases, which resists the rutting of pavements. The effect of aging is less on polymer modified binders compared to unmodified asphalt. Thus polymer modified mixtures can be expected to yield longer fatigue lives. However the effect of ageing on other modified binders is yet to be explored. From the survey of literature related to physical properties and performance of modified bituminous binders in pavement, it is observed that, majority of the investigators have focused on physical properties of binder and mechanical properties of mixes but the rheological and chemical characteristics are the main pointers to the material performance.

Chemistry of the bitumen mainly depends on the carbonyl and sulphoxide groups, and the increase of these components leads to the oxidation and in turn degradation of the quality of bitumen. Many studies have been conducted with regard to the effect of RAP inclusion in the pavement structure and its mechanical performance, yet the blending efficiency of the RAP and virgin binder is still to be understood. If there is not a complete blend concerns arise that the long term pavement life could be compromised. Hence, it is necessary to properly evaluate the blending efficiency of the reclaimed asphalt pavement and virgin asphalt.

Chapter 3

Materials and Methodology

3.1 Materials

From a performance point of view, bitumen is one of the most important constituents of an asphalt mixture. The response of bitumen to stress depends on temperature and loading time. At low temperatures or short loading times, bitumen behaves predominantly elastic. At high temperature or long loading time bitumen behaves like a liquid. For typical pavement temperatures and load conditions bitumen generally exhibits both viscous and elastic behaviour. RAP used in this study is collected from Mumbai International Airport Texiway.

The materials tested are

- 60/70 plain bitumen
- Benzene
- Recovered RAP binder
- Recovered RAP aggregate

3.1.1 Reclaimed Asphalt Pavement (RAP) Evaluation

In this experimental study broken Reclaimed Asphalt Pavement (RAP) was collected from Mumbai International Airport Taxiway. The age of RAP is 8 years and it was overlay material. The percentage of bitumen extracted from the RAP is 4.5%. The grade of Bitumen used in the RAP mixture is found out to be VG30. Virgin bitumen is purchased from the market having the same grade as that of the RAP mixture i.e.VG 30. Benzene is used for the process of the extraction of bitumen from RAP. It was made using 60/70 grade of bitumen and it served heavy traffic volume. The surface was broken for paving of concrete overlay. In this particular case we evaluated RAP for asphalt content. We took 5 kg sample for extraction purpose to avoid variations in sampling. A uniform sample of RAP. Extraction of aged bitumen from RAP sample is done using Centrifuge Bitumen Extractor (CBE) using benzene solvent.

The recommended test procedure for the centrifuge extraction test is as follows:

1- If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan and warm to 110°C, only until it can be handled or mixed.
2- Dry the empty centrifuge bowl with the filter paper to a constant weight and record this weight in the data sheet.
3- Dry the test sample at 110°C to remove the moisture from it.
4- Place a sample (650-2500 g) of the asphalt concrete mixture into the bowl of the centrifuge apparatus. Record this weight as W1.
5- Cover the test sample with trichloroethylene, trichloroethane, methylene chloride, or diesel and allow sufficient time for the solvent to disintegrate the test portion (not over 1 h).
6- Fit the filter paper on the bowl, clamp the cover on the bowl tightly and place a beaker under the drain to collect the extract.
7- Start the centrifuge revolving slowly and gradually increase the speed to a maximum of 3600 rpm or until solvent ceases to flow from the drain pipe.
8- Stop the machine, add 200 ml of the solvent, and repeat the centrifuge procedure.
9- Repeat Step # 8 sufficient times (not less than three) so that the extract has a light colour.
10- Collect the extract and the washings in a suitable graduated cylinder.
11- Dry the bowl with the filter paper to a constant weight in an oven at 110 + 5°C.

12- Weight the dried aggregate and the filter paper. Designate the weight of the aggregate with the increase in the weight of the filter paper as W2.

13- Determine the amount of mineral matter in the extract using the following procedure:

a. Record the volume of the total extract (from Step 8) in the graduated cylinder. Designate this volume as V1.
b. Agitate the extract thoroughly and immediately take a representative sample (between 300-500ml) from the extract. Designate this volume as V2.
c. Place the selected extract into a previously tared and calibrated flask.
d. Place the flask in a controlled-temperature bath controlled to ±0.1°C, and allow to come to the temperature at which the flask was calibrated.
e. Fill the flask with solvent which has been kept at the same temperature. Bring the level of the liquid in the flask up to the neck, insert the stopper, making sure the liquid overflows the capillary, and remove from the bath.
f. Wipe the flask dry, determine the mass to the nearest 0.1 g, and record this mass as the mass of flask plus extract.

3.1.2 Characterization of the Bitumen

The bitumen is tested in the laboratory as per the procedure laid in the IS: 73:1978
The bitumen is characterized for the following basic properties.

- Penetration
- Ductility
- Specific gravity
- Softening point

3.1.3 Characterization of the Aggregate

The aggregate is tested in the laboratory as per the procedure laid in the IS: 2386
The aggregate is characterized for the following basic properties.

- LA Abrasion
- Crushing
- Shape
- Impact

3.2 Tests on Bitumen

3.2.1 Penetration test (IS : 1203 - 1978)

1. **Scope**

1.1 This standard covers the method for the determination of penetration of asphaltic bitumen and fluxed native asphalt and blown type bitumen.

2. **Terminology**

2.0 For the purpose of this standard, the following definition and those given in IS : 334-1965* shall apply.

2.1 Penetration - The penetration of a bituminous material is the distance in tenths of a millimetre that a standard needle will penetrate vertically into a sample of the material under standard conditions of temperature, load and time.

3. **Apparatus**

3.1 Container - A metal or glass cylindrical, flat bottom container of essentially the following dimensions shall be used:

For penetrations below 225, Diameter, mm 55, Internal depth, mm 35

For penetrations between 225 and 350: Diameter, mm 70, Internal depth, mm 45

3.2 Needle - A straight, highly polished, cylindrical, stainless steel (SS 316) ,rod with conical and parallel portions co-axial, having the sharp, dimensions and tolerances given in Fig. 1. The needle is provided with a shank approximately 3 mm in diameter into which itis immovably fixed. The taper shall be symmetrical and the point shall be 'blunted' by grinding to a truncated cone of terms relating to bitumen and tar *(revised).*

3.3 Water Bath - water bath preferably with a thermostat maintained at 5 .0 ± 0.10(' containing not less than 10 litres of water.

The sample being immersed to a depth of not less than 100 mm from the top and supported on a perforated shell not less than 50 mm from the bottom of the bath.

3.4 Transfer Dish - A small dish or tray. Provided with some means which ensure a firm bearing and prevent the rocking of the container and of such capacity as will ensure complete immersion of the container during the test.

3.5 Penetration Apparatus - Any apparatus which will allow the needle to penetrate without appreciable friction, and which is accurately calibrated to yield results in tenths of millimetre shall be adopted.

3.6 Thermometer - It shall conform to the following requirements:

Table 3.1 Thermometer Requirement

Characteristic	*Requirement*
Range	0 to 44°C
Graduations	0.2°C
Immersion	65 mm
Overall length	340 ± 10 mm
Stem diameter	5.5 to 8.0 mm
Bulb length	10 to 16 mm
Bulb diameter	Not larger than stem diameter
Length of graduated portion	150 to 190 mm
Longer lines at each	1°C and 5°C
Figured at each	5°C
Scale	±O.2°C

3.7 Time Device - For hand-operated penetrometers, any convenient timing device, such as electric timer, stop watch, or any other spring actuated device may be used provided it is graduated 0.1 s or less and is accurate to within ±O.1 s for a 60-s interval. An audible second counter adjusted to provide 1 beat each 0.5 s may also be use. The time for all count interval shall be 5 ± 0.1 s. Any automatic timing device attached to a penetrometer shall be accurately calibrated to provide the desired test interval within ± 0.1 s.

4. **Procedure**

4.1 Preparation of Test Sample

4.1.1 Soften the material to a pouring consistency at a temperature not more than 60°C for tars and pitches and not more than 90°C for bitumen above the respective approximate softening point and stir it thoroughly until it is homogeneous and is free from air bubbles and water. Pour the melt into the container to a depth at least 10 mm in excess of the expected penetration.

4.1.2 In the case of cutback bitumen and Digboi type cutback bitumen, residue left after distillation shall be used for the test. The procedure for handling the residue shall be in accordance with the method described under 3.2.4 of the distillation test *(see* IS: 1213-1978*).

4.2 Testing

4.2.1 Unless otherwise specified, testing shall be carried out at25.0 ± O.1°C.

4.2.2 Fill the transfer dish with water from the water bath to a depth sufficient to cover the container completely; place the sample in it and put it upon the stand of the penetration apparatus. Adjust the needle(previously washed clean with benzene, carefully dried, and loaded with the specified weight) to make contact with the surface of the sample.

4.2.2.1 Accomplished by placing the needle point in contact With Its Image reflected by the surface of the material from a suitably placed source of light.

4.2.2.2 Unless otherwise specified, load the needle holder with the weight required to make a total moving weight (that is, the sum of the weights of the needle, carrier and superimposed weights) of100± 0.25 g.

4.2.3 Note the reading of the dial or bring the pointer to zero. Release the needle and adjust the points, if necessary to measure the distance penetrated. Make at least three determinations at points on the surface of the sample not less than 10 mm apart and not less than 10 mm from the side of the dish. After each test, return the sample and transfer dish to the water bath, and wash the needle clean with benzene and dry. In the case of material of penetration greater than 225, three determinations on each of two identical test specimens using a separate needle for each determination shall be made, leaving the needle in the sample on completion of each determination to avoid disturbance of the specimen.

4.2.4 For determining the penetration ratio, testing shall also be carried out a 4.0° ± 0.1°C.

NOTE - For test at 4°C. the total weight on the penetration needle shall be200 ± 0.25 g and the time of penetrations all be 60 s.

