# VIABILITY AND ECONOMICS OF WASTE PLASTIC AND RUBBER COATED AGGREGATES-BITUMEN MIX COMPOSITE FOR ROAD APPLICATION

Project Report submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology

in

**CIVIL ENGINEERING**

under the Supervision of

**Prof. Dr. VEERESH GALI**

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# Certificate

This is to certify that project report entitled "**VIABILITY AND ECONOMICS OF WASTE PLASTIC AND RUBBER COATED AGGREGATES-BITUMEN MIX COMPOSITE FOR ROAD APPLICATION**", submitted by **RAJ SHEKHAR, AMAN GUPTA and UMESH SHARMA** in partial fulfilment for the award of degree of Bachelor of Technology in Computer Science & Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

**Dr. VEERESH GALI**

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# Acknowledgement

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# ABSTRACT

Waste plastics both by domestic and industrial sectors can be used in the production of asphalt mix. Waste plastics, mainly used for packing are made up of Polyethylene Polypropylene polystirene. Their softening varies between 110°C – 140°C and they do not produce any toxic gases during heating but the softened plastics have tendency to form a film like structure over the aggregate, when it is sprayed over the hot aggregate at 160°C. The Plastics Coated Aggregates (PCA) is a better raw material for the construction of flexible pavement. PCA was then mixed with hot bitumen of different types and the mixes were used for road construction. PCA - Bitumen mix showed improved binding property and less wetting property. Waste plastic coated road aggregates can improve road strength. This modified bitumen mix and aggregates show better binding property, stability, density and more resistant to water thus increasing durability of roads with increased resistance to wear and tear of road. The roads laid since 2002 using PCA-Bitumen mixes are performing well. A detailed study on the performances of these roads shows that the constructed with PCA – Bitumen mix are performing well. This process is eco-friendly and economical too.

# Chapter 1. INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as ‘Plastic’. Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Plastics can be divided into two major categories: thermoset and thermoplastics. A thermoset solidifies or “sets” irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, polytetrafluorethylene, and polyethyleneterephthalate. A thermoplastic softens when exposed to heat and returns to original condition at room temperature. Thermoplastics can easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibres. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone, and polyurethane.

According to recent studies, plastics can stay unchanged for as long as 4500 years on earth with increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Plastic in different forms is found to be almost 5% in municipal solid waste, which is toxic in nature. It is a common sight in both urban and rural areas to find empty plastic bags and other type of plastic packing material littering the roads as well as drains. Due to its biodegradability it creates stagnation of water and associated hygiene problems. In order to contain this problem experiments have been carried out whether this waste plastic can be reused productively. The experimentation at several institutes indicated that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give higher strength, higher resistance to water and better performance over a period of time. Waste plastic such as carry bags, disposable cups and laminated pouches like chips, pan masala, aluminum foil and packaging material used for biscuits, chocolates, milk and grocery items can be used for surfacing roads.

Use of plastic along with the bitumen in construction of roads not only increases its life and smoothness but also makes it economically sound and environment friendly. Plastic waste is used as modifier of bitumen to improve some of bitumen properties Roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen.

Further it has been found that such roads were not subjected to stripping when come in contact with water. Use of higher percentage of plastic waste reduces the need of bitumen by 10%. It also increases the strength and performance of the road. Plastic increases the melting point of bitumen and hence missing can be done in more better and easier way. According to Dr. R. Vasudevan, Dean ECA and Professor, Department of Chemistry, Thiagarajar College of Engineering, Madurai, plastic waste replaces 10% to 15% of bitumen, and thereby saves approximately Rs.35000 to Rs.45000 per kilometre of a road stretch. Inclusion of plastic waste in road construction eliminates the plastic shrinkage cracking of road surface and reduces the drying shrinkage to some extent

## 1.1. Objectives

- **VARIOUS TESTS WERE CARRIED OUT TO FIND THE CHARACTERIZATION OF THE FOLLOWING.**

  1. Plastics coated aggregate
  2. Plastics coated aggregate mix with bitumen

- **COST BENEFIT ANALYIS FOR ROAD CONSTRUCTION**
- **CRUMB RUBBER USED IN PLACE OF PLASTIC WASTE AND VARIOUS TESTS WERE CARRIED OUT.**

## 1.2 PROBLEM STATEMENT AND MOTIVATION

Plastics waste scenario in the world, of the various waste materials, plastics and municipal solid waste are great concern. Finding proper use for the disposed plastics waste is the need of the hour. On the other side, the road traffic is increasing, hence the need to increase the load bearing capacities of the roads.

The use of plastics (be consistent in the use of polymer or plastic, since the focus is on plastic waste) coated aggregate for asphalt pavement allows the reuse of plastics waste. Plastics, are versatile packing materials and commonly used by man but they become problem to the environment. After using them mostly used plastics products are bags, cups, films and foams, made up of polyethylene, polypropylene or polystirene.

In INDIA consumption of Plastics will grow 15 million tonnes by 2015 and is set to be the third largest consumer of plastics in the world. Around 55% is being used for packing. They are mostly dropped and left to litter the environment, after the contents have been consumed. The littered plastics, a non biodegradable material, get mixed with domestic waste and make the disposal of municipal solid waste difficult. The municipal solid waste is either incinerated or land filled. Both disposal methods are not the best ways to dispose the waste and it causes both land and air pollution. Moreover, if municipal solid waste, contains PVC waste, when burnt, it produces toxic gases like dioxins. Disposal of plastic wastes in an eco friendly way is the main thrust area of today’s research works. The author has developed innovative technique to use the waste plastics for the construction of asphalt pavement. This process is eco friendly and can promote value addition to the waste plastic.

# Steel City residents to walk on 'plastic' road

**Debashish Sarkar**
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**JAMSHEDPUR:** In what may come as a surprise to many, Steel City residents are all set to walk on 'plastic' roads.

The Jamshedpur Utility and Services Company (Jusco), a cent percent subsidiary of Tata Steel, on Wednesday successfully constructed a 400-feet stretch of a road using plastic waste in the Circuit House area of the city. The road is near the income tax commissioner's office.

Earlier, there was a successful trial run before this stretch was taken up. This is the first time that such an endeavour has been made anywhere in the state.

The 400-feet stretch of a road using plastic waste in the Circuit House area of Jamshedpur. HT PHOTO

It bears recall that *Hindustan Times* in its September 10 edition had reported that Tata Steel and Jusco are working together to develop commercially viable methods of using plastic waste in laying roads to add to their life and strength.

Jusco has been trying out various ways to tackle the menace of plastic waste and to use it in a productive manner.

Subsequently, it consulted Dr R Vasudevan, who is associated with Thiagarajar College of Engineering (TCE), Madurai, and learnt about the technology of using plastic waste in laying roads. Bangalore was the first city in the country to adopt this technology.

"On Wednesday, we constructed a 400-feet stretch of a road in CH area and looking at the success of this endeavour, Jusco decided to explore the possibilities of using plastic waste in town roads in a big way," Jusco spokesperson Rajesh Ranjan stated in a press release on Thursday evening.

Earlier, the company had laid a small stretch by mixing plastic waste and tar near Jubilee Park nursery.

Listing the benefits of such roads, Ranjan further said that the process increases the strength of the road, helps it develop better resistance to water and water stagnation, ensures there are no potholes, increases binding and better bonding of the mix, increases load withstanding properties, decreases consumption of bitumen, reduces maintenance cost and the life span of such roads is increased substantially.

"Plastic in different forms constitutes almost five per cent of municipal solid waste, which is toxic in nature. It leads to stagnation of water and associated hygiene problems. As it is non-biodegradable, it can choke drains and other water bodies, resulting in the spread of many communicable diseases. Its use in building roads may go a long way in fighting this menace," reminded Ranjan.

**Fig 1.1 Media report on plastic roads**

THE NEW INDIAN EXPRESS
* CHENNAI MONDAY 7 OCTOBER 2013

A worker mixing plastic with bitumen; and a road being laid on the premises of a packaging company using plastic–bitumen mix, near Puducherry on Sunday | G PATTASIRAMAN

# Pvt Industry in Pondy Lays Plastic Road on Trial Basis

**Express News Service**

**Puducherry:** A private industrial unit near Kirumambakkam has laid plastic roads on its pemises on an experimental basis. The 250 metre road covering an area of about 1,500 square metres is being laid under the guidance of Prof Vasudevan of Thiagarajar College of Engineering, Madurai.

Dr N Ramesh of Pondicherry Pollution Control Committee (PPCC), who was present said 15 per cent of plastic waste is mixed with bitumen for road work. He claimed that the durability of roads laid with plastic waste is 10 years and the road strength would be 2,500 kg per kilometer compared to the 1,000 kg per km laid with ordinary bitumen. The durability of these roads is five years if pure bitumen mixture is used.

Stating that this was for the first time that plastic waste is being used for laying roads, Ramesh said if it is found viable, plastic roads could be undertaken in a big way. By using the plastic waste for road laying, the disposal of hazardous waste would become possible and the quality of roads would also be enhanced, he added. Puducherry generates about 20 tonnes of plastic waste from industries on a daily basis and the disposal of it is a big challenge for the administration, Ramesh said.

