ATME College of Engineering

13th K M Stone, Bannur Road, Mysore – 570028

ATME

College of Engineering

DEPARTMENT OF CIVIL ENGINEERING

(Academic Year 2025-26)

DESIGN AND CONSTRUCTION OF HIGHWAY PAVEMENT

SUB CODE: BCV613D

SEMESTER: VI

INSTITUTIONAL MISSION AND VISION

Vision of the Institute

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

Mission of the Institute

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as tourch bearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence

DEPARTMENT VISION AND MISSION

Vision of the Department

To develop globally competent Civil Engineers who excel in academics, research and are ethically responsible for the development of the society.

Mission of the Department

- To provide quality education through faculty and state of art infrastructure
- To identify the current problems in society pertaining to Civil Engineering disciplines and to address them effectively and efficiently
- To inculcate the habit of research and entrepreneurship in our graduates to address current infrastructure needs of society

Program outcomes (POs)

Engineering Graduates will be able to:

PO1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes (PSOs)

PSO 1 – Provide the necessary infrastructure for all situations through competitive plans, maps and designs with the aid of a thorough Engineering Survey and Quantity Estimation.

PSO 2 – Assess the impact of anthropogenic activities leading to environmental imbalance on land, in water & in air and provide necessary viable solutions revamping water resources and transportation for a sustainable development

Program Educational Objectives (PEOs)

PEO 1- Engaged in professional practices, such as construction, environmental, geotechnical, structural, transportation, water resource engineering by using technical, communication and management skills.

PEO 2- Engaged in higher studies and research activities in various civil engineering fields and life time commitment to learn ever changing technologies to satisfy increasing demand of sustainable infrastructural facilities.

PEO 3- Serve in a leadership position in any professional or community organization or local or state engineering board

PEO 4- Registered as professional engineer or developed a strong ability leading to professional licensure being an entrepreneur.

Module-1

AGGREGATES, BITUMEN AND TAR

1.1 Objective

The objective of the present module is to expose students to different materials which are used in pavement construction, impart knowledge about the engineering properties required.

1.2 Introduction

Aggregates form the major portion of pavement structure and they outline the prime materials used in pavement construction. Aggregates have to bear stresses occurring due to the wheel loads on the pavement and on the surface course, they also have to resist wear due to abrasive action of traffic. These are used in pavement construction in cement concrete, bituminous concrete and other bituminous constructions and also as granular base course underlying the superior pavement layers. Therefore, the property of the aggregates is of significant importance to the highway engineers.

1.3 Origin:

Most of the road aggregates are prepared from:

- Natural rock.
- Slags derived from metallurgical process (steel plants)

Road aggregates prepared by crushing of rocks. Gravel aggregates are small rounded stones of different sizes which are generally obtained as such from some river beds. Sand is fine aggregate from weathering of rock. The properties of the rock, from which the aggregates are formed, depend on the properties of constituent materials and the nature of bond between them.

1.4 Classification:

- The aggregates are specified based on their grain size, shape, texture and its gradation and it is specified by various agencies like ASTM, BSI, ISI and IRC.
- Based on strength property, the coarse aggregates are divided into hard aggregates and Soft aggregates.

➢ **<u>Based on the origin</u>**

Natural rocks are classified as igneous, sedimentary and metamorphic rocks.

(1) Igneous rocks

Predominantly crystalline and are formed by the cooling of molten rock magma.

Ex: Granite.

Further igneous rocks are classified as below:

<u>Classification based on grain size:</u>

a) Course (>2mm)

b) Medium (2mm to 0.2mm)

c) Fine (<0.2mm)

<u>Classification based on composition:</u>

a) Acid rocks (>66% silica, light in colour & specific gravity <2.75)

b) Intermediate rocks (55 to 66% silica)

c) Basic rocks (<55% silica, dark in colour & specific gravity >2.75)

(2) Sedimentary rocks

Formed either from the deposition of insoluble granular material resulting from the disintegration of pre-existing rocks, or form the inorganic remains of marine and animals which are deposited in great quantities on the sea floor. Sedimentary rocks are deposited in layers; they have stratified or laminated structure.

<u>Classification based on predominating mineral:</u>

a) Calcareous rock (chalk, lime stone & dolomite)

b) Siliceous rock (sand stone, flint & chert)

c) Argillaceous (clay & shale)

(3) Metamorphic rock

These are sedimentary or igneous rocks that have been subjected to great heat or to great pressure or both, that has resulted in the formation of minerals and in textures different from those of the original rock.