5. **Report**

5.1 Express the depth of penetration of the needle in tenths of millimetre.

5.2 The value of penetration reported shall be the mean of not less than three determinations whose values do not differ by more than the amount given below:

Table 3.2 Penetration Maximum Difference

Penetration	Maximum Difference
o to 49	2
50 to 149	4
150 to 249	6
250 and above	8

6. Precision

6.1 The duplicate results should not differ by more than the following:

Table 3.3 Penetration Duplicate Results

Penetration	Repeatability	Reproducibility
Below 50	1 unit	4 units
Above 50	3% of their mean	8% of their mean

7. **Precautions**

7.1 If the sample contains extraneous matter, it should be sieved through IS Sieve 30(*see* IS: 460-1962*).

7.2 To avoid overheating at the bottom of the container, use of an air oven or sand bath is recommended.

7.3 While the needle is penetrating into the sample, if there is any movement of the container, that determination shall be discarded.

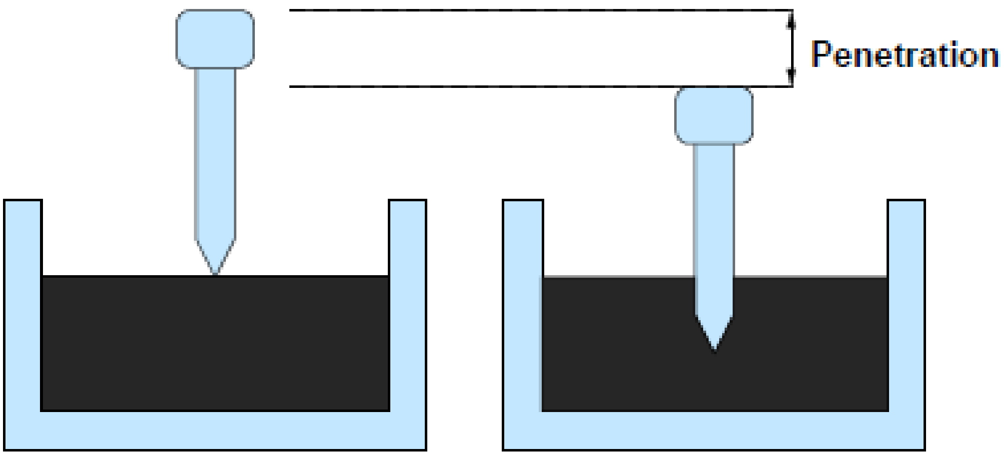


Figure 3.1(Source: Mathew and Krishna Rao, 2006)

3.2.2 Softening Point Test(IS : 1205 - 1978)

1. **Scope**

1.1 This standard covers the method for the determination of softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen.

2. **Terminology**

2.0 For the purpose of this standard, the following definition and those given in IS : 334-1965* shall apply.

2.1 Softening Point - The temperature at which the substance attains a particular degree of softening under specified condition of test.

3. **Apparatus**

3.1 Ring and Ball Apparatus - A convenient form of apparatus

3.1.1 Steel Balls - two; each 9.5 mm in diameter and weighing3.50 ± 0.05 g.

3.1.2 Brass Rings - two; the rings shall be tapered and shall conform to the following dimensions:

Table 3.4 Ring & Ball Apparatus Dimensions

Depth	6.4 ± 0.1 mm
Inside diameter at bottom	15.9 ± 0.1 mm
Inside diameter at top	17.5 ± 0.1 mm
Outside diameter	20.6 ± 0.1 mm

4. **Procedure**

4.1 Preparation of Test Sample - Heat the material to a temperature between 75°C and 100°C above its softening point. Stir until it is completely fluid and free from air bubbles and water, and filter, if necessary, through IS Sieve 30 (*see* IS: 460-1962*). Place the rings, previously heated to a temperature approximating to that of the molten material, on a metal plate which has been coated with a mixture of equal parts of glycerine and dextrin, and fill with sufficient melt to give an excess above the level of cooled. Intercooling for 30 minutes in air, level the material in the ring by removing the excess with a warmed, sharp knife.

4.2 Materials of Softening Point Below 80°C - Assemble the apparatus with the rings. thermometer and ball guides in position and fill the bath to a height of 50 mm above the upper surface of the rings with freshly boiled distilled water at a temperature of 5°C. Maintain the bath at a temperature of 5°C for 15 minutes after which place a ball. previously cooled to a temperature of 5°C, by means of forceps in each ball guide. Apply heat to the bath and stir the liquid so that the temperature rises at a uniform rate of 5.0 ± 0.5°C per minute until the material softens and allows the ball to pass through the ring. The rate of temperature rise shall not be averaged over the period of the test, and any test in which the rate of temperature rise does not fall with in the specified limits after the first three minutes shall be rejected. Make the determination in duplicate.

4.3 Materials of Softening Point Above 80aC - The procedure for materials of softening point above 80°C is similar to that described under 4.2 with the difference that glycerine is used in place of water in the bath and the starting temperature of the test is 35°C. Make the determination in duplicate.

5. **Report**

5.1 Record for each ring and ball, the temperature shown by the thermometer at the instant the sample surrounding the ball touches the bottom plate of the support, if any, or the bottom of the bath. Report to the nearest 0.5°C the mean of the temperature recorded m duplicate determinations, without correction for the emergent stem of the thermometer, as the softening point.

6. **Precision**

6.1 Test results shall not differ from the mean by more than the following:

Table 3.5 Ring & Ball Precision Value

Softening Point °C	*Repeatability* °C	*Reproducibility* °C
40 to 60	1.0	5.5
61 to 80	1.5	5.5
81 to 100	2.0	5.5
101 to 120	2.5	5.5
121 to 140	3.0	5.5

7. **Precautions**

7.1 Only freshly boiled distilled water shall be used in the test, as otherwise air bubbles may form on the specimen and affect the accuracy of the results.

7.2 The prescribed rate of heating shall be rigidly adhered to for ensuring accuracy of results.

7.3 A sheet of filter paper or thin amalgamated sheet, placed on the bottom of the glass vessel and conveniently weighed would prevent the material from sticking to the glass vessel, and considerable time and trouble in cleaning would thereby be saved.

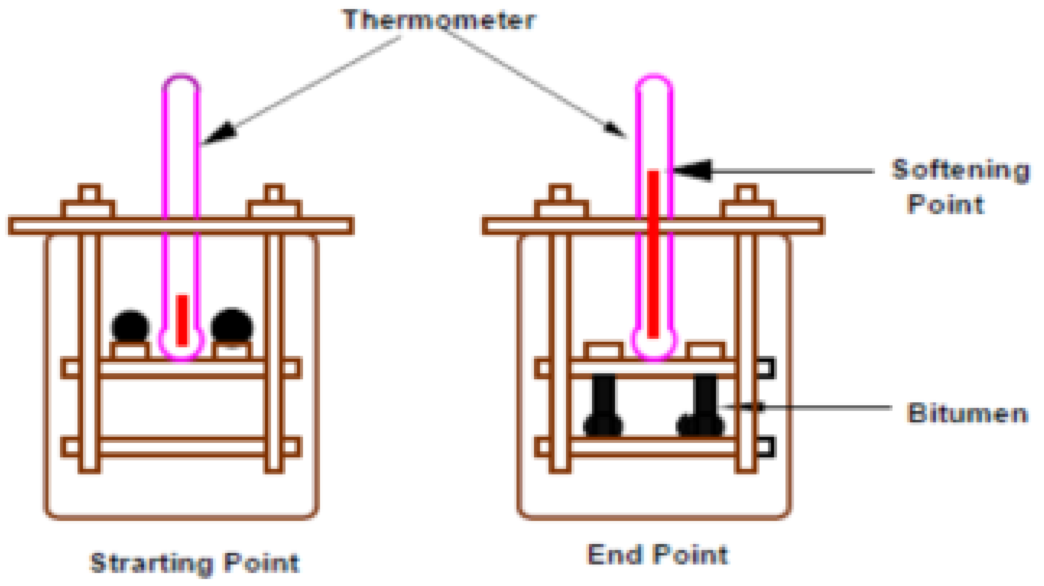


Figure 3.2 (Source: Mathew and Krishna Rao, 2006)

3.2.3 Ductility Test(IS : 1208 - 1978)

1. **Scope**

1.1 This standard covers the method of determination of ductility of distillation residue of cutback bitumen, blown type bitumen and other bituminous products.

2. **Terminology**

2.1 For the purpose of this standard the following definition and those given in IS : 334-1965* shall apply.

2.2 Ductility - The ductility of a bituminous material is measured byte distance in centimetres to which it will elongate before breaking when a briquette specimen of the material of the form described under3.1 are pulled apart at a specified speed and at a specified temperature.

3.**Apparatus**

3.1 Mould - made of brass with the shape, dimensions and tolerances. The ends band *b*1 are known as clips, and the parts a and a I as sides of the mould. The dimensions of the mould shall be such that when properly assembled, it will form a briquette specimen having the following dimensions:

Table 3.6 Ductility Apparatus Dimensions

Total length	75.0 ± 0.5 mm
Distance between clips	30.0 ± 0.3 mm
Width at mouth of clip	20.0 ± 0.2 mm
Width at minimum cross-section (halfway between clips)	10.0 ± 0.1 mm
Thickness throughout	10.0 ± 0.1 mm

3.2 Water Bath - A bath preferably with a thermostat maintained within ± 0.l°C of the specified test temperature, containing not less than 10 litres of water, the specimen being immersed to a depth not less than 100 mm and supported on a perforated shelf not less than50 mm from the bottom of the bath.

3.3 Testing Machine - For pulling the briquette of bituminous material apart, any apparatus may be used which is so constructed that the specimen will be continuously immersed in water as specified under 4.3 while the two clips are pulled apart horizontally with minimum vibrations at a uniform speed, as specified and with suitable arrangement for stirring the water for attaining uniformity in temperature.

3.4 Thermometer - conforming to the following requirements:

Table 3.7 Ductility Thermometer Requirements

Characteristic	*Requirement*
Range	0-44°C
Graduations	2°C
Immersion	65 mm
Overall length	340 ± 10 mm
Stem diameter	5.5 to 8.0 mm
Bulb length	10 to 16 mm
Bulb diameter	Not larger than stem diameter
Length of graduated portion	150 to 190 mm
Longer lines at each	l°C and 5°C
Figured at each	5°C
Scale	± 0.2°C

4. **Procedure**

4.1 Unless otherwise specified, the test shall be conducted at. A temperature of 25.0 ± 0.5°C and at a rate of pull of 50.0 ± 2.5 mm/min.