It may be recalled that earlier in May this year, Tamil Nadu Chief Minister J Jayalalithaa had announced the plan of laying nealry 1,100 km roads using plastic waste.

**Fig 1.2 Media report on plastic roads**

# Chapter 2. LITERATURE REVIEW

The concept of utilization of waste plastic in construction of flexible road pavement has been done since 2000 in India. In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength and life of road pavement. But its resistance towards water is poor. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with synthetic polymers like rubber and plastics. Use of plastic waste in the bitumen is similar to polymer modified bitumen. The blending of recycled LDPE to asphalt mixtures required no modification to existing plant facilities or technology. Polymer modified bitumen has better resistance to temperature, water etc. This modified bitumen is one of the important construction materials for flexible Road pavement. Since 90's, considerable research has been carried out to determine the suitability of plastic waste modifier in construction of bituminous mixes. Zoorab & Suparma (April,2000) reported the use of recycled plastics composed predominantly of polypropylene and low density polyethylene in plain bituminous concrete mixtures with increased durability and improved fatigue life. Dense bituminous macadam with recycled plastics, mainly low density polyethylene (LDPE) replacing 30% of 2.36–5mm aggregates, reduced the mix density by 16% and showed a 250% increase in Marshall Stability; the indirect tensile strength (ITS) was also improved in the 'Plastiphalt' mixtures D.N. Little worked on the same theme and he found that resistance to deformation of asphaltic concrete modified with low density polythene was improved in comparison with unmodified mixes. It is found that the recycled polyethylene bags may be useful in bituminous pavements resulting in reduced permanent deformation in the form of rutting and reduced low temperature cracking of pavement surfacing Bindu et al. investigates the benefits of stabilizing the stone mastic asphalt (SMA) mixture in flexible pavement with shredded waste plastic. Conventional (without plastic) and the stabilized SMA mixtures were subjected to performance tests including Marshall Stability, tensile strength and compressive strength tests. Triaxial tests were also conducted with varying percentage bitumen by weight of mineral aggregate (6% to 8%) and by varying percentage plastic by weight of mix (6% to 12% with an increment of 1%). Plastic content of 10% by weight of bitumen is recommended for the improvement of the performance of Stone Mastic Asphalt mixtures.

10% plastic content gives an increase in the stability, split tensile strength and compressive strength of about 64%, 18% and 75% respectively compared to the conventional SMA Mix. Triaxial test results show a 44% increase in cohesion and 3% decrease in angle of shearing resistance showing an increase in the shear strength. The drain down value decreases with an increase in plastic content and the value is only 0.09 % at 10% plastic content and proves to be an effective stabilizing additive in SMA mixtures. Stone Mastic Asphalt is a gap graded bituminous mixture containing a high proportion of coarse aggregate and filler. It has low air voids with high levels of macro texture when laid, resulting in a waterproof layer with good surface drainage. Stabilizing additives are needed in the mastic which is rich in binder content to prevent the binder from draining down from the mix. Polymers and fibers are the commonly used stabilizing additives in SMA. Based on many research reports and engineering case studies has been shown that the use of stone mastic asphalt (SMA) on road surfaces can achieve better rut-resistance and durability. Recycled LDPE of a size between 0.30 and 0.92mm replacing 15% aggregates in asphalt surfacing nearly doubled the Marshall quotient, and increased the stability retained (SR) by 15%, implying improved rutting and water resistance. A 20% increase of binder content was required in this case.

# 2.1 DATA ON PLASTIC CONSUMPTION & GENERATION OF PLASTIC WASTE

A material that contains one or more organic polymers of large molecular weight, solid in its finish state and at some state while manufacturing or processing into finished articles, can be shaped by its flow is termed as plastics. The plastic constitutes two major category of plastics; (i) Thermoplastics and (ii) Thermoset plastics. The thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total postconsumer plastics waste generated. The following table describes the average municipal solid waste production from 0.21 to 0.50 Kg per capita per day in India.

**TABLE 2.1 Municipal solid waste generation in Indian Cities**

| POPULATION RANGE (Millions) | AVERAGE PER CAPITA VALUE |
|---|---|
| 0.1-0.5 | 0.21 |
| 0.5-1.0 | 0.25 |
| 1.0-2.0 | 0.27 |
| 2.0-5.0 | 0.35 |
| >5 | 0.50 |

Table 2.2 provides the data on total plastics waste consumption in India during last decade.

**TABLE 2.2 Plastic consumption in India**

| YEAR | CONSUMTPTION |
|---|---|
| 1996 | 61000 |
| 2001 | 400000 |
| 2006 | 700000 |
| 2011 | 13500000 |

Due to the change in scenario of life style, the polymer demand is increasing everyday across the globe. Following table gives the polymer demand in India from 1995 to 2011.

**TABLE 2.3 POLYMER DEMAND IN INDIA**

| S. No. | TYPE OF POLYMER | 1995-96 | 2001-02 | 2006-07 | 2010-11 |
|---|---|---|---|---|---|
| 1 | PE | 0.83 | 1.83 | 3.27 | 7.12 |
| 2 | PP | 0.34 | 0.88 | 1.79 | 3.88 |
| 3 | PVC | 0.49 | 0.87 | 1.29 | 2.87 |
| 4 | PET | 0.03 | 0.14 | 0.29 | 0.75 |
| TOTAL | | 1.69 | 3.72 | 6.64 | 14.62 |

The comparison of per capita plastic consumption in India with rest of the word is presented in Table 2.4.

**TABLE 2.4 PLASTIC WASTE CONSUMPTION (P/C/YEAR)**

| COUNTRY | PER YEAR CONSUMPTION (kg) |
|---|---|
| INDIA | 6.0 |
| EAST EUROPE | 10.0 |
| SOUTH EAST ASIA | 10.0 |
| CHINA | 24.0 |
| WEST EUROPE | 65.0 |
| NORTH AMERICA | 90.0 |
| WORLD AVERAGE | 25.0 |

India has among the lowest per capita consumption of plastics and consequently the plastic waste generation is very low as seen from the table. 2.5

**TABLE 2.5 PLASTIC WASTE CONSUMPTION**

| DESCRIPTION | WORLD | INDIA |
|---|---|---|
| PER CAPITA PER YEAR CONSUMPTION OF PLASTIC% | 24-28 | 12-16 |
| RECYCLING% | 25 | 60 |
| PLASTIC IN SOLID WASTE% | 7 | 9 |

## 2.2 PLASTIC WASTE CLASSIFICATION

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

Thermoplastic and Thermosetting materials are tabulated in Table 2.6.

**TABLE 2.6 THERMOPLASTIC AND THERMOSETTING MATERIALS**

| **THERMOPLASTIC** | **THERMOSETTING** |
|---|---|
| PET | BAKELITE |
| PP | EPOXY |
| PVA | MELAMINE |
| PVC | POLYSTER |
| PS | POLYURETHANE |
| LDPE | UREA |
| HDPE | ALKYD |

Most of thermoplastics on heating soften at temperature between 130-140°C. The TGA analysis of thermoplastics has proven that there is no gas evolution in the temperature range of 130-180℃ and beyond 180℃ gas evolution and thermal degradation may occur. Thus the waste plastic can easily be blended with the bitumen as the process for road construction using bitumen is carried out in the range of 155-165℃.

## 2.3 BITUMEN

Bitumen is a sticky, black and highly viscous liquid or semi-solid, in some natural deposits. It is also the residue or by-product of fractional distillation of crude petroleum. Bitumen Composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen), up to 5% sulfur, 1% nitrogen, 1% oxygen and 2000ppm metals. Also bitumen is Mixture of about 300 - 2000 chemical components, with an average of around 500 - 700. It is the heaviest fraction of crude oil, the one with highest boiling point (525ºC).

### 2.3.1 DIFFERENT FORMS OF BITUMEN

**Cutback Bitumen**: A suitable solvent is mixed to reduce viscosity.

**Bitumen Emulsion**: bitumen is suspended in finely divided condition in aqueous medium 60% bitumen and 40% water.

**Bituminous Primers**: Mixing of penetration bitumen with petroleum distillate.

**Modified Bitumen**: Blend of bitumen with waste plastics & or crumb rubber.

### 2.3.2 VARIOUS GRADES OF BITUMEN USED FOR PAVEMENT PURPOSE

Grade: 30/40; Grade: 60/70; Grade: 80/100

### 2.3.3 THE DESIRABLE PROPOERTIES OF BITUMEN FOR PAVEMENT

- Good cohesive and adhesive binding property.
- Water repellant property.

- It is its thermoplastic nature, (stiff when coldliquid when hot), that makes bitumen so useful.

### 2.3.4 DRAWBACKS OF BITUMEN

- Temperature Effect: At high temperature bleeding of road occurs reducing performance of road.
- Oxidation Effect: Due to oxidation bitumen may led to cracking & crazing phenomenon.
- Water Effect: Due to water, bitumen strip off from the aggregate forming pothole on roads as being water repellent material. Reducing life of roads.
- High Cost – Being petroleum product it costs much higher

### 2.3.5 WHY WASTE PLASTIC? AS A BINDER AND MODIFIER

- Soften at around 130°C.
- No gas evolution in the temperature range of 130-180°C.
- Have a binding property hence used as a binder.
- Can also be mixed with binder like bitumen to enhance their binding property.