Classification based on grain size:

a) Fine grain size (hornfels & schist)

b) Coarse grain size (gneiss & Granulite)

➢ **Based on the strength property**

The coarse aggregates may be divided as hard aggregates and soft aggregates.

- Generally for the bearing course of superior pavement types, hard aggregates are preferred to resist the abrading and crushing effects of heavy traffic loads and to resist adverse weather conditions.
- In the case of low-cost road construction for use in lower layers of pavement structures, soft aggregates can also be used. The soft aggregates include moorum, kankar, laterite, brick aggregates and slag. A different set of test specifications are adopted for soft aggregates.

Requirements:

- They must be crushed aggregate.
- They shall be clean, hard, durable and cubical in shape.
- They must be free from the dust, organic matter and other deleterious matter.
- They must not be flaky or elongated.
- They must not consist of injurious or harmful materials such that they reduce the strength of structure.
- They should resist wear due to abrasive action of traffic on the surface course.

Properties of aggregates:

The aggregate have three properties

1. Physical properties.
2. Mechanical properties.
3. Chemical properties.

1.5 Most desirable properties of aggregate

(1) Strength

- The aggregates to be used in road construction should be sufficiently strong to withstand the stresses due to traffic wheel loads.
- The aggregates which are to be used in top layer of the pavements, particularly in the wearing course have to be capable of withstanding high stresses
- In addition to wear and tear; hence they should possess sufficient strength and resistance to crushing.

(2) Hardness

- The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic.
- They should be hard enough to resist the wear due to abrasive action of traffic.
- Abrasive action may be increased due to the presence of abrasive material like sand between the tyres of moving vehicles and the aggregates exposed at the top surface.
- This action may be severe in the case of steel tyred vehicles.
- Heavy wheel loads can also cause deformations on some types of pavement resulting in relative movement of aggregates and rubbing of aggregates with each other within the pavement layer.
- The mutual rubbing of stones is called **attrition**, which also may cause a little wear in the aggregates; however attrition will be negligible or absent in most of the pavement layers.

(3) Toughness

- Aggregates in the pavements are also subjected to impact due to moving wheel loads.
- Severe impact like hammering is quite common when heavily loaded steel tyred vehicles move on water bound macadam roads where stones protrude out especially after the monsoons.
- Jumping of the steel tyred wheels from one stone to another at different levels causes' severe impact on the stones.
- The magnitude of impact would increase with the roughness of the road surface, the speed of the vehicle and other vehicular characteristics.
- The resistance to impact or toughness is hence another desirable property of aggregates.

(4) Durability

- The stone used in the pavement construction should be durable and should resist disintegration due to the action of weather.
- The property of the stones to withstand the adverse action of weather may be called soundness.
- The aggregates are subjected to the physical and chemical action of rain and ground water, the impurities there-in and that of atmosphere.
- Hence it is desirable that the road stones used in the construction should be sound enough to withstand the weathering action.

(5) Shape of aggregates

- The size of the aggregates is first qualified by the size of square sieve opening through which an aggregate may pass, and not by shape.
- Aggregates which happen to fall in a particular size range may have rounded cubical, angular flaky or elongated shape of particles.
- It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same stone.
- Hence too flaky and too much elongated aggregates should be avoided as far as possible.
- The voids present in a compacted mix of coarse aggregates depend on the shape factors.
- Highly angular, flaky and elongated aggregates have more voids in comparison with rounded aggregates.
- Based on the shape of the aggregate particle, stones may be classified as rounded, angular, flaky and elongated.
- Angular particles possess well-defined edges formed at the intersection of roughly plane faces and are commonly found in aggregates prepared by crushing of rocks.
- Flaky aggregates have lesser thickness when compared to the length and width.
- Elongated aggregates have one of the dimensions or the length higher than the width and thickness.
- The shape factors of aggregates depend on the source, properties of the rock & the type and condition of the crushers.
- The shape of aggregates is generally described in terms of its shape factors such as flakiness index, elongation index and angularity number.
- Several researchers have indicated that in pavement construction flaky and elongated aggregates are to be avoided, particularly in surface course.

- If flaky and elongated aggregates are present in appreciable proportions, the strength of the pavement layer would be adversely affected due to possibility of breaking down during compaction and under loads.

(6) Adhesion with Bitumen

The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous material; otherwise the bituminous coating on the aggregates will be stripped off in presence of water.