4.1.1 When a low temperature ductility test is desired, the test shall be made at a temperature of 4.0 ±O.5°C and at a rate of pull of 10.0 ± 0.5mm/min.

4.2 Completely melt the bituminous material to be tested to a temperature of 75 to 100°C above the approximately softening point until it becomes thoroughly fluid. Assemble the mould on a brass plate and in order to prevent the material under test from sticking, thoroughly coat the surface of the plate and interior surfaces of the sides of the mould with a mixture of equal parts of glycerine and dextrin. In filling, pour the material in a thin stream back and forth from end to end of the mould until it is more than level full. Leave it to coolat the room temperature for 30 to 40 min, and then place in a water bath maintained at the specified temperature for 30 min after which cut off the excess bitumen by means of a hot, straight-edged putty knife or spatula so that the mould shall be just level full.

4.3 Testing - Place the brass plate and mould with briquette specimen, in the water bath and keep at the specified temperature for about 85 to 95 minutes. Then remove the briquette from the plate, detach the side pieces, and test the briquette immediately.

4.3.1 Attach the rings at each end of the clips to the pins or hooks in the resting machine and pull the two clips apart horizontally at a uniform speed as specified until the briquette ruptures. Measure the distance in centimetres through which the clips have been pulled to produce rupture. While the test is being made, make sure that the water in the tank of the testing machine covers the specimen both above and below it by at least 25 mm and is maintained continuously within ±O.5°C of the specified temperature.

5. **Precautions**

5.1 The plate upon which the mould is placed shall be perfectly flatland level so that the bottom surface of the mould touches it throughout.

5.2 In filling the mould, care shall be taken not to disarrange the parts and thus distort the briquette and to see that no air pocket shall be within the moulded sample.

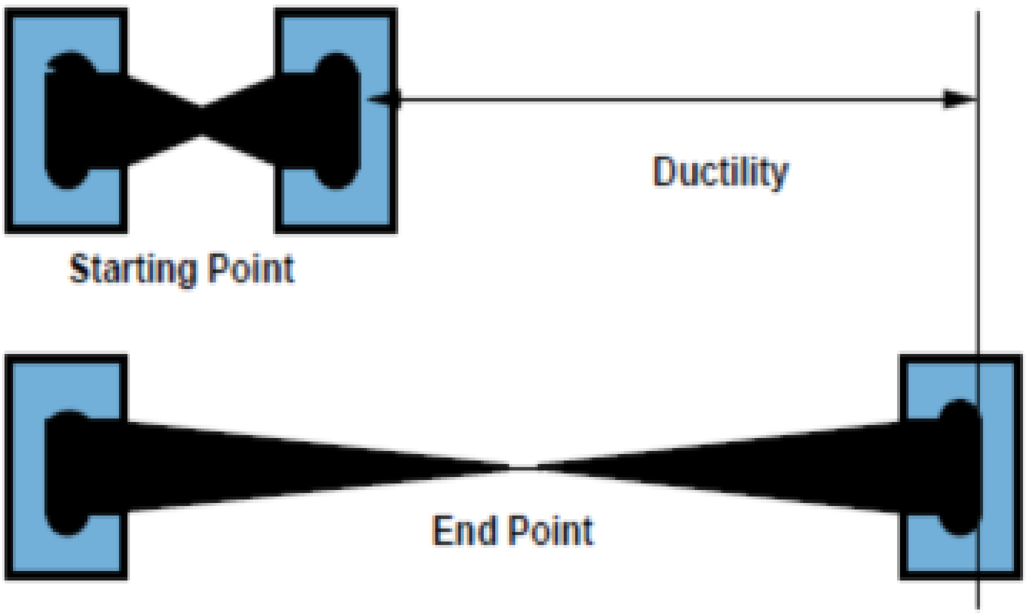


Figure 3.3 (Source: Mathew and Krishna Rao, 2006)

3.2.4 Specific Gravity Test (IS : 1202 - 1978)

1. **SCOPE**

1.1 This standard covers the methods for the determination of specific gravity of asphalt, bitumen, bituminous products, road tar, coal tar, coal tar pitch, creosote and anthracite.

2. **Method A (Pyknometer Method)**

2.1 This method covers the determination of specific gravity for semisolid bitumen road tars and creosote and anthracite oil.

2.2 Apparatus- Specific gravity bottles of 50 ml capacity shall be used. One of the two types of specific gravity bottles, namely (a) the ordinary capillary type specific gravity bottle with a neck of 6 mm diameter and (b) the wide-mouthed capillary type specific gravity bottle with a neck of 25 mm diameter shall be used.

The stopper shall be provided with a bore 1.0 to 2.0 mm in diameter centrally located in reference to the vertical axis. The top surface of the stopper shall be smooth and substantially plain and the lower surface shall be concave in order to allow all air to escape through the bore. The height of the concave section shall be 4.0 to 6.0 mm at the centre.

2.2.1 The ordinary specific gravity bottle shall be used for materials which remain absolutely fluid at 25°C while the wide mouth capillary type shall be used for materials which remain semisolid or high viscous at 25°C.

2.2.2 Constant Temperature Bath - A water bath having a depth greater than that of Pyknometer capable of being maintained within0.2°C of the desired temperature.

2.2.3 Bath Thermometer - It shall conform to the following requirements:

Table 3.8 Pyknometer Thermometer Requirement

Characteristic	*Requirement*
Range	0 to 44°C
Graduations	0.1°C
Immersion	65mm
Overall length	340± 10 mm
Stem diameter	5.5 to 8.0 mm
Bulb length	10 to 16 mm
Bulb diameter	Not larger than stem

Length of graduated portion	150 to 190 mm
Longer lines at each	1°C and 5°C

2.3 Procedure - Clean, dry and weigh the specific gravity bottle together with the stopper (a). Fill it with freshly boiled and cooled distilled water and insert 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 of27.0 ± 0.l°C 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 (b) the bottle shall be dried again.

2.3.1 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 mentioned at 3.3 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 temperature between 60 - 70°C, then cool to I the specified temperature and weigh with the stopper (c).

2.3.2 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.

2.3.3 In the case of liquids such as creosote and anthracite 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 ± 0.1°C, remove the bottle from the beaker, wipe all surplus water from the surface with a clean, dry cloth and weigh again.

2.4 Calculation - Calculate the specific gravity of the material as follows:

a) Specific gravity (solids and semisolids) = (c-a)/((b-a)-(d-c))

b) Specific gravity(liquids) = (e-a)/(b-a)

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

e = mass of the specific gravity bottle completely filled with the material.

2.5 Report - Results of the test shall be expressed as the ratio of mass of a given volume of the material at a temperature specified under 2.1.2to the mass of the same volume of water at the same temperature.

2.6 Precision - With samples which are neither very volatile nor very viscous and using a pyknometer of at least 25 ml capacity.

2.7 Precautions - When making the specific gravity determination, it is important that:

a) only freshly boiled and cooled distilled water shall be used;

b) at no time of weighing shall the temperature of the apparatus bellowed to exceed the specified temperature;

c) precautions shall be taken to prevent expansion and over-flow of the contents resulting from the heat of the hand when wiping the surface of the apparatus;

d) all air bubbles shall be eliminated in filling the apparatus and inserting the stopper;

e) weighing shall be done quickly after filling the apparatus and shall be accurate to 0.1 mg; and

f) to prevent breakage of the apparatus when cleaning after a determination has been made upon a very viscous of semisolid material, it is advisable to warm it in an oven at a temperature not above 100°C, until most of the material is poured out and then to swab it with a piece of soft cloth or cotton waste. When cool, it may be finally rinsed with carbon disulphide, benzol or other solvent and wiped clean.

3. **Method B (Balance Method)**

3.1 This balance method of test is intended for the determination of the specific gravity of all bituminous materials sufficiently solid to be handled in fragments.

3.2 Apparatus

3.2.1 Balance Analytical

3.2.2 Thermometer - as given in Method A.

3.2.3 Balance Straddle - A pan straddle of convenient size beaker and permit determination of the weight of the specimen In water

3.2.4 Thread - A length of fine, waxed, silk thread.

3.2.5 Brass Moulds- cubical, measuring approximately 20 mm on each edge.

3.3 Test Specimen - The test specimen shall be a cube of the material measuring approximately 20 mm on each edge. Prepare the specimen by melting a small sample of the material by gentle application of heat, taking care to prevent loss by evaporation, and pouring the material when sufficiently fluid into a 20 mm brass cubical mould that has been treated with a 1 : 1 mixture of glycerine and dextrin and placed on a brass plate previously so treated. Take precautions to prevent the inclusion of air bubbles. The hot material should be slightly more than that required to fill the mould, and when cool, the excess may be cut off with a hot spatula. Remove the specimen from the mould when cooled to room temperature.

3.4 Procedure - Tare the balance first with a piece of fine waxed silk thread sufficiently long to reach from the hook on one of the pan supports to the rest. Attach the test specimen to the thread. so as to be suspended about 25 mm above the straddle from the hook on the pan support, and weigh to the nearest 0.1 mg. Weigh the specimen. Still suspended by thread, and completely immersed in freshly boiled and cooled distilled water at 27.0 ± 0.1°C, to the nearest 0.1 mg, adhering air bubbles being first removed with a fine wire.

3.5 Calculation - Calculate the specific gravity of the material as follows:

Specific gravity = $a/(a-b)$

a = mass of the dry specimen, and

b = mass of the specimen when immersed in distilled water.

3.6 Report - Report the specific gravity to the nearest 0.001 at 25°C/ I25°C. The buoyancy/correction in this case is negligible.

3.7 Precision - The duplicate results shall not differ by more than the following:

Size of Sample5g or larger.

3.3 Tests On Aggregate

3.3.1 Shape Test

Objective

To determination of Flakiness Index and Elongation Index of Course Aggregates.