# 2.4 PROPERTIES OF WASTE PLASTICS

### Thermal Study

Thermal behavior of the polymers namely polyethylene, polypropylene and polystyrene is shows in Table 2.7

**TABLE 2.7 THERMAL BEHAVIOR OF PE, PP, PS**

| POLYMER | SOLUBILITY | | SOFTENING TEMP. IN DEG.C | PRODUCTS REPORTED | DECOMPOSITION TEMP DEG.C | PRODUCTS REPORTED | IGNITION TEMP RANGE | PRODUCTS REPORTED |
|---|---|---|---|---|---|---|---|---|
| | WATER | EPT | | | | | | |
| PE | Nil | Nil | 100-120 | No gas | 270-350 | C2H2 | >700 | CO2 |
| PP | Nil | Nil | 140-160 | No gas | 270-300 | C2H2 | >700 | CO2 |
| PS | Nil | Nil | 110-140 | No gas | 300-350 | C2H2 | >700 | CO2 |

### 2.4.1 Binding Property

The molten plastics waste exhibits good binding property. Various raw materials like granite stone, ceramics etc. were coated with plastics and then molded into a stable product. On cooling, it was tested for compression and bending strengths. Vasudevan et al. found that the values of the compression strength and bending strength increases with above formulation shows that the plastics can be used as a binder.

## 2.5 PROPERTY REQUIREMENTS FOR MATERIALS IN ASPHALTING OF FLEXIBLE PAVEMENTS

In order to withstand tire and weather, pavement surface layers contain the strongest and most expensive materials in road structures. Characteristics they exhibit like friction, strength, noise and ability to drain off surface water are essential to vehicles safety and riding quality. Some are already associated with a standard test method. Apart from the nature of component binder and aggregates, asphalt performance strongly depends on the mixture type.

Selection of a type for surface layers has to consider a multitude of factors including traffic, climate, condition of existing surface, and economics. No single mixture type could provide all the desired properties, often some are improved at the expense of others, making the selection difficult and contentious.

A number of properties are required of the component (particularly the coarse) aggregates such as resistance to fragmentation, affinity with bitumen, water absorption resistance, leaching etc. Dense bituminous macadam (DBM) is commonly used in binder course and base.

## 2.6 CRUMB RUBBER

### 2.6.1 Crumb Rubber Overview

Crumb rubber is the name given to any material derived by reducing scrap tires or other rubber into uniform granules with the inherent reinforcing materials such as steel and fiber removed along with any other type of inert contaminants such as dust, glass, or rock.

Crumb rubber is manufactured from two primary feed stocks: tire buffing, a by - product of tire retreading and scrap tire rubber. Scrap tire rubber comes from three types of tires: passenger car tires, which represent about 84 percent of units or approximately 65 percent of the total weight of scrap tires; truck tires, which constitute 15 percent of units, or 20 percent of the total weight of. scrap tires; and off-the-road tires, which account for 1 percent of units, or 15 percent of the total weight of scrap tires. End product yields for each of these tire types are affected by the tire's construction, strength and weight. On average, 10 to 12 pounds of crumb rubber can be derived from one passenger tire

### 2.6.2 Crumb Rubber Modified Bitumen

Crumb Rubber Modified Bitumen (CRMB) is hydrocarbon binder obtained through physical and chemical interaction of crumb rubber (produced by recycling of used tires) with bitumen and some specific additives. The Flextal range of CRMB offers binders which are stable and easy to handle with enhanced performances.

CRMB is suitable for pavements submitted to all sorts of weather conditions, highways, traffic denser roads, junctions, heavy duty and high traffic sea port roads etc. It is a durable and economical solution for new construction and maintenance of wearing courses.

# Chapter 3. MATERIALS AND METHODS

## 3.1 CHARACTERISTICS OF PLASTIC COATED AGGREGATE (USED FOR FLEXIBLE PAVEMENT)

### 3.1.1 Moisture Absorption and Void Measurement

For the flexible pavement, hot stone aggregate (170°c) is mixed with hot bitumen (160°c) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetration value and viscoelastic property. The aggregate, when coated with plastics improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

### 3.1.2 Soundness Test

Soundness test is intended to study the resistance of aggregate to weathering action. The weight loss is attributed to the poor quality of the aggregate. The plastic coated aggregate, did not show any weight loss, thus conforming the improvement in the quality of the aggregate.

### 3.1.3 Aggregated Impact Value

A study on the effect of plastic coating was extended to study on the aggregate impact value. Aggregate was coated with 1% & 2% plastics by weight and the plastic coated aggregate was submitted to Aggregate Impact Value test and the values were compared with values for non coated aggregate.

### 3.1.4 Los Angel's Abrasion Test

The repeated movement of the vehicle with iron wheeled or rubber tire will produce some wear and tear over the surface of the pavement. This wear and tear percentage of an aggregate is determined with the help of Los Angeles abrasion study. Under this study the percentage of wear and tear values of the plastic coated aggregate is found to be in decreasing order with respect to the percentage of plastics. When the Los Angeles abrasion value of plain aggregate value is compared with the Plastic coated aggregate the values are less for polymer coated aggregate.

### 3.1.5 Marshall Stability

Marshall stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/min. Marshall stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses.

### 3.1.6 Softening point test

This test is conducted using Ring and ball apparatus. The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

### 3.1.7 Penetration Index Test

It is measured using Penetrometer. The penetration of a bituminous material is the distance in tenths of a millimeter, which a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.

### 3.1.8 Ductility Index Test

The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature

### 3.1.9 Softening point test

(Ring and ball apparatus):-The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test

### 3.1.10 Flash and Fire point test

In the interest of safety, legislation has been introduced in most countries fixing minimum flash point limits to prevent the inclusion of highly inflammable volatile fractions in kerosene distillates.

# 3.2 PROCESSES FOR MANUFACTURING BITUMEN MIX ROAD USING WASTE PLASTIC

There are two important processes namely **dry process** and **wet process** used for bitumen mix flexible pavement.

## 3.2.1 Dry Process

For the flexible pavement, hot stone aggregate (170C) is mixed with hot bitumen (160 C) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetration value and viscoelastic property. The aggregate, when coated with plastics improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

### 3.2.1.1 Advantages of Dry Process

- Plastic is coated over stones – improving surface property of aggregates.
- Coating is easy & temperature required is same as road laying temp.
- Use of waste plastic more than 15% is possible.
- Flexible films of all types of plastics can be used.
- Doubles the binding property of aggregates.
- No new equipment is required.
- Bitumen bonding is strong than normal.
- The coated aggregates show increased strength.
- As replacing bitumen to 15% higher cost efficiency is possible.
- No degradation of roads even after 5 -6 yrs after construction.
- Can be practiced in all type of climatic conditions.

- No evolution of any toxic gases as maximum temperature is 180ºC.

#### 3.2.1.2 Disadvantages of Dry Process

The process is applicable to plastic waste material only.

### 3.2.2 Wet Process

Waste plastic is ground and made into powder; 6 to 8 % plastic is mixed with the bitumen. Plastic increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life. Use of shredded plastic waste acts as a strong “binding agent” for tar making the asphalt last long. By mixing plastic with bitumen the ability of the bitumen to withstand high temperature increases. The plastic waste is melted and mixed with bitumen in a particular ratio. Normally, blending takes place when temperature reaches 45.5°C but when plastic is mixed, it remains stable even at 55°C. The vigorous tests at the laboratory level proved that the bituminous concrete mixes prepared using the treated bitumen binder fulfilled all the specified Marshall mix design criteria for surface course of road pavement. There was a substantial increase in Marshall Stability value of the mix, of the order of two to three times higher value in comparison with the untreated or ordinary bitumen. Another important observation was that the bituminous mixes prepared using the treated binder could withstand adverse soaking conditions under water for longer duration.

#### 3.2.2.1 Advantages of Wet Process:

This Process can be utilized for recycling of any type, size, shape of waste material (Plastics, Rubber etc.)

#### 3.2.2.2 Disadvantages of Wet Process:

- Time consuming- more energy for blending.
- Powerful mechanical is required.

- Additional cooling is required as improper addition of bitumen may cause air pockets in roads.
- Maximum % of waste plastic can be added around 8 %.

## 3.3 Various Tests to be performed on Bitumen and Crumb Rubber Modified Bitumen

### 3.3.1 Penetration Test

This test is done to determine the penetration of bitumen as per IS: 1203 – 1978. The principle is that the penetration of a bituminous material is the distance in tenths of a mm, that a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.

### 3.3.2 Softening Point Test

This test is done to determine the softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen as per IS: 1205 –1978. The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

### 3.3.3 Specific gravity Test

This test is done to determine the specific gravity of semi-solid bitumen road tars, creosote and anthracene oil as per IS: 1202 – 1978. The principle is that it is the ratio of mass of a given volume of bitumen to the mass of an equal volume of water, both taken at a recorded/specified temperature.