Tests on Road Aggregates and Properties Evaluated

SL No.	Type of test	Required property
01	Aggregate impact test	Toughness or resistance to impact
02	Los Angeles Abrasion Test	Hardness or resistance to abrasion
03	Aggregate Crushing Test	Strength or resistance to crushing
04	Soundness/ Durability/ Accelerated weathering test	Durability or resistance to weathering
05	Shape test: Flakiness Index, Elongation Index, Angularity Number	Assessment of suitable shape or shape factors of coarse aggregates
06	Specific gravity Test	To measure the quality or strength of material
07	Water absorption Test	To measure the porosity
08	Bitumen adhesion/Stripping Test	Adhesion of bitumen
09	Polished stone value test or accelerated polishing test	Resistance to getting smooth or polished

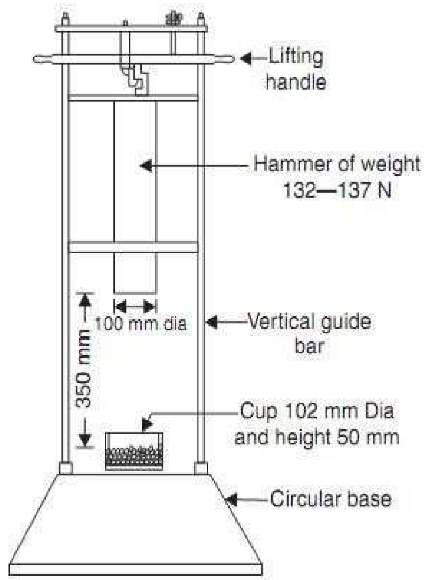
1.6 Different tests on Aggregates

1. Aggregate Impact Test

Aim: To determine the impact value of the given aggregate

Apparatus: IS sieves (12.5 mm, 10.0 mm and 2.36 mm), cylindrical measure & cylindrical cup, Weighing balance & Tamping rod.

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. A test designed to evaluate the toughness of stones i.e. the resistance of the stones to fracture under repeated impacts may be an impact test for road aggregate. The aggregate impact value indicates a **"**relative measure of the resistance of an aggregate to a sudden shock or an impact, which in some aggregate differs from its resistance to a slow compressive load**"**. The method of tests specifies the procedure for determining the aggregate impact value of coarse aggregate.



Procedure:

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers, where each layer is tamped for 25 numbers of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W1).

Desirable value:

Various agencies have specified the maximum permissible aggregate impact values for the different types of pavements, those recommended by the Indian Roads Congress are given below:

Sl No.	Types of pavement material/layer	Aggregate impact value, maximum, %
1	Water bound macadam (WBM), sub-base course	50
2	Cement concrete, base course (as per ISI)	45
3	(i) WBM base course with bitumen surfacing	40
	ii)Built-up spray grout, base course	
4	Bituminous macadam, base course	35
5	(i) WBM, surfacing course	30
	(ii) Built-up spray grout, surfacing course	
	(iii) Bituminous penetration macadam	
	(iv) Bituminous macadam, binder course	
	(v) Bituminous surface dressing	
	(vi) Bituminous carpet	
	(vii) Bituminous/Asphalt concrete	
	(viii) Cement concrete, surface course	

For deciding the suitability of soft aggregates in base course construction, this test has been commonly used. A modified impact test is also often carried out in the case of soft aggregates to find the wet impact value after soaking the test samples.

The recommendations is given in the below table.

Condition of sample	Maximum aggregate impact value percent	
	Sub-base and base	Surface course
Dry	50	32
Wet	60	39

Aggregate impact value is used to classify the stones in respect of their toughness property as indicated below:

<10% Exceptionally strong

10-20% Strong

20-30% Satisfactory for road surfacing

>35% Weak for road surfacing

The aggregate impact value should not normally exceed 30% for aggregate to be used in wearing course of pavements. The maximum permissible value is 35% for bituminous macadam and 40% for water bound macadam base courses.

2. Aggregate Crushing Value

Aim: To determine the crushing value of the given sample of aggregate.

Apparatus:

a) Steel cylinder with open ends and a square plate

b) Compression testing machine, Plunger with piston

c) Cylindrical measure, weighing balance & Steel Tamping Rod

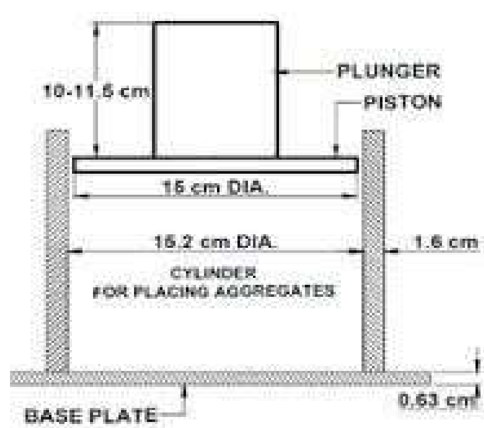
e) IS sieves (12.5 mm, 10.0mm & 2.36 mm)

Theory:

The Principal mechanical properties required in road stones are

- Satisfactory resistance to crushing under the roller during construction
- Adequate resistance to surface abrasion under traffic.