Reference

IS : 2386 (Part I) – 1963, IS: 383-1970, IS : 460-1962.

Theory

Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio. Generally, flat and elongated particles are avoided or are limited to about 15 % by weight of the total aggregate.

Apparatus

The metal gauge shall be of the pattern shown in Fig. 10.1, Balance, Gauging Trowel, Stop Watch, etc.

Procedure

1. Sample - A quantity of aggregate shall be taken sufficient to provide the minimum number of 200 pieces of any fraction to be tested.
2. Sieving - The sample shall be sieved in accordance with the method described in Exp. 3(b) with the sieves specified in Table 3.18.

Table 3.9 Shows Dimensions Of Thickness And Length Gauges

Size of Aggregate Thickness		Length of Gauge* mm	Gauge† mm
Passing through IS Sieve	Retained on IS Sieve		
63 mm	50 mm	33.90	–
50 mm	40 mm	27.00	81.0
40 mm	25 mm	19.50	58.5
31.5 mm	25 mm	16.95	–
25 mm	20 mm	13.50	40.5
20 mm	16 mm	10.80	32.4
16 mm	12.5 mm	8.55	25.6
12.5 mm	10.0 mm	6.75	20.2
10.0 mm	6.3 mm	4.89	14.7

* This dimension is equal to 0.6 times the mean Sieve size.

† This dimension is equal to 1.8 times the mean Sieve size.

3. Separation of Flaky material- Each fraction shall be gauged in turn for thickness on a metal gauge of the pattern shown in Fig. 11.1, 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 co1 3 of Table 3.18 for the appropriate size of material.

4. Weighing of Flaky Material - 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.

5. 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.

6. Sieving - The sample shall be sieved in accordance with the method described in Exp. 3(b) with the sieves.

7. Separation of Elongated Material- Each fraction shall be gauged individually for length on a metal length gauge of the pattern shown in Fig. 11.2. The gauge length used shall be that specified in co1 4 of Table 3.18 for the appropriate size of material.

8. Weighing of Elongated Material - The total amount retained by the length gauge shall be weighed to an accuracy of at least 0.1 percent of the weight of the test sample.

9. 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.

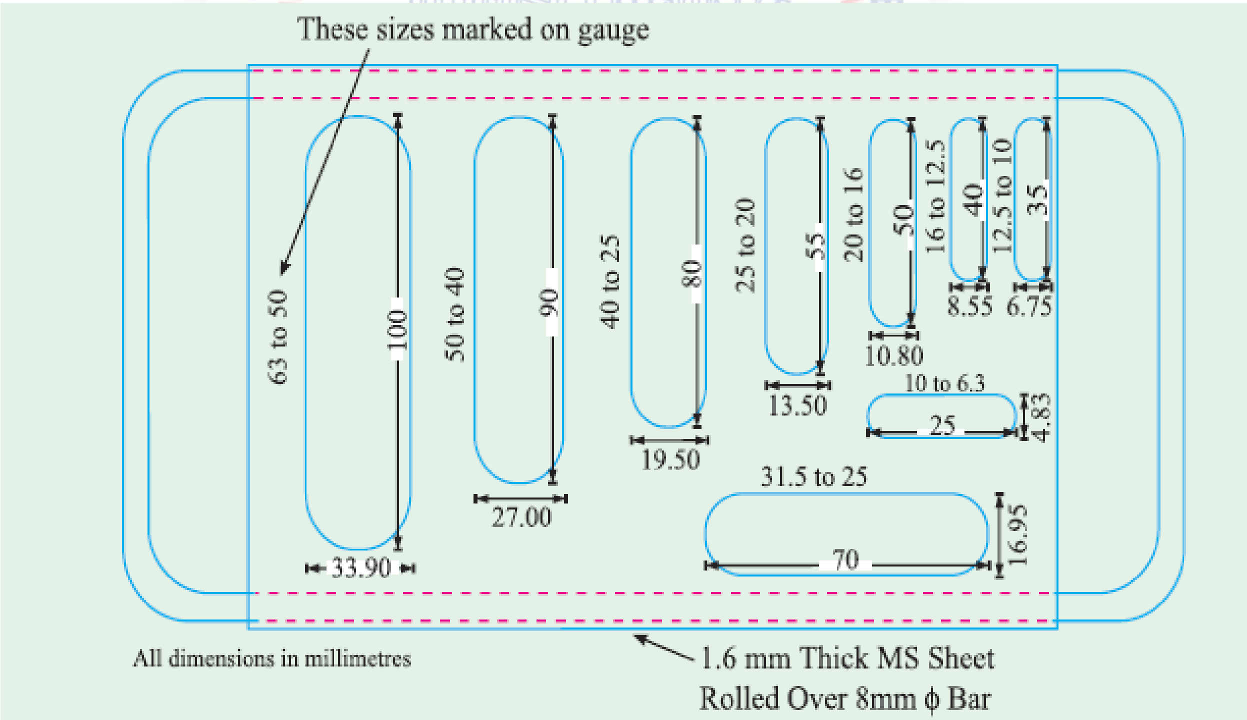


Figure 3.4 Elongation

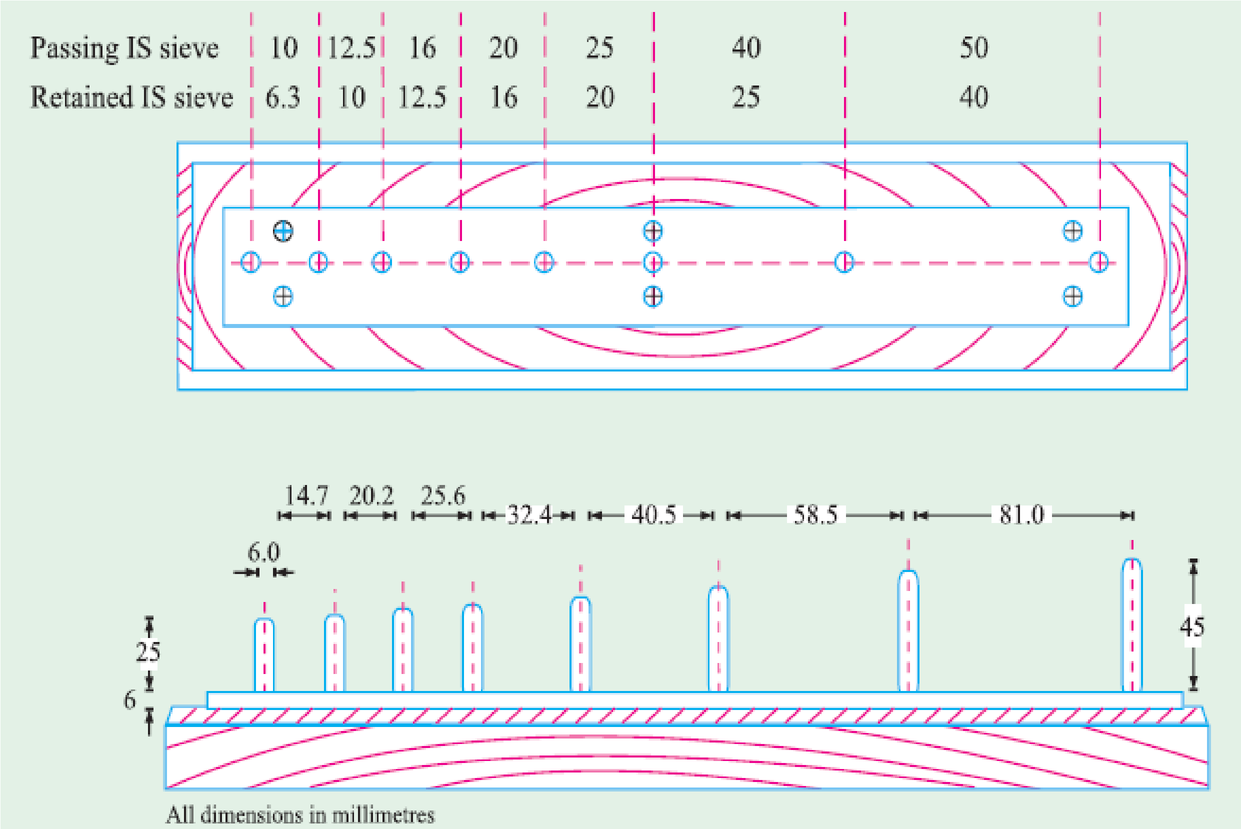


Figure 3.5 Flakiness

3.3.2 Crushing Test

Objective This method of test covers the procedure for determining the aggregate crushing value of coarse aggregate.

Reference

IS : 2386 (Part IV) – 1963, IS: 383-1970

Theory

The aggregate crushing value' gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. With aggregate of _aggregate crushing value' 30 or higher, the result may be anomalous, and in such cases the ten percent fines value' should be determined instead.

Apparatus

A 15-cm diameter open-ended steel cylinder, with plunger and base-plate, of the general form and dimensions shown in Fig. ,A straight metal tamping rod, A balance of capacity 3 kg, readable and accurate to one gram, IS Sieves of sizes 12.5, 10 and 2.36 mm, For measuring the sample, cylindrical metal measure of sufficient rigidity to retain its form under rough usage and of the following internal dimensions: Diameter 11.5 cm and Height 18.0 cm.

Figure

Figure 3.6 Crushing Test

Procedure

1. The material for the standard test shall consist of aggregate passing a 12.5 mm IS Sieve and retained on a 10 mm IS Sieve, and shall be thoroughly separated on these sieves before testing.
2. The aggregate shall be tested in a surface-dry condition. If dried by heating, the period of drying shall not exceed four hours, the temperature shall be 100 to 110°C and the aggregate shall be cooled to room temperature before testing.
3. The appropriate quantity may be found conveniently by filling the cylindrical measure in three layers of approximately equal depth, each layer being tamped 25 times with the rounded end of the tamping rod and finally leveled off, using the tamping rod as a straight-edge.
4. The weight of material comprising the test sample shall be determined (Weight A) and the same weight of sample shall be taken for the repeat test.