### 3.3.4 Ductility Test

This test is done to determine the ductility of distillation residue of cutback bitumen, blown type bitumen and other bituminous products as per IS: 1208 – 1978. The principle is : The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature.

### 3.3.5 Viscosity test

This test is done to determine the viscosity of bitumen as per IS: 1206-1978. The principle is that viscosity denotes the fluid property of bituminous material and it is a measure of resistance of flow. On application of temperature, it greatly influences the strength of resulting paving mixes.

# Chapter 4. RESULTS AND DISCUSSIONS

## 4.1 CHARACTERISTICS OF PLASTIC COATED AGGREGATE

For the asphalt pavement, stone aggregate with specific characteristics is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity. The aggregate was coated with waste plastic material by the following process. The waste plastics namely films, cups and foams shredded to the required size of 2.5mm – 4.36mm. The aggregate is heated to 170°c. The shredded waste plastic was sprayed over the hot aggregate. Plastics got softened and coated over the aggregate. The extent of coating was varied by using different percentage of plastics. Higher percentage of plastics was used up to 25% to evaluate the binding property, whereas lower percentage of plastics like 1% to 5% to evaluate the properties like moisture absorption and soundness.

### 4.1.1 MOISTURE ABSORPTION:

A known quantity of plastics coated aggregate was taken. It was then immersed in water for 24hrs. Then the aggregate was dried using dry clothes and the weight was determined. The water absorbed by the aggregate was determined from the weight difference. The test was repeated with plain aggregate for comparison of results.

**TABLE 4.1 WATER ABSORPTION OF PCA**

| % OF POLYMER COATED OVER AGG. | Wt. OF ADDED PLASTIC IN gms | WATER ABSORPTION | | | |
|---|---|---|---|---|---|
| | | SAMPLE 1 | SAMPLE 2 | SAMPLE 3 | AVERAGE |
| - | - | 0.56 | 0.57 | 0.55 | 0.56 |
| 0.5 | 2.50 | 0.44 | 0.40 | 0.42 | 0.42 |
| 0.75 | 3.75 | 0.32 | 0.28 | 0.28 | 0.29 |
| 1.0 | 5.00 | 0.24 | 0.22 | 0.20 | 0.22 |

### 4.1.2 SOUNDNESS TEST

Soundness is mainly to test the stability towards weathering of the aggregates and its chemical resistance. The plain aggregate when exposed to stagnation of water, the water penetrates easily inside the pores of the aggregates. Since the water contains dissolved salts, the salt gets crystallized and expands inside the pores during evaporation resulting in the breaking of the aggregates. The low soundness property directly depends upon the amount of voids and porosity of the aggregates . This is evaluated by conducting accelerated weathering test cycle. The average loss in weight of aggregate for 5 cycles should not exceed 12 % when tested with sodium sulphate.

### 4.1.3 AGGREGATE IMPACT TEST

It is used to evaluate the toughness of stone or the resistance of the aggregate to fracture under repeated impacts. The aggregates were subjected to 15 blows with a hammer of weight 14kg and the crushed aggregates were sieved on 2.26mm sieve. The aggregate impact value is the percentage of fine (passing through the 2.36mm sieve size) to the total weight of the sample. The aggregate impact value should not exceed 30% for use in wearing course of pavements. Maximum permissible values are 35% for bituminous macadam and 40 % for water bound macadam. The plastic coated aggregates were subjected to this test.

### 4.1.4 LOS ANGELES ABRASION TEST

The principle of Los Angeles abrasion (L.A.R) test is to find the percentage wear due to relative rubbing action between the aggregate and the steel balls used as abrasive. LAR value should be less than 30% for pavements. For the L.A. abrasion test, the portion of a plastics coated aggregate sample retained on the 1.70 mm (No. 12) sieve was placed in a large rotating drum that contains a shelf plate attached to the outer wall. A specified number of steel spheres were then placed in the machine and the drum was rotated for 500 revolutions at a speed of 30 – 33 revolutions per minute (rpm). The material was then extracted and separated into material passing the 1.70 mm (No. 12) sieve and material retained on the 1.70 mm (No. 12) sieve. The retained material (larger particles) was then weighed and compared to the original sample weight. The difference in weight was reported as a percent of the original weight and called the percentage loss. LAR value should be less than 30 percent for pavements.

### TABLE 4.2 RESULTS OF VARIOUS TESTS ON PCA

| % OF PLASTICS | MOISTURE ABSORPTION | SOUNDNESS | VOIDS | AGG. CRUSHING TEST | LA abrasion | Agg. Impact value |
|---|---|---|---|---|---|---|
| Nil | 4% | 5% | 4% | 26% | 37% | 25.4% |
| 1% | 1% | NIL | 2.2% | 21% | 32% | 21.20 % |
| 2% | 1% | NIL | 1% | 20% | 29% | 18.5% |
| 3% | 0.5% | NIL | NIL | NA | NA | NA |
| 5% | 0.35% | NIL | NIL | NA | NA | NA |
| 10% | 0.12% | NIL | NIL | NA | NA | NA |

## 4.2 CHARACTERISTICS OF "PCA-BITUMEN MIX"

The hot plastic coated aggregate was mixed with 80/100 bitumen at 160°C. The bitumen polymer coated aggregate mix was subjected to tests like Stripping test, Bitumen extraction test and Marshall Value determination test.

### 4.2.1 STRIPPING

Stripping value is the determination of binding strength of the aggregate and the bitumen. It is tested by immersing bitumen coated aggregate in water for 24hrs at 40°C. When bitumen coated aggregate was immersed in water, the water penetrates into the pore and voids of the stone resulting in the peeling of the bitumen. This in turn results in the loosening of the aggregate and forming potholes. 200gm of PCA-bitumen mix was taken and cooled to room temperature and weighed. The mixture was immersed in water bath maintained at 40°C for 24hrs. After 24hrs the stripping was observed and the percentage of stripping was noted

**TABLE 4.3 STRIPPING VALUE OF PCA**

| TYPE OF AGG | TIME | STRIPPING |
|---|---|---|
| PLAIN BITUMEN COATED AGG | 24hrs | 5% |
| POLYMER COATED AGG | 72hrs | Nil |

### 4.2.2 BITUMEN EXTRACTION TEST ASTM D2172

The extraction tests were carried out in the following order.

1. Bitumen coated aggregate was treated with TCE and the bitumen was extracted. Here the extraction was almost complete
2. PCA bitumen mix was first treated with TCE and the bitumen extracted was separated and estimated. Complete removal of bitumen did not take place
3. So further extraction was carried out using another solvent, namely decaline, which can act as a solvent to extract plastics also.
4. The PCA bitumen mix obtained from step 2 is then treated with decaline for another 30 minutes and separated bitumen was estimated.
5. The extraction was again repeated after refluxing the mix for 5 minutes. Further separation took place.

The process was repeated using aggregate, coated with different percentage of plastics.

**TABLE 4.4 BITUMEN EXTRACTION TEST RESULTS**

| Plastic content (% by weight) | Bitumen extracted after 5 min % | Bitumen extracted after 10 min % | Bitumen extracted after 15 min % |
|---|---|---|---|
| 0 | 96.0 | 98.0 | 99.0 |
| 0.5 | 63.5 | 88.7 | 92.3 |
| 0.75 | 63.2 | 86.7 | 90.7 |
| 1.0 | 61.3 | 76.7 | 83.6 |

### 4.2.3 MARSHALL STABILITY

Marshall Stability value is the basic study on the stability of the mix with application of load. The standard mixture was prepared in accordance with IRC specifications. The aggregates were coated with plastics waste as described earlier. This plastics coated aggregates mix was then mixed with 5% of total quantity of 80/100 bitumen. The mixture was transferred to the mould. It was compacted with 75 blows on either side. The specimens (64 mm height and 10.2 mm diameter) were prepared by

1. Varying the percentage of plastics waste and
2. by varying bitumen quantity.

These specimens were tested. The voids present in the mix also play an important role in deciding the performance of the mix. The following properties were determined: Voids filled with Mineral Aggregate, Air Voids, Voids filled with bitumen, Bulk Density, Specific Gravity and Voids in Mix. The results are reported in the Table-4.6. Marshal Stability Value is indicative of load withstanding property of the flexible pavement. The minimum value is fixed as 4KN by IRC with 5% of bitumen and 95% of stone aggregate

**TABLE 4.5 MARSHALL STABILITY VALUE OF PCA**

| % OF BITUMEN | %OF POLYMER wrt wt of bitumen | Type of bitumen | PCA | Marshall value Kn | FLOW VALUE X0.25mm | Void percentage | Marshall quotient Kn/mm |
|---|---|---|---|---|---|---|---|
| 4.5 | 5 | PP | PCA | 16 | 4 | 53 | 4 |
| 4.5 | 10 | PP | PCA | 20 | 5 | 55 | 4 |
| 4.5 | 5 | LDPE | PCA | 16 | 4 | 55 | 4 |
| 4.5 | 10 | LDPE | PCA | 17.5 | 4 | 55 | 4.38 |
| 4.5 | 10 | PE foam | PCA | 20 | 4 | 58 | 5 |
| 4.5 | 15 | PE foam | PCA | 22.5 | 4 | 56 | 5.63 |
| 4.5 | 20 | PE foam | PCA | 26.5 | 4 | 56 | 6.62 |