Also stresses under rigid tyre rims of heavily loaded animal drawn vehicles are high enough to consider the crushing strength of road aggregate as an essential requirement in India. Crushing strength of road aggregate may be determined either on aggregate or on cylindrical specimens cut out of rocks. These two tests are quite different not only in the approach but also in the expression of the results. Aggregate used in road construction, should be strong enough to resist crushing under traffic wheel loads. If the aggregate are weak, the stability of the pavement stretches is likely to be adversely affected, the strength of coarse aggregate is assessed by aggregate crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate value should be preferred.



Procedure:

The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load. The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions. Dry aggregates passing through 12.5 mm sieves and retained 10 mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tampered 25 times with at standard tamping rod. The test sample is weighed and placed in the test cylinder in three layers each layer being tampered again. The specimen is subjected to a compressive load of 40 tonnes gradually applied at the rate of 4 tonnes per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weight of passing material (W2) is expressed as percentage of the weight of the total sample (W1) which is the aggregate crushing value. A value less than 10 signifies an exceptionally strong aggregate while above 35 would normally be regarded as weak aggregates.

Aggregate Crushing value= (W1/W2) X 100

Desirable value:

Strong aggregates give low aggregate crushing value. IRC and ISI have specified that the aggregate crushing value of the coarse aggregate used for cement concrete pavement at surface should not exceed 30 percent. For aggregates used for concrete other than for wearing surfaces, the aggregates crushing value shall not exceed 45 percent. However aggregate crushing values have not been specified by the IRC for coarse aggregates to be used in bituminous pavement construction methods.

3. Los Angeles Abrasion Test

Aim: To determine the abrasion of the given aggregate sample.

Apparatus: Los Angles Abrasion Machine

Steel balls-11 no.

Weighing balance

IS Sieves: 20, 12.5, 10, 1.7mm.

Theory:

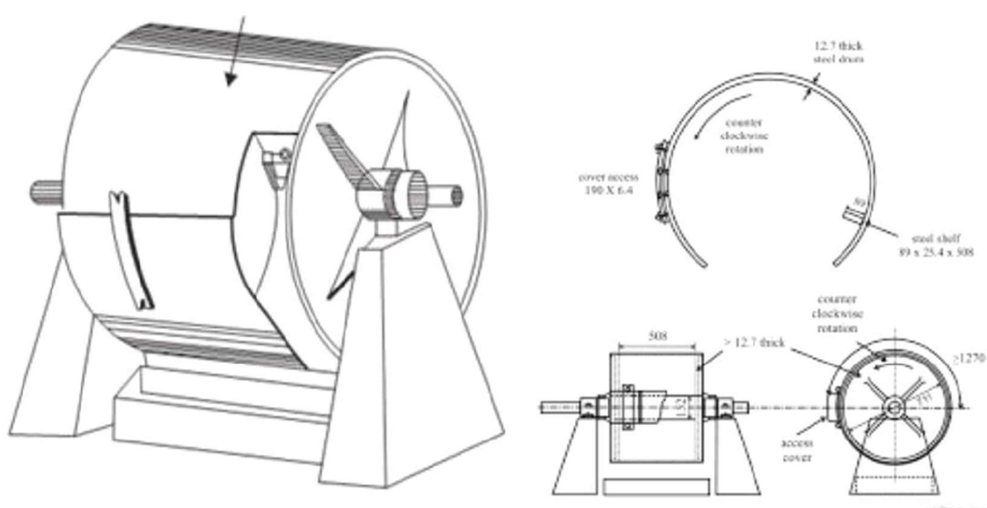
Due to the movement of traffic, the road stones used in the surfacing course are subjected to wearing action at the top. Resistance to wear or hardness is hence an essential property for road aggregates especially when used in wearing course. Thus road stones should be hard enough to resist the abrasion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

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (IS: 2386 part-IV). The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Procedure:

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated. An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.