5. The apparatus, with the test sample and plunger in position, shall then be placed between the platens of the testing machine and loaded at as uniform a rate as possible so that the total load is reached in 10 minutes. The total load shall be 400 kN.

6. The load shall be released and the whole of the material removed from the cylinder and sieved on a 2.36 mm IS Sieve for the standard test. The fraction passing the sieve shall be weighed (Weight B).

Calculation

The ratio of the weight of fines formed to the total sample weight in each test shall be expressed as a percentage, the result being recorded to the first decimal place:

Crushing value = B/A * 100.

Conclusion / Result

The aggregate crushing value of given sample of coarse aggregate is ……….. %

The aggregate crushing value should not be more than 45 per cent for aggregate used for concrete other than for wearing surfaces, and 30 per cent for concrete used for wearing surfaces such a runways, roads and air field pavements.

3.3.3 Impact Value Test

Objective This method of test covers the procedure for determining the aggregate impact value of coarse aggregate.

Reference

IS : 2386 (Part IV) – 1963, IS: 383-1970

Theory

The aggregate impact value‘ gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load.

Apparatus

An impact testing machine of the general form shown in Fig. 2 and complying with the following:

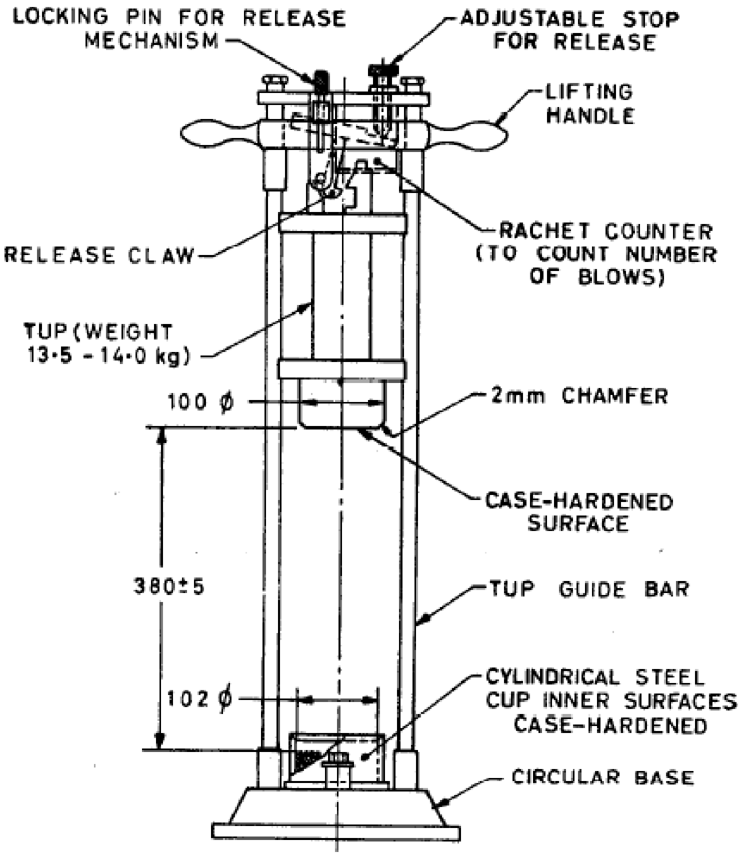
1. A cylindrical steel cup of internal dimensions: Diameter 102 mm, Depth 50 mm and not less than 6.3 mm thick

2. A metal hammer weighing 13.5 to 14.0 kg, the lower end of which shall be cylindrical in shape, 100.0 mm in diameter and 5 cm long, with a 2 mm chamfer at the lower edge, and case-hardened. The hammer shall slide freely between vertical guides so arranged that the lower (cylindrical) part of the hammer is above and concentric with the cup.

3. Means for raising the hammer and allowing it to fall freely between the vertical guides from a height of 380.0 mm on to the test sample in the cup, and means for adjusting the height of fall within 5 mm.

Sieves-The IS Sieves of sizes 12.5, 10 and 2.36 mm, Tamping Rod, balance of capacity not less than 500 g, Oven etc.

Figure



All dimensions in millimetres.

Figure 3.7 Aggregate Impact Test Machine

Procedure

1. The test sample shall consist of aggregate the whole of which passes a 12.5 mm IS Sieve and is retained on a 10 mm IS Sieve. The aggregate comprising the test sample shall be dried in an oven for a period of four hours at a temperature of 100 to 110°C and cooled.
2. The measure shall be filled about one-third full with the aggregate and tamped with 25 strokes of the rounded end of the tamping rod. The net weight of aggregate in the measure shall be determined to the nearest gram (Weight A)
3. The impact machine shall rest without wedging or packing upon the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.
4. The cup shall be fixed firmly in position on the base of the machine and the whole of the test sample placed in it and compacted by a single tamping of 25 strokes of the tamping rod.
5. The hammer shall be raised until its lower face is 380 mm above the upper surface of the aggregate in the cup and allowed to fall freely on to the aggregate. The test sample shall be subjected to a total of 15 such blows each being delivered at an interval of not less than one second.
6. The crushed aggregate shall then be removed from the cup and the whole of it sieved on the 2.36 mm IS Sieve until no further significant amount passes in one minute. The fraction passing the sieve shall be weighed to an accuracy of 0.1 g (Weight. B).
7. The fraction retained on the sieve shall also be weighed (Weight C) and, if the total weight (C+B) is less than the initial weight (Weight A) by more than one gram, the result shall be discarded and a fresh test made. Two tests shall be made.

Calculation

The ratio of the weight of fines formed to the total sample weight in each test shall he expressed as a percentage, the result being recorded to the first decimal place:

Impact value = B/A * 100

Conclusion / Result

The aggregate Impact value of given sample of coarse aggregate is ……….. %

The aggregate impact value should not be more than 45 per cent for aggregate used for concrete other than for wearing surfaces, and 30 per cent for concrete used for wearing surfaces such a runways, roads and air field pavements.

3.3.4 Los Angeles Abrasion Test

Objective This method of test methods of determining the abrasion value of coarse aggregate By the use of Los Angeles machine.

Reference

IS : 2386 (Part IV) – 1963, IS: 383-1970

Theory

Abrasive Charge-The abrasive charge shall consist of cast iron spheres or steel spheres approximately 48 mm in. diameter and each weight between 390 and 445 g.
The test sample consist of clean aggregate which has been dried in an oven at 105°C to 110°C and it should conform to one of the grading.

Apparatus

Los Angeles machine - The Los Angeles abrasion testing machine shall consist of a hollow steel cylinder, closed at both ends, having an inside diameter of 700 mm and an inside length of 500 mm. The cylinder shall be mounted on stub shafts attached to the ends of the cylinders but not entering it, and shall be
mounted in such, a manner that it may be rotated about its axis in a horizontal position. An opening in the cylinder shall be provided for the introduction of the test sample. A removable steel shelf, projecting radially 88 mm into the cylinder and extending its full length, shall be mounted along one element of the interior surface of the cylinder. The shelf shall be of such thickness and so mounted, by bolts or other approved means, as to be firm and rigid. The 1.70 mm IS Sieve.

Figure

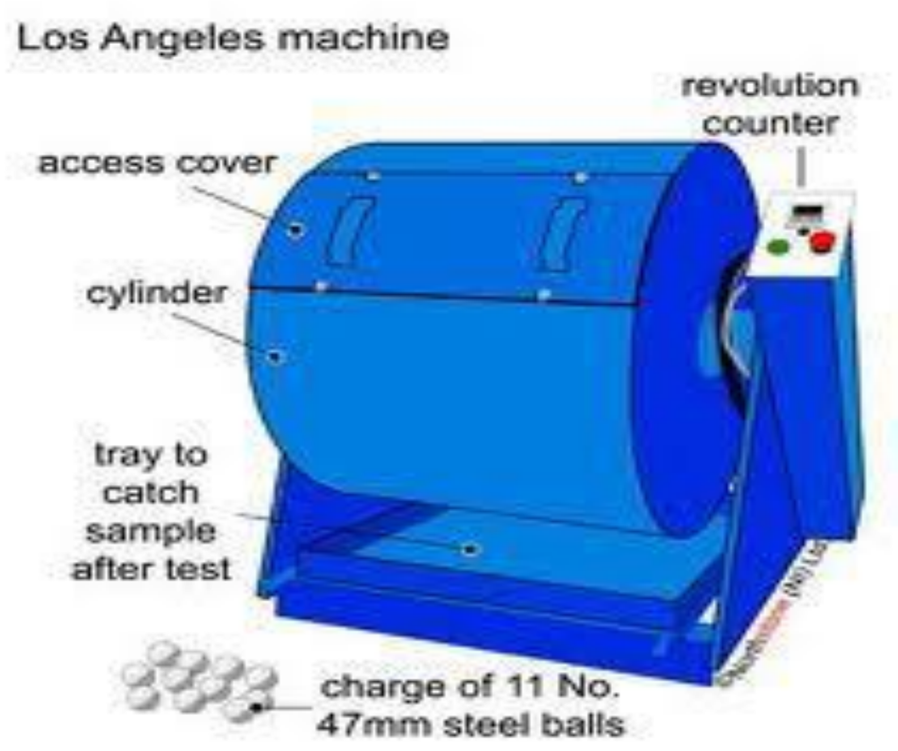


Figure 3.8 Los Angeles Machine

Procedure

1. The test sample shall consist of clean aggregate which has been dried in an oven at 105 to 110°C to substantially constant weight and shall conform to one of the grading shown in Table 3.22. The grading or grading used shall be those most nearly representing the aggregate furnished for the work.

2. 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 rev/min. 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 1 000 revolutions.

3. The machine shall be so driven and so counter-balanced as to maintain a substantially uniform peripheral speed. 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.

5. The material coarser than the 1.70 mm IS Sieve shall be washed dried in an oven at 105 to 110°C to a substantially constant weight, and accurately weighed to the nearest gram.

Calculation

The difference between the original weight and the final weight of the test sample is expressed as a percentage of the original weight of the test sample. This value is reported as the percentage of wear.