**TABLE 4.6 MARSHALL STABILITY VALUE OF POLYMER MODIFIED BITUMEN**

| % OF BITUMEN | %OF POLYMER wrt wt of bitumen | Type of bitumen | PMB | Marshall value Kn | FLOW VALUE X0.25mm | Void percentage | Marshall quotient Kn/mm |
|---|---|---|---|---|---|---|---|
| 4.5 | 5 | PP | **PMB** | 14.5 | 3 | 56 | 4.83 |
| 4.5 | 10 | PP | **PMB** | 17.0 | 3.3 | 62 | 5.15 |
| 4.5 | 10 | PE foam | **PMB** | 18.0 | 3.4 | 66 | 5.29 |
| 4.5 | 5 | LDPE | **PMB** | 15.0 | 3.3 | 62 | 4.55 |
| 4.5 | 10 | LDPE | **PMB** | 17.0 | 3.5 | 62 | 4.86 |

# 4.3 RESULTS OF TESTS ON CRUMB RUBBER

## 4.3.1 SIEVE ANALYSIS OF CRUMB RUBBER

WEIGHT OF THE SAMPLE TAKEN = 200gm

**TABLE 4.7 SIEVE ANALYSIS OF CRUMB RUBBER**

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

### 4.3.2 SPECIFIC GRAVITY

**TABLE 4.8 SPECIFIC GRAVITY OF CRUMB RUBBER**

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

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

Where

m1 = Mass of density bottle in gm

m2 = mass of bottle and dry soil in gm

m3 =mass of bottle, soil and water in gm

m4 = mass of bottle when full of water only in gm

### 4.3.3 SOFTENING POINT

SOFTENING POINT FOR UPPER PART OF SAMPLE = 45℃

SOFTENING POINT FOR LOWER PART OF SAMPLE =44℃

**TABLE 4.9 PENETRATION, SOFTENING POINT AND DUCTILITY OF RUBBER MODIFIED BITUMEN**

| RUBBER % | PENETRATION(in mm) | Softening point (in °C) | DUCTILITY(in cm) |
|---|---|---|---|
| 0 | 48 | 51 | 56 |
| 2.5 | 41.8 | 50 | 23.5 |
| 5 | 38 | 52 | 19 |
| 7.5 | 36.5 | 54 | 22 |
| 10 | 30.9 | 53 | 28 |
| 16 | 21.66 | 64.75 | 25 |
| 18 | 20.4 | 65 | 27 |