Desirable value:

Sl No.	Types of pavement layer	Los Angeles abrasion value, Maximum %
1	Water bound macadam (WBM), sub-base course	60
2	(i) WBM base course with bituminous surfacing (ii) Bituminous Macadam base course (iii) Built-up spray grout base course	50
3	(i) WBM surfacing course (ii) Bituminous Macadam binder course (iii) Bituminous penetration Macadam (iv) Built-up spray grout binder course	40
4	(i) Bituminous carpet surface course (ii) Bituminous surface dressing, single or two coats (iii) Bituminous surface dressing, using precoated aggregates (iv) Cement concrete surface course (as per IRC)	35
5	(i) Bituminous/Asphaltic concrete surface course (ii) Cement concrete pavement surface course (as per ISI)	30

The Los Angeles abrasion value of good aggregates acceptable for cement concrete, bituminous concrete and other high quality pavement materials should be less than 30%. Values up to 50% are allowed in base courses like water bound and bituminous macadam.

4. <u>Shape Test</u>

Aim: To determine the Flakiness Index, Elongation Index and Angularity Number of the given sample of aggregate.

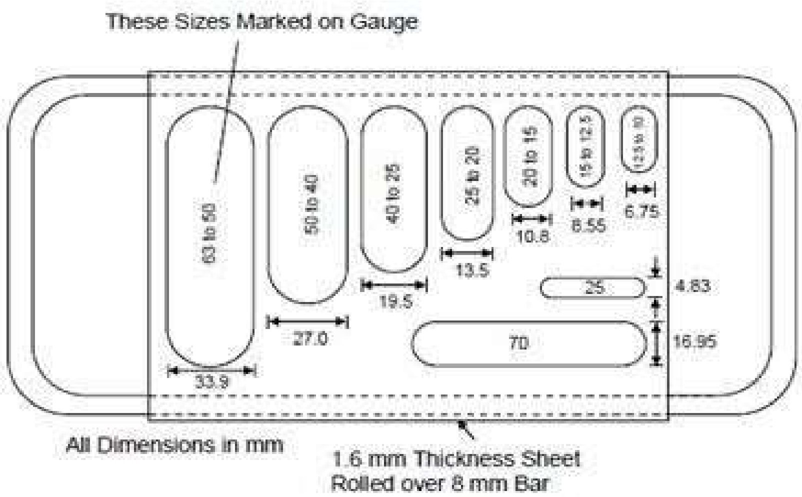
Theory:

The particle shape of aggregate is determined by percentages of flaky and elongated particles contained in it. In case of gravel it is determined by its angularity number. For base course and construction of bituminous and cement concrete types, the presence of flaky and elongated particles are considered undesirable as they may cause inherent weakness with possibilities of breaking down under heavy loads. Rounded aggregate are preferred in cement concrete road construction as the workability of concrete improves. Angular shape of particles is desirable for granular base course due to increased stability derived from the better interlocking. Thus evaluation of shape of the particles, particularly with reference to flakiness, elongation and angularity is necessary.

A. <u>Flakiness Index</u>

The Flakiness index of aggregate is the percentage by weight of particles whose least dimension [thickness] is less than three- fifths [0.6] times of their mean dimension. The test is not applicable to aggregate size smaller than 6.3 mm.

It is desirable that the flakiness index of aggregates used in road construction is less than 15% and normally does not exceed 25%.

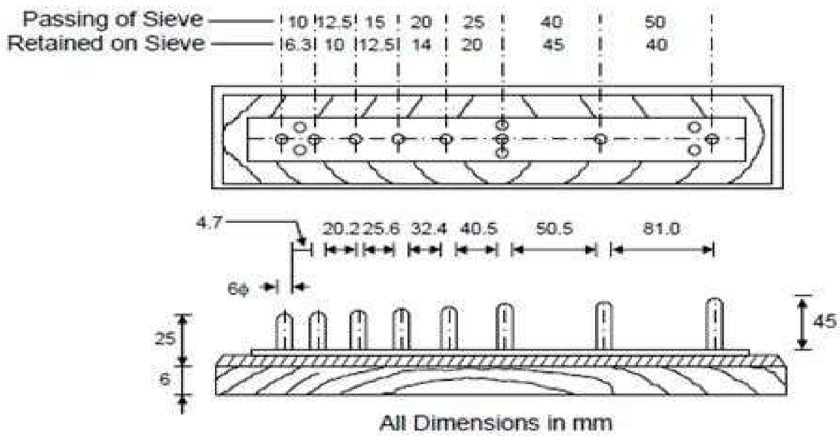


Desirable value

Sl. No	Type of pavement construction	Maximum limit of Flakiness Index, %
1	Bituminous carpet	30
2	(i) Bituminous/Asphaltic concrete (ii) Bituminous surface dressing (single coat, two coats and pre-coated) (iii) Bituminous penetration macadam (iv) Built-up spray grout	25
3	(i) Bituminous macadam (ii) Water bound macadam, base and surfacing courses	15

B. <u>Elongation Index</u>

The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension. This test is applicable to aggregates larger than 6.3 mm. This test is also specified in (IS: 2386 Part-I).