Abrasion Value = B/A * 100

Conclusion / Result

The aggregate Abrasion Value of given sample of coarse aggregate is ……….. %

The percentage of wear should not be more than 16 per cent for concrete aggregates.

3.4 Summary

This chapter provided a basic overview about the process and test methodology adopted. It includes binder evaluation for both virgin binder and RAP modified asphalt binder and aggregates. This chapter also describes the procedure to be adopted for testing of bitumen and aggregate.

Chapter 4

Results and Discussions

4.1 General

RAP modified asphalt binder samples were tested for physical properties according to the methods described in chapter 3. The observations made on the results are presented and discussed in the following paragraphs.

4.2 Extraction and Evaluation Of Bitumen From The RAP

After extracting the binder from RAP by centrifuge extractor, the extracted solution was subjected to open air for the recovery of binder. The diluted sample (bitumen + benzene) to be processed was fed directly into the Deep Tray. The sample is kept for the exposure to atmosphere, in certain time the benzene gets evaporated and bitumen is left over.

4.3 Evaluation Of Binder Mixed With Different Percentages Of RAP

The virgin bitumen was heated to around 90^{0}C and was mixed with different percentages of recovered binder which were also preheated to around 90^{0}C varying from 10 to 50%. The basic tests were conducted for evaluation of binders for various basic properties.

Table 4.1 Schedule Of Different Proportions Of Mixing

Materials	Proportion of mixing						
RAP bitumen	10%	20%	30%	40%	50%	100%	---
Virgin Bitumen	90%	80%	70%	60%	50%	---	100%

Table 4.2 Comparison Between Reclaimed Asphalt Pavement (RAP) And Virgin Bitumen Properties

Tests on bitumen	Virgin bitumen	10% RAP	20% RAP	30% RAP	40% RAP	50% RAP	RAP bitumen	IS limits (min)
Penetration test (mm)	62mm	58mm	54mm	50mm	46mm	43mm	23mm	60/70
Softening point test (^{0}C)	45 ^{0}C	48 ^{0}C	50 ^{0}C	53 ^{0}C	58 ^{0}C	61 ^{0}C	64 ^{0}C	45-55 ^{0}C
Ductility test (cm)	>75cm	62cm	58cm	54cm	45cm	33cm	16cm	75cm
Specific Gravity	1.03	1.029	1.0275	1.0253	1.023	0.937	0.9	0.99

4.3.1 Penetration:

The penetration decreases as the percentage of RAP binder increases due to the loss of volatiles in the aged RAP binder. The penetration value of virgin bitumen is 62 mm. For the respective RAP binder proportions, with the increase of RAP % penetration decreases and for 100% RAP bitumen after the long term ageing penetration value is 23mm, the lowest.

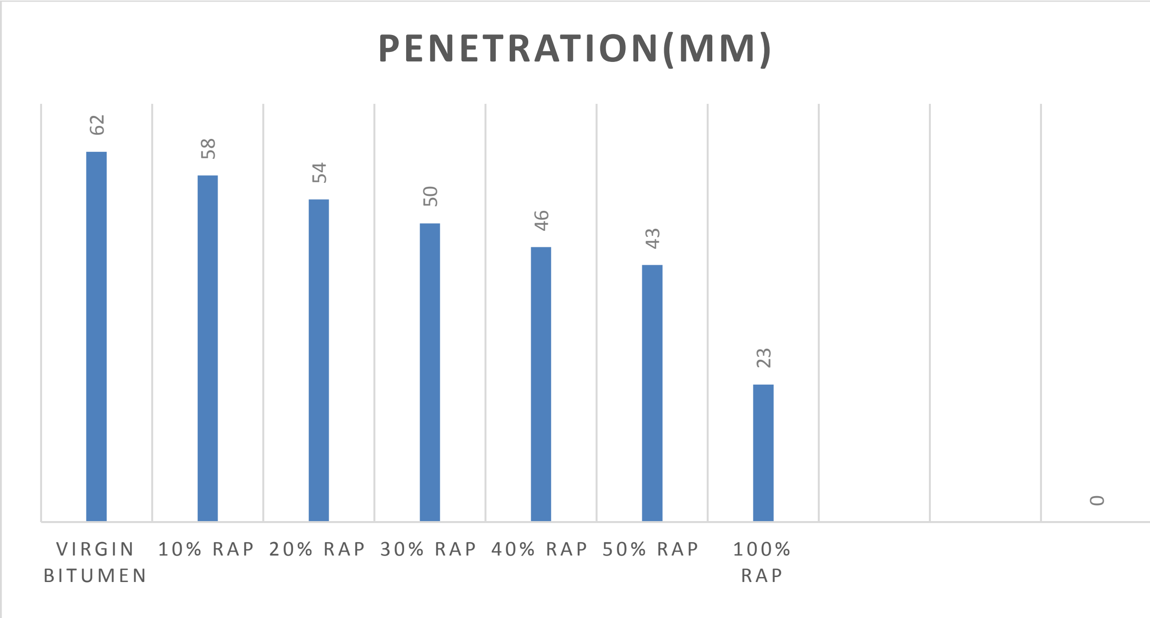


Figure 4.1 Variation Of Penetration Values For Different Percentage Of RAP

4.3.2 Softening Point:

The softening point of all RAP binder proportions increase as they undergo ageing because of hardening. 100% RAP bitumen exhibits the highest softening point at 64°C after being subjected to long term ageing, whereas virgin bitumen has a softening point of 45°C. Figure increase of softening point values, respectively of RAP modified binders.

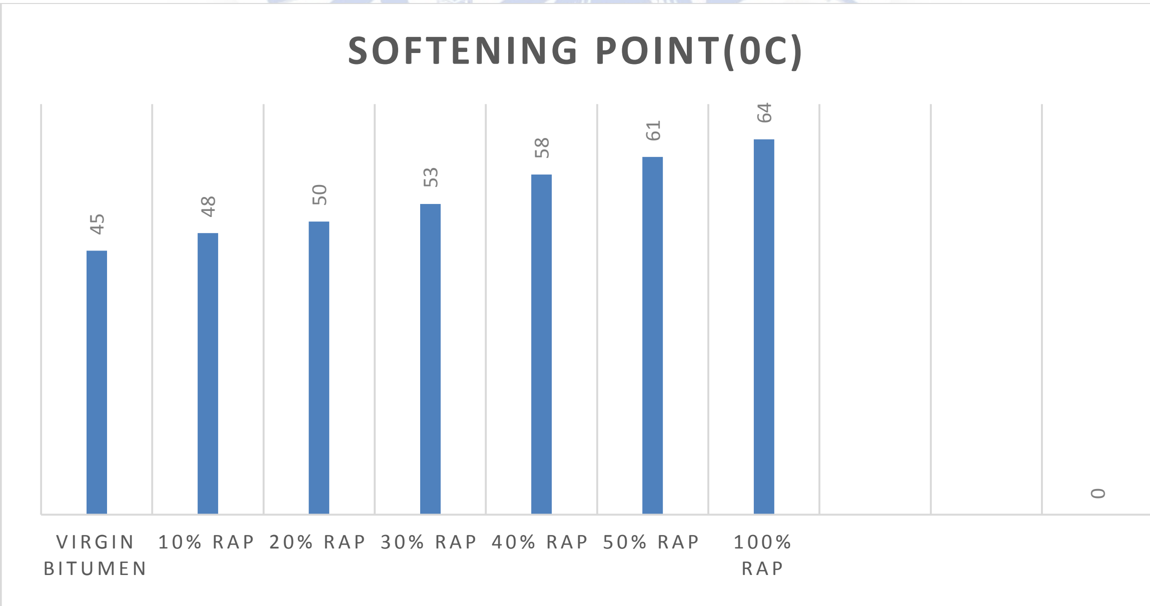


Figure 4.2 Variation Of Softening Point Values For Different Percentage Of RAP

4.3.3 Ductility:

The ductility decreases as the percentage of RAP binder increases due to the loss of volatiles in the aged RAP binder. The ductility value of virgin bitumen is 80 cm. For the respective RAP binder proportions, with the increase of RAP % ductility decreases and for 100% RAP bitumen after the long term ageing ductility value is 16 cm, the lowest.

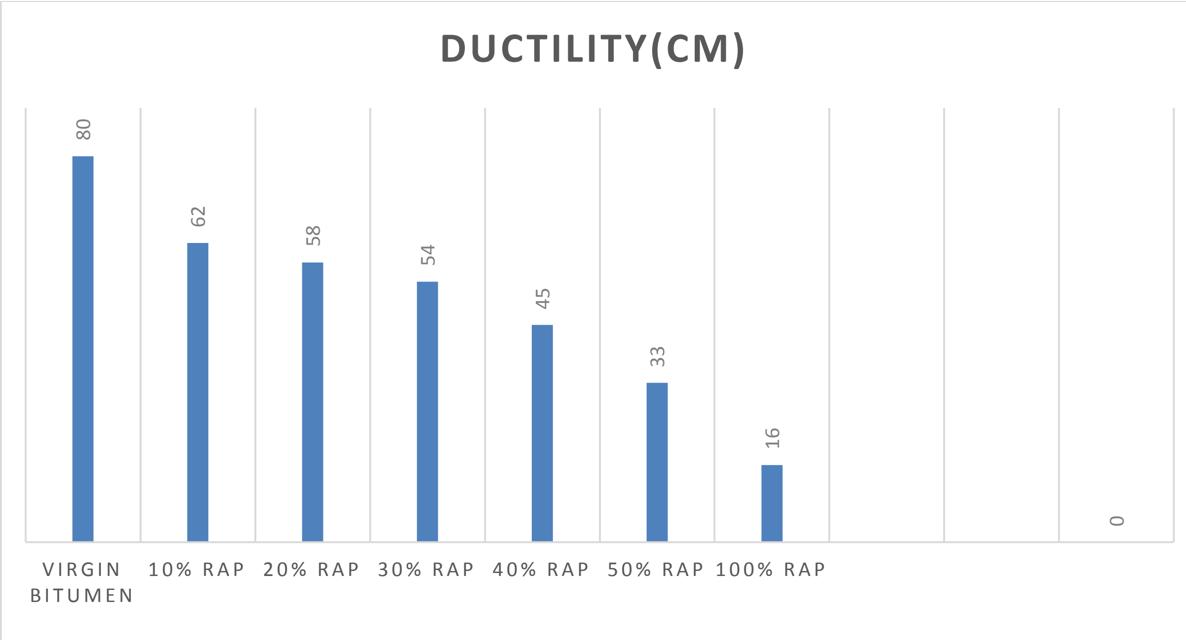


Figure 4.3 Variation Of Ductility Values For Different Percentage Of RAP

4.3.4 Specific Gravity:

The specific gravity decreases as the percentage of RAP binder increases. The specific gravity value of virgin bitumen is 1.03. For the respective RAP binder proportions, with the increase of RAP % ductility decreases and for 100% RAP bitumen after the long term ageing ductility value is 0.937, the lowest.