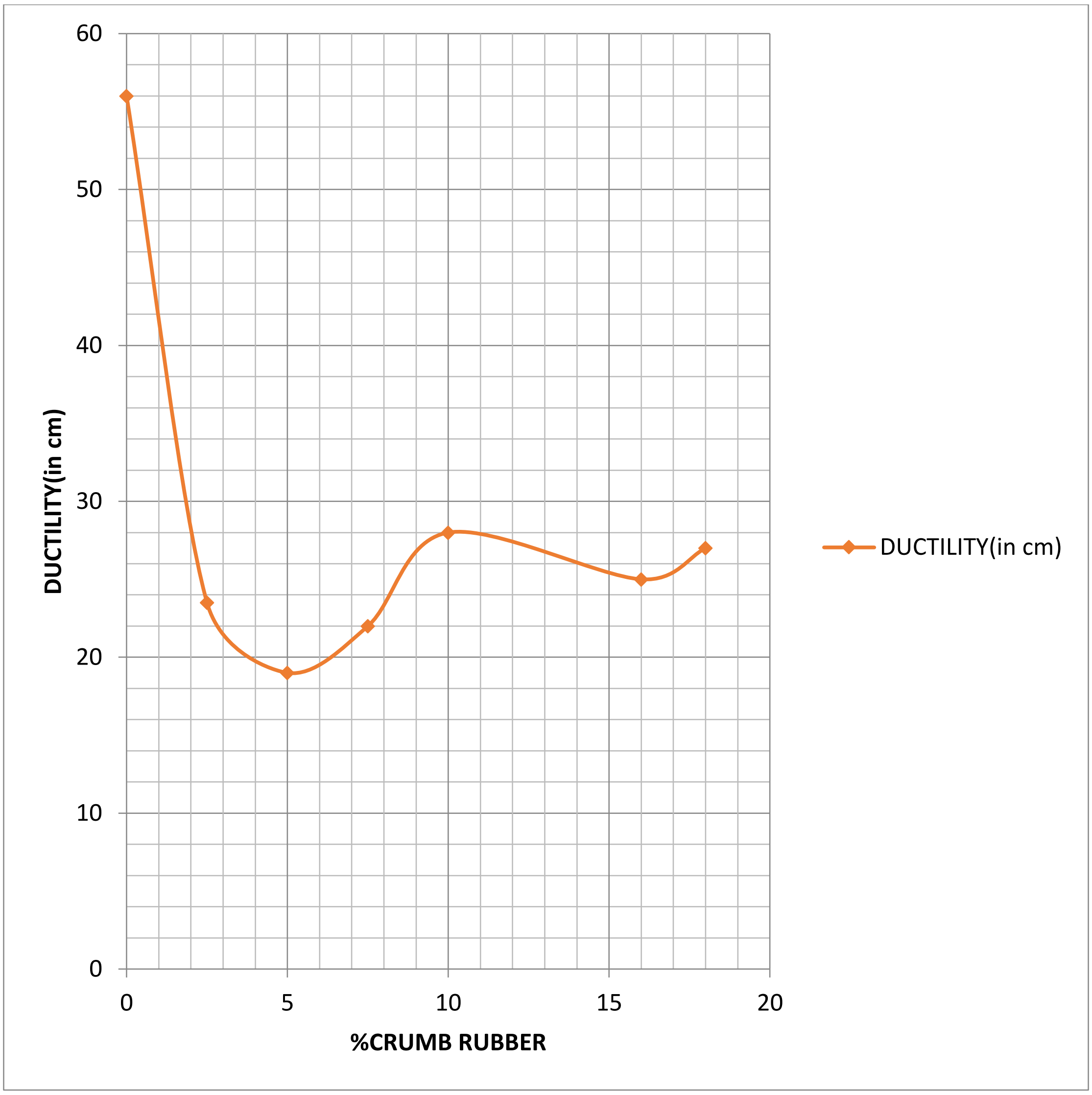



**Fig . 4.1 % Crumb rubber vs. Ductility of crumb rubber modified bitumen**

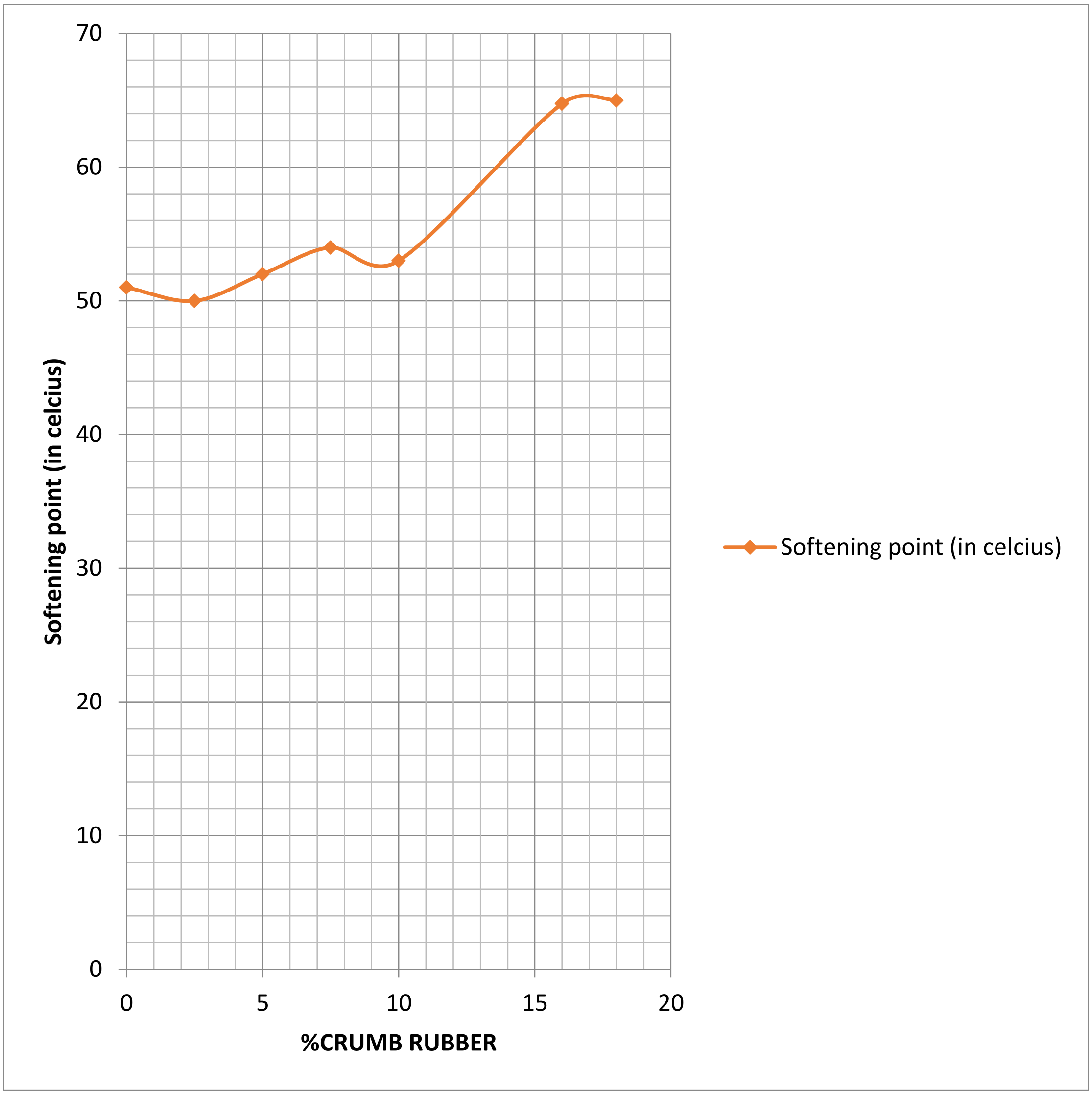



**Fig. 4.2 % Crumb rubber vs. Softening point of crumb rubber modified bitumen**

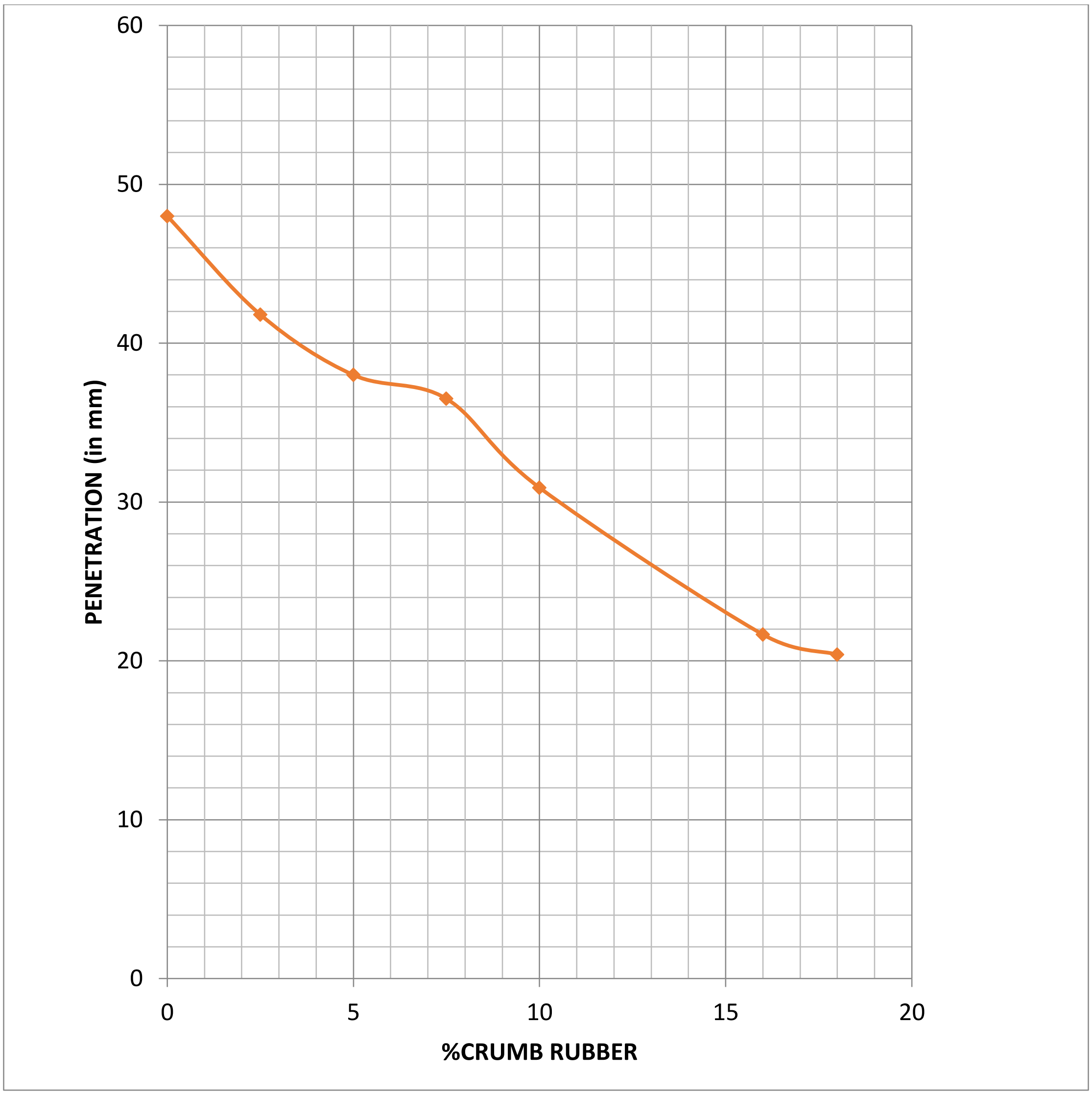



**Fig. 4.3 % Crumb rubber vs. penetration of crumb rubber modified bitumen**

## 4.4 Binding Property

The aggregate coated with higher percentage of plastics was compacted into a block and compacted blocks showed a compressive strength not less than 12 N/mm2. This shows that the molten plastics have a good adhesion property. The increase in the values of the compression strength and bending strength show that the plastics can be used as a binder. Moreover the strength increases with the increase in the percentage of plastics used for coating. It is also depended on the types of plastics used like PE, PP and PS . The following is the increasing order of strength of block produced PS<PE<PP<Laminated films<BOPP. This order is in agreement of the chemical nature of the above polymers.

## 4.5 Aggregate characterization

It was found that there is significant improvement in the strength properties of the aggregates when coated with molten plastics. This is due to the fact that when the plastic was coated over the aggregate, the aggregate surface is covered with the thin film of polymer. The film of polymer also fills the pores at the surface and there is no water absorption. Hence there is significant improvement in the general properties of the aggregate like soundness, abrasion resistance, etc., Moreover, the PCA mixed with bitumen shows better stripping property.

**4.5.1 Soundness:** Plastics coated aggregate showed no value for soundness. This can be explained as follows. The coating of plastics fills the pores and voids present at the surface of the aggregate. There is no penetration of water and there is no salt deposition. Hence there was no disintegration.

**4.5.2** In **Los Angeles Abrasion,** the hardness of aggregate is measured. Plastics coated aggregates show better resistance to higher wear and tear load The resistance increases with the increase of coating thickness of the plastics coated. This is because coating of polymers over aggregate gives better adhesion over the surface particles. It reduces the roughness of the aggregate and thus resulting in the reduction of abrasion over the surface of aggregate.

**4.5.3 Impact value**. The brittleness of the aggregate is measured as Impact value. Coating of waste polymers over the aggregate reduces the voids and the air cavities present in the aggregates. The film formed helps in preventing the cracking The toughness of the stones is also increased. Hence, the impact value of the plastics coated aggregate is lower when compared with the plain aggregate.

## 4.6 PLASTIC COATED AGGREGATE - BITUMEN MIX CHARACTERIZATION

### 4.6.1 Extraction Characteristics:

The experimental results of extraction of bitumen from the PCA - bitumen mix clearly show explain the bonding nature of the mixture. It was observed that the TCE could remove bitumen almost from the plain bitumen coated aggregates, whereas in the PCA- bitumen mix the removal of the bitumen by TCE was a slow process and not all the bitumen was removed. The TCE cannot remove completely all the bitumen from PCA- bitumen mix. Decaline, an organic solvent remove both bitumen and plastic on further treatment. Complete removal is possible only by refluxing the PCA -bitumen mix with decaline for more than 30 minutes. The following observations were made from the results of extraction test. In the case of PCA bitumen mix, TCE removed only loosely bonded bitumen. It could not remove the bitumen bonded with the aggregate through the plastics. Decaline (being a solvent to plastic) could remove the bonded bitumen further. Only after refluxing was complete removal of Bitumen and plastic achieved. Moreover, when the percentage of coating of plastics was more, the extent of bitumen removal was correspondingly less. This observation helps to conclude the bonding of bitumen over plastic coated aggregate is strong.

### 4.6.2 Stripping Value:

In the case of polymer coated aggregates, the surface is covered by the polymer film and there are no pores. The molten polymer not only fills the voids of the aggregate and binds the aggregate together but also strongly binds with bitumen forming an organic bonding. Water cannot penetrate over polymer coated aggregate, hence peeling out of bitumen from the PCA was zero even after 96 hours, thus having better stripping value.