Elongation index value in excess of 15% percent is considered undesirable; however no recognized limits have been laid down for elongation index.

C. Angularity Number

The angularity number of an aggregate is the amount by which the percentage voids exceeds 33, after being compacted in a prescribed manner.

Angularity number = (67 - 100 * W / CG)

Here the value 67 represents the percentage volume of solids of most rounded gravel, which would have 33 percent voids.

The angularity number measures the percent voids in excess of 33 percent which is obtained in the case of the most rounded gravel particles. The angularity number of aggregates generally ranges from zero for highly rounded gravel to about 11 for freshly crushed angular aggregates. Slightly higher values of angularity number also may be obtained in the case of highly angular and flaky aggregates. Thus higher the angularity number, more angular and less workable is the aggregate mix.

5. Specific Gravity and Water Absorption Test on Aggregates

Aim: To determine the specific gravity and water absorption of given sample of aggregates.

Apparatus

a) Density basket

b) Weighing balance

c) Water tank

d) Tray

e) IS sieves- 10mm and 20mm

Theory

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity values. The specific gravity test helps in the identification of stone. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. The aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used: apparent specific gravity and bulk specific gravity.

Procedure:

1) Take about 2kg of given aggregates passing IS 20mm sieve and retained on 10mm sieve. 2) Keep the aggregate in density basket and then keep the basket in water.

3) Allow the aggregate and basket to be in water for 24 hours.

4) After 24 hours find the suspended weight of basket with aggregate.

5) Remove the basket out of water and remove the aggregate.

6) Keep the empty basket back in water and find the suspended weight.

7) Wipe the surface of aggregate using a cotton cloth to make them surface dry.

8) Find the weight of surface dry aggregate in air.

9) Keep the aggregate in oven at 110° C for 24 hours.

10) Now find the weight of dried aggregate in air.

11) Then specific gravity and Water absorption is calculated from the relation:

$$\text{Specific gravity} = W4 / W3-(W1-W2)$$

Water absorption gives an idea of strength of rock stones having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness. Water absorption, the difference between the apparent and bulk specific gravities is nothing but the water-permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a saturated, surface dry condition, with all permeable voids filled with water. The difference of the above two is the weight of dry aggregates minus weight of aggregates saturated surface dry condition.

Water absorption = (W3-W4/ W4)*100

Desirable value:

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average value of about 2.68. Though high specific gravity of an aggregate is considered as an indication of high strength, it is not possible to judge the suitability of a sample of road aggregate without finding the mechanical properties such as aggregate crushing, impact and abrasion values.

Water absorption of an aggregate is accepted as measure of its porosity. Sometimes this value is even considered as a measure of its resistance to frost action. Water absorption value ranges from 0.1 to about 2.0 percent for aggregate normally used in road surfacing. Stones with water absorption upto 4.0 percent have been used in base courses. Generally a value of less than 0.6 percent is considered desirable for surface course, though slightly higher values are allowed in bituminous constructions. IRC has specified the maximum water absorption value as 1.0 percent for aggregates used in bituminous surface dressing and built-up sprays grout.

6. Soundness Test

Aim: To study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycle

Apparatus:

a) Sodium sulphate or magnesium sulphate

b) Oven

c) Weighing balance

d) IS sieves

Procedure:

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles. The Porous aggregates subjected to freezing and thawing is likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test as specified in IS: 2386 part-V. Aggregates of specified size are subjected to cycles of alternate wetting in a saturated solution of either sodium sulphate or magnesium sulphate for 16 - 18 hours and then dried in oven to a constant weight. After five cycles, the loss in weight of aggregates is determined by sieving out all undersized particles and weighing. And the loss in weight should not exceed 12 percent when tested with sodium sulphate and 18 percent with magnesium sulphate solution.

Desirable value:

IRC has specified 12 percent as the maximum permissible loss in soundness test after 5 cycles with sodium sulphate, for the aggregate to be used in bituminous surface dressing, penetration macadam and bituminous macadam constructions.

7. Bitumen Adhesion/Stripping Test

Several laboratory tests have been developed to determine the adhesion of bituminous binder to an aggregate in presence of water.

These tests may be classified into six types:

a) Static immersion test

b) Dynamic immersion test

c) Chemical immersion test

d) Immersion mechanical test

e) Immersion trafficking test and

f) Coating test

The static immersion test is very commonly used as it is quite easy and simple. The principle of this type of test is by immersing aggregate fully coated with the binder in water maintained at specified temperature and by estimating the degree of stripping. The result is reported as the percentage of stone surface that is stripped off after the specified time periods.