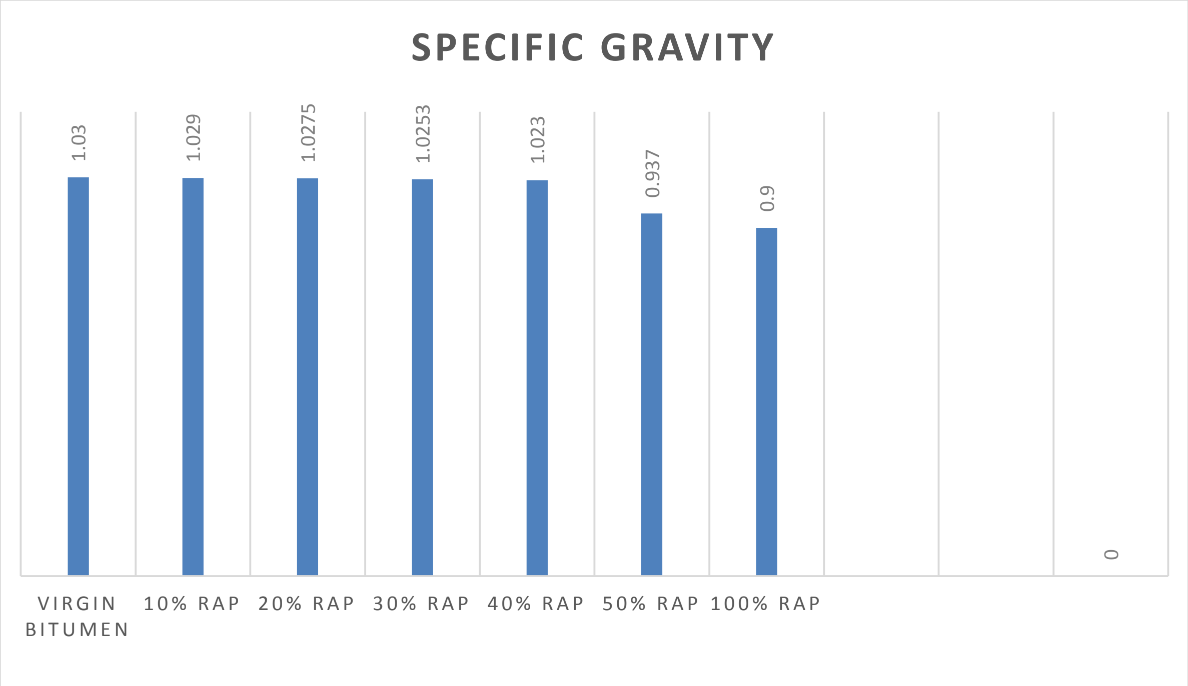


Figure 4.4 Variation Of Specific Gravity Values For Different Percentage Of RAP

4.4 Evaluation Of Aggregates Of Crushed Aggregate

Table 4.3 Evaluation Of Aggregates of Crushed Aggregates

Tests on Aggregate	Virgin Aggregate	Crushed Aggregate	IS limits (min)
Los Angeles Abrasion	29.1%	38.8%	<40%
Crushing	16.6%	35.71%	<30%
Flakiness	9.8%	19.7%	<15%
Elongation	11.2%	21.84%	<15%
Impact	8.66%	32.8%	<30%

Comparison between Crushed Aggregates and Virgin Aggregates properties

4.4.1 Los Angeles Abrasion Test:

As seen in test results the virgin aggregate's value is 29.1% which is very strong but the crushed aggregate is 38.8% which indicates it is not that strong therefore it can be used in low traffic pavement or in base layer of pavement.

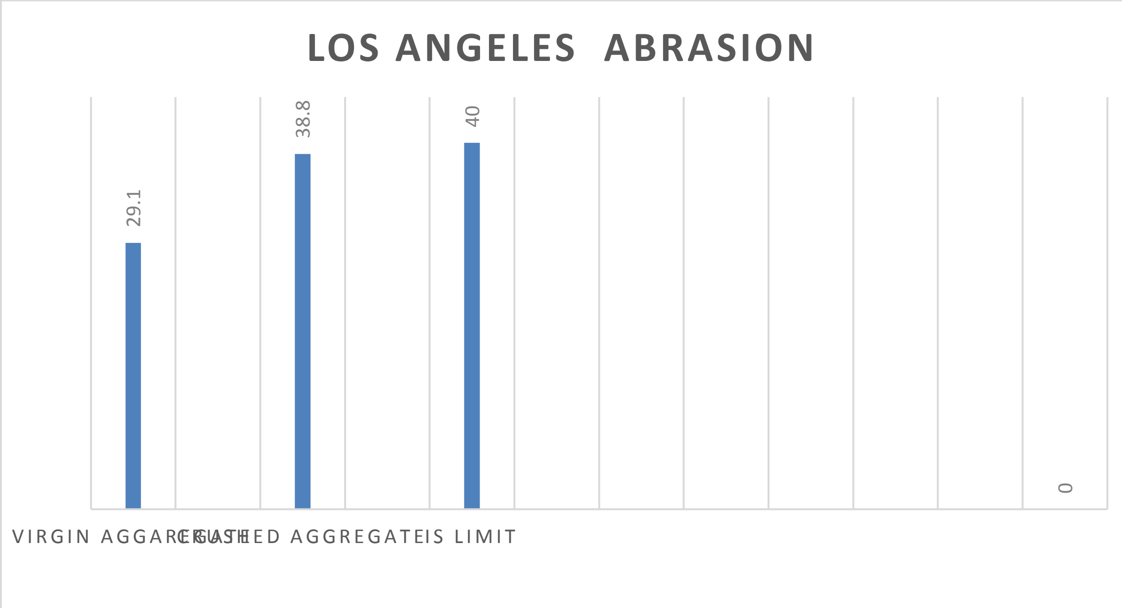


Figure 4.5 Variation Of Abrasion Values For Different Percentage Of RAP

4.4.2 Crushing Test:

As seen in test results the virgin aggregate's value is 16.6% which is very strong but the crushed aggregate is 35.71% which indicates it is weak in strength, therefore it can be used in base layer of pavement.

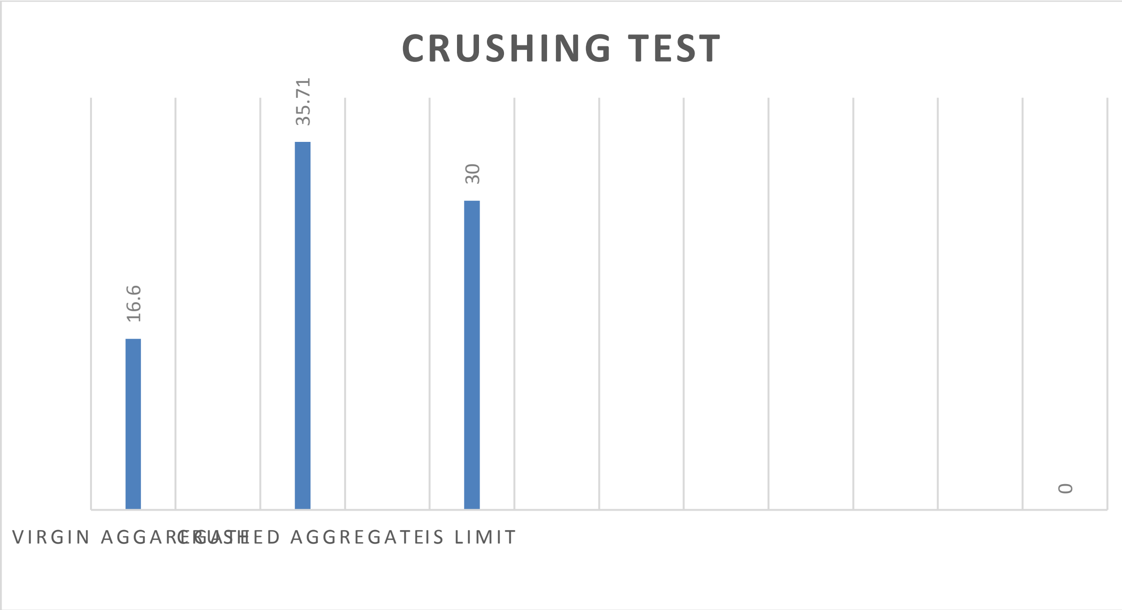


Figure 4.6 Variation Of Crushing Values For Different Percentage Of RAP

4.4.3 Shape Test:

As seen in test results the virgin aggregate's flakiness and elongathion index value is 9.8% % 11.2% respectively which is well shaped aggregates but for the crushed aggregate it is 19.7% & 21.84% which indicates it is not fit for use in pavement but it can be used as sub base layer of the pavement.