### 4.6.3 Marshall Stability Value:

Marshall Stability Value (kN), Flow Value (mm) and Marshall quotient (kN/mm) were obtained for plain aggregate bituminous mixes and polymer coated aggregate bituminous mixes of varied compositions.

For an effective asphalt pavement, the flow values should be in the range 2-5 and the ratio of MSV and FV (referred to as Marshall Quotient) should not be more than 500. The results obtained for the PCA are within this range. Voids filled with bitumen (VFB) are expected to be around 65%. The observed value is around 58%. The reduction is attributed to the reduction in the use of percentage of bitumen (90%) and the reduction in voids. The data also suggest that with the use of plastics waste coated aggregate, the quantity of bitumen needed for a good mix can be reduced by 0.5% of the total weight. This accounts for 10% reduction in the quantity of bitumen needed to be used. It is a good saving of natural resource. The following observations are made

- The use of PCA increases the MSV of the mix
- As the percentage of the waste plastics coated increases the MSV is also increased
- Higher percentage of plastics (more than 15%) results in lesser compatibility with bitumen and lesser bonding resulting in lower MSV.
- The use of PP gives higher MSV value than PE
- The foams of PP and PE also gives better MSV results
- The waste plastics available as foams or films can also be used

- The use of optimum percentage of plastics was arrived using mathematical modelling and it is found to be 10% of bitumen used.
- The flow value and the voids filled with bitumen are within the tolerance value
- The MSV of PCA - bitumen mix is compared with PMB mix. It was observed that the values of the PCA bitumen mix are 50% to 60% higher than that of the PMB mix, showing that the binding strength is higher in the case of PCA bitumen mix.

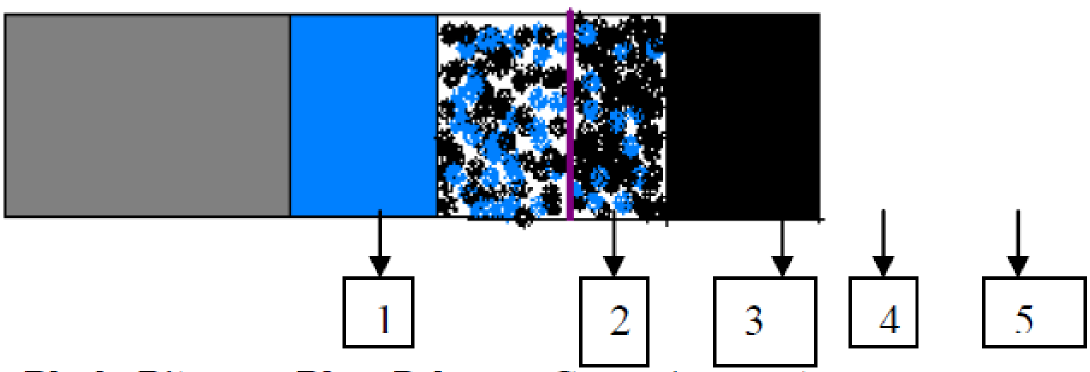
## 4.7 Theoretical Explanation

The shredded plastics on spraying over the hot aggregate melted and spread over the aggregate giving a thin coating at the surface. When the aggregate temperature is around 1400 C to 160oC the coated plastics remains in the softened state. Over this, hot bitumen (160oC) is added. The added bitumen spreads over the aggregate. At this temperature both the coated plastics and bitumen are in the liquid state, capable of easy diffusion at the inter phase. This process is further helped by the increase in the contact area (increased surface area).

These observations may be explained as follows. Waste polymers namely PE, PP and PS are hydrocarbons with long chains. The bitumen is a complex mixture of asphaltenes and maltenes which are also long chain hydro carbon. When bitumen was mixed with plastic coated aggregate, a portion of bitumen diffuse through the plastic layer and binds with aggregate. The plastic layer has already bonded strongly with aggregate. During this process three dimensional internal cross linked net work structure results between polymer molecules and bitumen constitutes. Therefore the bond becomes stronger and the removal of bonded bitumen becomes difficult.

The results of the studies on the extraction of bitumen by dry process showed that the bonding between stone aggregate and bitumen is improved due to the presence of polymers. This may be explained by the following structural models. Using these models the extraction pattern is explained.

**A plastic aggregate bitumen interaction model for the Plastics waste coated aggregate bitumen mix (Not to Scale) Fig 4.4**




**Key: Black- Bitumen; Blue- Polymer; Grey - Aggregate**

Aggregate

1. Area of Plastics bonded with aggregate (polymer coating)
2. Area of Bitumen–plastics blend (due to diffusion between molten plastics & hot bitumen)
3. Area of Loosely bonded bitumen with dispersed plastics
4. Area of Plain bitumen layer

On the whole, the coating of plastics over the stone aggregate helps bitumen to have a strong bonding at the surface. Basing on the above observations, the increased value of MSV, nil stripping and improved strength of road is explained.

## 4.7.1 Reduction of Carbon dioxide Emission:

Littered waste plastics are otherwise burnt along with domestic waste resulting in the production of green house gases thus aiding global warming. In the Dry process, waste plastics are used as a coating material by softening the plastic and not by burning. Hence there is no evolution of gases like carbon dioxide. For a distance of one Kilometre single lane plastic bitumen road, a minimum of one ton of waste plastics is used. This accounts for a reduction of Carbon Dioxide to a tune of 3 tons. Using this technology we have laid more than 2500kms of plastic bitumen road at various places in India. This amounts to a prevention of burning of waste plastics to an extent of 2500tonnes. This means that the process prevented the formation of Carbon Dioxide to an extent of 7500tonnes. (If this waste plastic is burnt along with MSW, nearly 2, 50,000tonnes of Carbon Dioxide would have been produced)

## 5.7.2 Construction of the test roads:

It is observed from the results that the plastic roads laid since 2002 to 2012 are showing results which are the characteristics of a good road. They are showing better results and maintain good quality compared to the plain bitumen roads laid in 2002 .Hence it can be concluded that the plastic tar roads are performing much better than the plain bitumen road. In addition to this, the physical surface condition survey of the plastic tar road (procedure adopted by Central Road Research Institute, New Delhi) shows that there is no pot hole formation, cracking, deformation, rutting, raveling and edge flaw. The photos of these roads taken recently are also attached for having a visual exhibition. Hence it can be concluded that the plastic tar roads are having good skid resistance values, good texture values, good surface evenness, reasonably good strength and field density with least change.

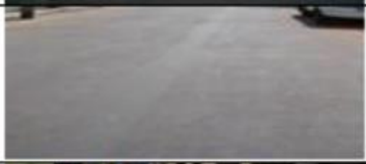
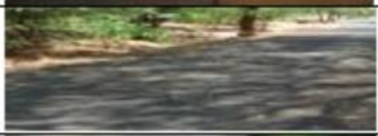
| Site Name | Surface Condition Survey | Photo |
|---|---|---|
| Jumbulingam road, Chennai (2002)<br>Photo Date: 21-12-2012 | 1. No Pothole<br>2. No Cracking<br>3. No Deformation<br>4. No Edge Flaw |  |
| Veerbadhra Street, Erode(2003)<br>Photo Date: 04-01-2013 | 1. No Pothole<br>2. No Cracking<br>3. No Deformation<br>4. No Edge Flaw |  |
| Vandiyur Main road (2004)<br>Photo Date: 01-02-2013 | 1. No Pothole<br>2. No Cracking<br>3. No Deformation<br>4. No Edge Flaw |  |
| Vilachery Main road (2005)<br>Photo Date: 11-02-2013 | 1. No Pothole<br>2. No Cracking<br>3. No Deformation<br>4. No Edge Flaw |  |
| Canteen road (2006)<br>Photo Date: 05-01-2013 | 1. No Pothole<br>2. No Cracking<br>3. No Deformation<br>4. No Edge Flaw |  |
| Plain bituminous road (2002)<br>Photo date: 21.12.2012 | 1. Pothole developed<br>2. Cracking is there.<br>3. Deformation is there<br>4. Edge Fault |  |

**Fig 4.5 Condition of existing plastic roads**

## 4.8 ECONOMY OF THE PROCESS

Based on the experimental evidences and the amount of raw materials used for 25mm Semi Dense Bituminous Concrete (SDBC- this top layer of the bituminous road. 10M2 SDBC road the following calculation has been arrived

**TABLE 4.10 ECONOMY OF THE PROCESS**

| **MATERIAL NEEDED** | **PLAIN BITUMEN** | **PCA** |
|---|---|---|
| 80/100 BITUMEN | 11250kg | 10125kg |
| PLASTIC WASTE | - | 1125kg |
| COST | Rs. 393750 | Rs.35375 + Rs 13500= Rs. 367875 |
| COST REDUCED | NIL | Rs. 25875.00 |
| CARBON CREDIT ACHIEVED ON AVOIDING BURNING OF PLASTIC | | 3.5 tonnes |

- Cost Bitumen Approx: 35,000/ton and Waste Plastic : Rs. 12000/tons
- Savings of bitumen = 1 ton
- Use of Plastics waste – (11,25, 000) carry bags (1.125 ton)
- Bitumen needed– 10125kg
- Plastics waste needed – 1125 kg.