Desirable value:

IRC has specified the maximum stripping value as 25 percent for aggregate to be used in bituminous construction like surface dressing, penetration macadam, bituminous macadam and carpet. IRC has specified that stripping value of aggregates should not exceed 25percent for use in bituminous surface dressing, penetration macadam, bituminous macadam and carpet constructions, when aggregate coated with bitumen is immersed in water bath at 40°C for 24 hours.

8. Polished Stone Value Test or Accelerated Polishing Test

Aim: To determine polished stone value of the given aggregate sample.

Apparatus:

Accelerated polishing machine

Pendulum type friction tester

Abrading material (sand and emery powder)

IS sieves: 10.8, 0.425, 0.3, 0.212 and 15mm

Mould of size 90.5 mm x 44.5 mm

Theory:

The aggregates used in the surface course of pavements are subjected to abrasion and rubbing action due to traffic movements and particularly during application of brakes. The presence of fine particles of sand and dust between the pavement surface and tyres of vehicles accelerates the process of the pavement surface getting smoothened along the wheel paths. The smoothened pavement surface becomes slippery under wet conditions, resulting in skidding of high speed vehicles when brakes are applied suddenly and the wheels are locked. Therefore the aggregates used in pavement surface course should have resistance from getting polished or smooth rapidly under traffic movement in order to prevent the pavement surface becoming too slippery resulting in accidents due to skidding of high speed vehicles under wet weather condition.

The test is conducted in two stages:

In the first stage, the sample of aggregates are placed in a mould and subjected to accelerated polishing action in machine, under standard test conditions.

In the second stage, the polished sample is subjected to friction test using a pendulum type skid resistance tester to determine the coefficient of friction expressed as percentage or polished stone value.