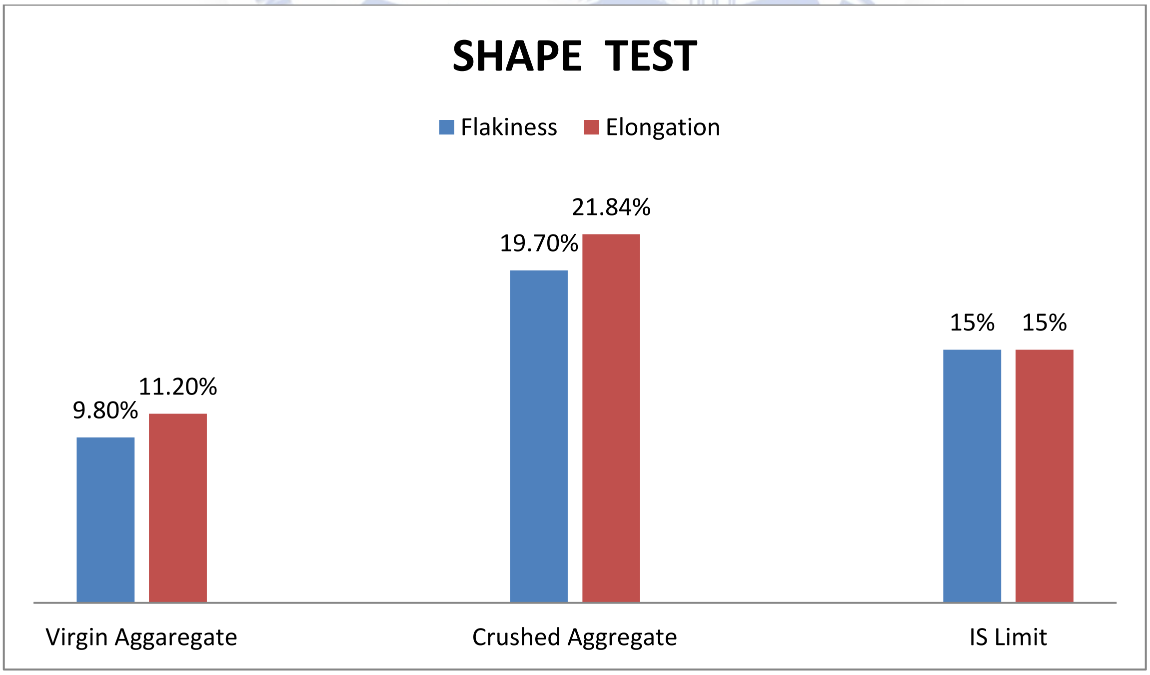


Figure 4.7 Variation Of Shape Values For Different Percentage Of RAP

4.4.4 Impact Test:

As seen in test results the virgin aggregate's value is 8.66% which is very strong but the crushed aggregate is 32.8% which indicates it is weak in strength, therefore it can be used in low traffic pavement , in base layer or in sub base layer of pavement.

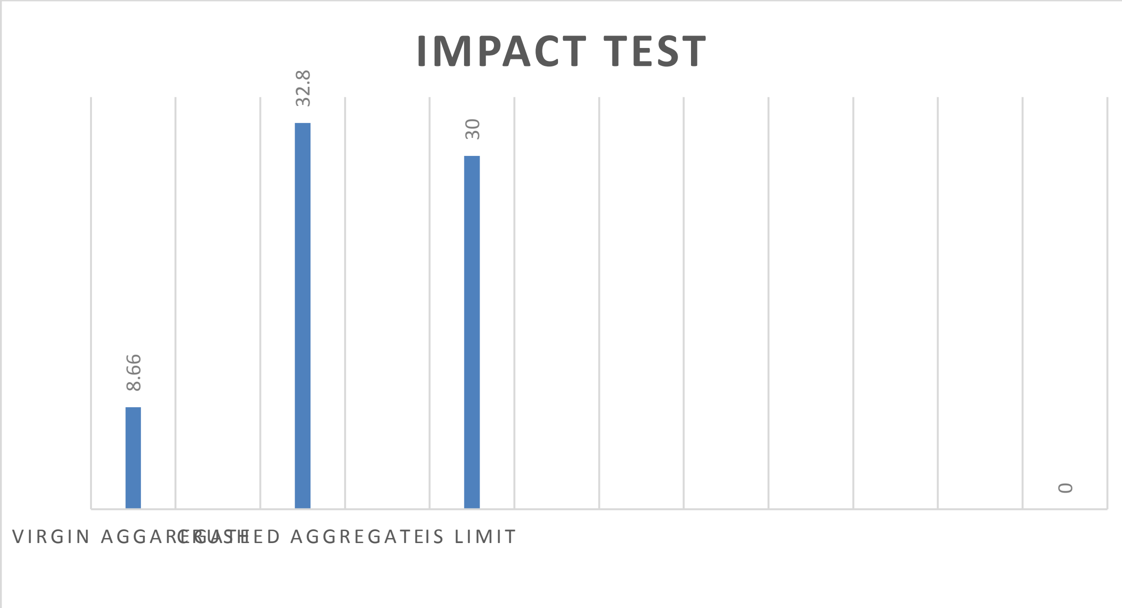


Figure 4.8 Variation Of Impact Values For Different Percentage Of RAP

Chapter 5

Conclusions and Future Scope

5.1 Conclusions

The present study will be helpful for objective identification and characterization of RAP material, the optimum portion of RAP binder will be used in virgin binder and RAP aggregates can be reused in asphalt and sub-base as well.

RAP materials can be successfully used in granular sub base layer of flexible pavements after blending to match the required grading as per MORTH specifications for sub base material.

Asphalt recycling will be sustainable, Asphalt recycling will be economical & Asphalt recycling works will start.

RAP is a new technology with the help of which bituminous pavements can be constructed at a reduced cost as it involves the usage of old bituminous pavement materials. Also it ensures optimization of resources and supports sustainable development. The future will bring greater emphasis on using reclaimed asphalt pavement in mixtures. The industry will improve the effectiveness of using recycled material.

The optimum asphalt content will decrease as the RAP percent increase

5.2 Future Scope

RAP can be successfully used in the construction of a new pavement.

All the problem of disposal of RAP wastes can be easily solved and adverse effect on environment may be avoided by using the RAP materials in flexible pavement construction

It is clear from the different researches, 30% replacement of natural aggregate can be successfully done in base course of flexible pavements, resulting in a savings of around 25-30% in construction cost.

To replace a small fraction of virgin aggregates with RAP, in base layers to promote RAP usage in the pavement industry.

Using RAP does not only help in minimizing the cost of project but also ensures proper utilization of resources.

REFERENCES

1. Khushbu M. Vyas, Shruti B. Khara,“ Technical Viability Of Using Reclaimed Asphalt Pavement In Ahmedabad Brts Corridor For Base Course”.
2. Ahmed Mohamady, Ashraf Elshahat, Mahmoud Fathy Abd-Elmaksoud, Mohamed Hoseny Abdallah, “Effect Of Using Reclaimed Asphalt Pavement On Asphalt Mix Performance”
3. T.Anil Pradyumna, Abhishek Mittal, Dr.P.K.Jain, “Characterization Of Reclaimed Asphalt Pavement (Rap) For Use In Bituminous Road Construction”.
4. BrajeshMishra,“A Study On Use Of Reclaimed Asphalt Pavement (Rap) Materials In Flexible Pavements”.
5. Jaspreet Singh, Jashanjot Singh, A.K Duggal,“A Review Paper On Reclaimed Asphalt Pavement (Rap)”
6. Dharmesh Kumar, Dr. R.K Pandey, “A Reappraisal Paper On Reclaimed Asphalt Pavement (Rap)”
7. K. R. Hansen, A. Copeland, Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage, 2009-2012.
8. I. Sonmez, A. Topcu, S. A. Yildirim, B. K. Eren, E. Gunay, M. Kara, B.Kavakli, “Recycling and reuse of old asphalt coatings in hot bituminous mixtures,” in 24th World Road Congress, 2011.
9. M. Tao, R. B. Mallick, “Effects of Warm-Mix Asphalt Additives on Workability and Mechanical Properties of Reclaimed Asphalt Pavement Material,” Transp. Res. Rec. J. Transp. Res. Board. vol. 2126, pp. 151-160, 2009.
10. Edward J. Hoppe, D. Stephen Lane, G. Michael, Sameer Shetty, “Feasibility Of Reclaimedasphalt Pavement (Rap) Use As Road Base And Subbase Material”.
11. S. M. Mhlongo, O. S. Abiola, J. M. Ndambuki, W. K. Kupolati, “Use Of Recycled Asphalt Materials For Sustainable Construction And Rehabilitation Of Roads”
12. Khanna.S.K And Justo.C.E.G (2001), “Highway Engineering”, 8th Edition, Nemchand And Brothers Publications, Roorkee.
13. S.K.Khanna And C.E.G.Justo, (2000) “Highway Material Testing Manual”, Nemchand And Brothers Publications.
14. H. Ziari & M. M. Khabiri, Effect of Bitumen and RAP Content on Resilient Modulus of Asphalt Concrete,(2005).

15. Rajib, Luis," Performance Evaluation Of Warm Mix Asphalt Mixtures Incorporating Reclaimed Asphalt Pavement."
16. A. Ongel, M. Hugener, "Impact of rejuvenators on aging properties of bitumen," Constr. Build. Mater., vol. 94, pp. 467-474, 2015.
17. IS : 1202 – 1978
18. IS : 1203 – 1978
19. IS : 1205 – 1978
20. IS : 1208 – 1978
21. IS : 2386 (Part I) – 1963, IS: 383-1970, IS : 460-1962
22. IS : 2386 (Part IV) – 1963, IS: 383-1970

ACKNOWLEDGEMENT

We sincerely thank to our guide Ms. Tehsin A. Kazi for her guidance and support for carrying out our project work.

We are also thankful to Dr Abdul Razak Honnutagi, Directorof AIKTC, New-Panvel, Dr R. B. Magar, Head of Civil Engineering Department, AIKTC, New-Panvel, with their guidance and valuable advice helped us in the project for giving a lot of freedom and encouragement and the faculty members of AIKTC, New-Panvel, for providing all kind of possible help throughout for the completion of research work.

Kadir Ahmed Abdul Qayum (12CE23)

Shaikh Asgar Ali Gaffar Ali (14CE54)

Ansari Tahir Ahmad Khurshid (14CE11)

Khan Salman Mehboob (14CE31)