The cost of bitumen is much higher than that of plastics and this process also helps to save the natural resources. There is no maintenance cost for a minimum period of five years. Hence the process is cheap and eco friendly.

## 4.8.1 Benefits of laying plastic roads – Rural Roads

- Rural Roads- 24.5 lakhs Km if these roads are constructed as plastic tar roads – we need 24.5 lakhs tones of waste plastics!!!!!!-
- We prevent nearly 75 lakh tones of Carbon Dioxide entering our atmosphere by burning waste plastics
- We save 24.5 lakhs tons of bitumen
- We save nearly Rs 12250 crores worth of bitumen
- No maintenance cost for ten years
- Total waste plastics used for packing material per in India is around 20 lakhs tones only.
- The plastic available is insufficient for laying rural roads only.
- In a nut shell the Government provides not only good roads but also uses all the waste plastics and reduces carbon dioxide – bitumen usage.
- Not less than 20000 crores saved
- To convert all roads in India to plastic roads we need import plastic waste from other countries

# Chapter 5. CONCLUSION

In Dry process, the aggregate is modified by coating with polymers and producing a new modified raw material for flexible pavement. Coating of polymers on the surface of the aggregate has resulted in many advantages and ultimately helps to improve the quality of flexible pavement. The coating of plastics over aggregate also improves the quality of the aggregate. In addition to the improvement of the quality of the road, this technology has helped to use the waste plastics obtained from domestic and industrial packing materials. This has added more value to the dry process as this process helps to dispose 80 percentages of the waste polymers usefully by an eco-friendly method. This has already been accepted by the Central Pollution Control Board, New Delhi. They have already released a guideline on the technique of the road laying by dry process and its advantage. By this technique, which is in-situ, waste polymer like carry bags, foam, laminated sheets, cups are all used for road laying. Moreover, the use of polymers helps to reduce equivalent quantity of bitumen, thus reducing the cost of the road laying. In a net shell the Dry Process thus helps to

1. Use higher percentage of plastics waste.
2. Reduce the need of bitumen by around 10%.
3. Increase the strength and performance of the road.
4. Avoid the use of anti stripping agents.
5. Reduce the cost to around Rs. 30000/ km of single lane road as on date.
6. Carry the process in situ.
7. Avoid industrial involvement.
8. Avoid disposal of plastics waste by incineration and land filling.
9. Generate jobs for rag pickers.
10. Add value to plastics waste.
11. Develop a technology, which is eco-friendly.

Our studies on the performance of plastic tar road conclusively proves that it is good for heavy traffic due to better binding , increased strength and better surface condition for a prolonged period of exposure to variation in climatic changes Above all, the process helps to dispose waste plastics usefully and easily.

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# APPENDIX 1

## 1. AGGREGATE CRUSHING VALUE TEST(IS :2386-PART-4)

**Apparatus/Equipments Required:**

1. Steel cylinder of 15.2 cm internal diameter with base plate and plunger. The height of the cylinder may vary from 13 to 14 cm. The thickness of cylinder walls may be 1.6 cm.
2. Cylindrical measure of internal diameter 11.5 cm. and height18 cm.
3. Steel tamping rod 45 to 60 cm. long and 1.6 cm diameter having a pointed end.
4. Compression testing machine capable of applying load of 40 tonnes, at a uniform rate of loading of 4 tonnes per minute.
5. Balance of cap. 3 kg with accuracy up to 1 g
6. Sieves of 12.5 mm, 10 mm and 2.36 mm.

**Theory:**

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

**Procedure:**

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

2. Now the test sample is weighed and filled in the test cylinder in three equal layers and tamped each layer 25 times. Let the weight of aggregate be $W_1$ Kg.
3. Now the plunger is placed on the top of the test specimen and whole apparatus is put in the compression testing machine.
4. Now the specimen is loaded to a total load of 40 tonnes at the rate of 4 tonnes per minute i.e., the total load s reached in 10 minutes in the compression machine.
5. Now the test cylinder is removed from the compression machine and aggregate sieved through 2.36 mm sieve. The material passed through the 2.36 mm sieve is weighed. Let the weight be $W_2$ Kg.

**Observation:**

| Serial No. | Details | Trial No. | |
|---|---|---|---|
| | | 1 | 2 |
| 1. | Total Weight of aggregate sample filling the Cylindrical measure = $W_1$ g | | |
| 2. | Weight of aggregate passing 2.36 mm sieve after the test = $W_2$ g | | |
| 3. | Weight of aggregate retained on 2.36 mm sieve after the test = $W_3$ g | | |

**Calculation**

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

# 2.WATER ABSORPTION TEST IS: 2386 (Part III) – 1963

**Apparatus**

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

**Theory:**

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

**Procedure:**

i) The sample should 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 and 32$^{o}$C.

ii) After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 + ½ hrs afterwards.

iii) The basket and aggregates should then be removed from the water, allowed to drain for a few minutes, after which the aggregates should be gently emptied from the basket on to one of the dry clothes and gently surface-dried with the cloth, transferring it to a second dry cloth when the first would remove no further moisture. The aggregates should be spread on the second cloth and exposed to the atmosphere away from direct sunlight till it appears to be completely surface-dry. The aggregates should be weighed (Weight 'A').

iv) The aggregates should then be placed in an oven at a temperature of 100 to 110°C for 24hrs. It should then be removed from the oven, cooled and weighed (Weight 'B')

**Observations:**

| S.No. | Determination No. | I | II |
|---|---|---|---|
| 1 | Weight of saturated surface dried sa sample in grams (A) | | |
| 2 | Weight of oven dried sample in grams (B) | | |

**Calculations:**

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

# 3. AGGREGATE ABRASION VALUE TEST (IS :2386-PART-4)

**Apparatus/Equipments Required:**

1. It consists of a hollow cylindrical machine closed at both ends having 70 cm internal diameter and 50 cm long, mounted on supports so that it may rotate about its horizontal axis.
2. Steel spherical balls 4.5 cm diameter and weighing 390grams to 445 grams. The weight and number of balls per charge of aggregate depends upon the grading of aggregate sample.
3. Sieve of size 1.7 and balance of capacity 10 kg.

**Theory:**

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

**Procedure:**

1. Aggregate sample weighing 5 kg or 10 kg depending on the grading is put in the machine along with the abrasive charge.
2. The machine is rotated at a speed of 30 to 33 r.p.m for the specified number of revolutions (500 to 1000) depending on the grading of aggregate.
3. Now the sample is taken out of the machine and sieved through 1.7 mm I.S. Sieve and the weight of aggregate passing through 1.7 mm sieve is determined.

**Observation:**

1. Type of aggregate =
2. Grading =
3. Number of spheres used =
4. Weight of charge =
5. Number of revolution =

| Observations | Sample 1 | Sample 2 |
|---|---|---|
| L Let the original weight of aggregate = $W_1$ g | | |
| Weight of aggregate retained on 1.7 mm IS sieve after the test = $W_2$ g | | |
| Loss in weight due to wear = $W_1$ - $W_2$ g | | |
| Percentage wear = $\frac{(W_1 - W_2)}{W_1} \times 100$ | | |
| | | |

**Calculation**

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

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

**1. Apparatus/Equipments Required:**

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

**2. Theory:**

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

**3. Procedure:**

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

## 4. Observation:

| S S.No. | Details | Trial No. | |
|---|---|---|---|
| | | 1 | 2 |
| 1. | T Total weight of aggregate sample filling the cylindrical measure = $W_1$ g | | |
| 2. | W Weight of aggregate passing 2.36 mm sieve after the test = $W_2$ g | | |
| 3. | W Weight of aggregate retained on 2.36 mm sieve after the test = $W_3$ g | | |

## 5. Calculation

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

# APPENDIX 2

## SPECIFIC GRAVITY

### OBJECTIVE

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

### APPARATUS REQUIRED

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

### PROCEDURE

1. Clean and dry the density bottle

2. Weigh the empty bottle with stopper ($M_1$)

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

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

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

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

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

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

# SEPRATION TEST

## PRINCIPLE

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

## APPARATUS

- AluminumTubes-25.4 mm(1inch) diameter and 136.5 mm (5.5 inch) length blind aluminium tubes (thickness of foil 1 mm), used to hold the test sample during the conditioning.

- Oven, capable of maintaining 163 ± 5°C.

- Freezer, capable of maintaining 6.7 ± 5°C.

## PROCEDURE

1. Place the empty tube, with sealed end down in the rack. Heat the sample carefully until sufficiently fluid to pour. Care should be taken to prevent localized over heating. Pass the molten sample through IS Sieve of 600 micron mesh size. After through stirring, pour 50.0 g into the vertically held tube. Fold the excess tube over two times, and crimp and seal.

2. Place the rack containing the sealed tubes in a 163 ± 5 ℃ oven. Allow the tubes to stand undisturbed in the oven for a period of 24 ± 4 h. At the end of the period, remove the rack from the oven, and place immediately in the freezer at 6.7 ± 5 °C, taking care to keep the tubes in a vertical position at all times. Leave the tubes in the freezer for a minimum of 4 h to solidify the sample completely.

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

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