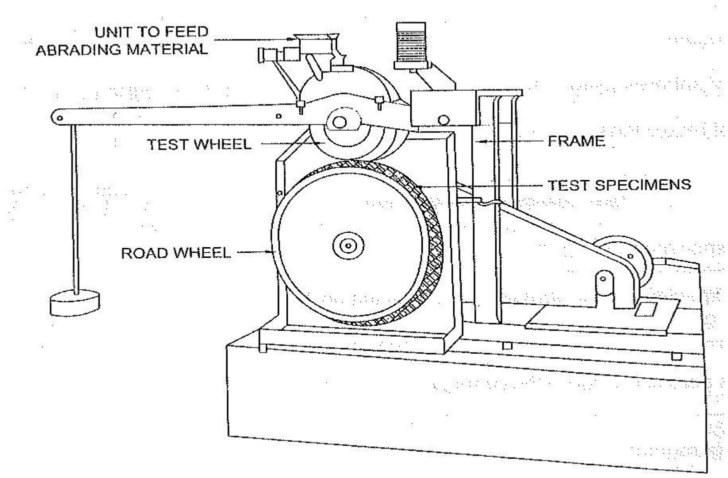


Fig: Accelerated polishing machine

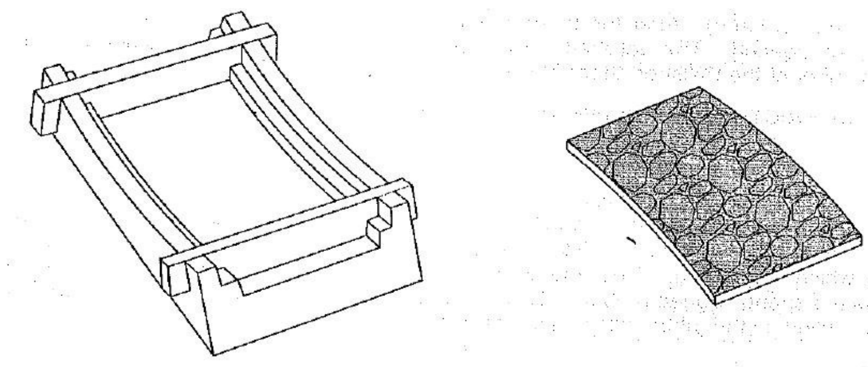


Fig: Mold and test specimen for accelerated polishing

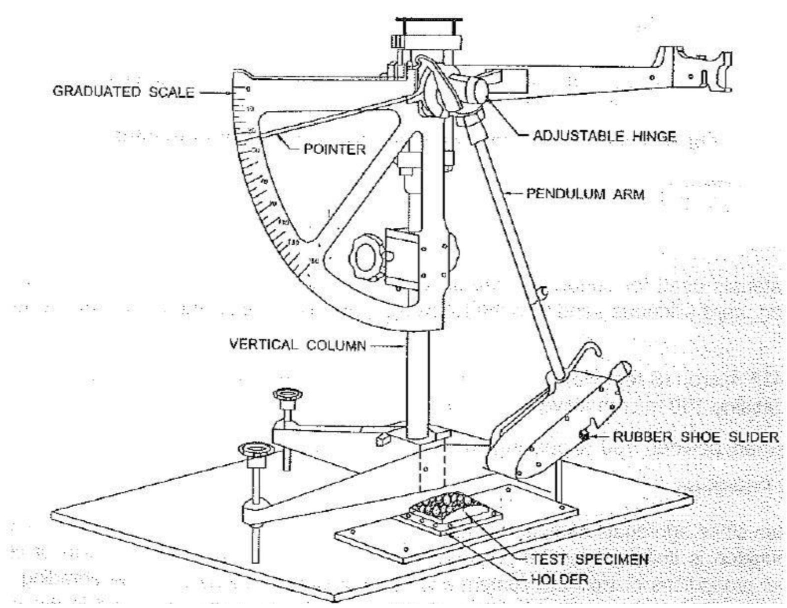


Fig: Pendulum type friction tester

Procedure:

Preparation of Test Specimen

About 3 kg of clean stone aggregate sample passing through 10 mm and retained on 8 mm IS test sieves (not flaky or elongated) are collected for the preparation of test specimen. A stiff paste of cement mortar is prepared using equal proportions of cement and sand, with required quantity of water. A thin layer of this mortar is placed in the mould and each particle of aggregate sample is set in the mortar in single layer by hand as closely as possible. The mortar is allowed to set so that the stone aggregate are held firmly in position.

Accelerated polishing Test Procedure:

The test specimens are clamped around the rim of the wheel with the help of strips of polythene sheet beneath and in between the adjoining test specimens.

The rubber tyred test wheel is lowered until it rests on the surface of the test specimens fixed around the road wheel. The required weight is added at end of lever such that total effective load of 40 kg is applied on test wheel through the lever system.

The motor is switched on and the road wheel rotates at a speed of 320 to 325 rpm. Abrading sand and water are released at the specified rate and these are uniformly spread over the surface of test specimen and tyre of the test wheel where they are in contact.

The road wheel is continued to be rotated and the test specimens are subjected to abrading action or polishing for a period of 3 hours. The machine is stopped and the test specimens are thoroughly cleaned by washing with water to remove sand and other fine particles of stone.

Measurement of Friction of Polished Specimens:

Machine used to determine the coefficient of friction or the skid resistance value is pendulum type friction tester.

The friction tester is placed on a firm level surface and leveling screws are adjusted such that the column is vertical. The pointer is set to zero.

One of the specimens of aggregate which was subjected to accelerate polishing is properly fixed in the slot provided, with its longer side in the track of the pendulum swing.

The surfaces of specimen and rubber shoe are wetted with clean water. The pendulum and pointer are released from horizontal position by pressing the button. The pointer reading is noted as the skid number or polished stone value from the graduated scale. Similarly the procedure is repeated using new specimens until two values are within this limit.

Desirable value:

As per the MORTH specifications for road and bridge works, the polished stone value of coarse aggregates used in bituminous concrete, semi dense bituminous concrete, open graded pre-mix carpet and close graded premix surfacing of roads, should be not less than 55 and for the aggregate used in surface dressing should be not less than 60.

1.7 Hydrophilic and Hydrophobic Aggregates

Most of the road stones have surfaces that are electrically charged. Silica, a common constituent of igneous rocks posses a weak negative charge and hence these have greater attraction with the polar liquid water than with bituminous binders having little polar activity. These aggregates which are electronegative are water-linking and are hydrophilic.

Basic aggregates like lime-stones have a dislike for water and greater attraction to bitumen, as they have positive surface charge. These aggregates are called hydrophobic.

Type of charge of aggregates used in road plays a vital role in bituminous construction. Bitumen is also available as cationic or positive and anionic or negative and hence a suitable selection may be made depending on aggregates available. Cationic (+) bitumen may be selected for electronegative aggregate and anionic (-) bitumen for electropositive aggregates.

1.8 Concepts of Size and Gradation

The gradation analysis or sieve analysis of weight the coarse and the fine aggregates available is carried out by sieving through the standard IS sieves.

Dry sieve analysis is generally used when aggregates contain fine slit or clay sticking to a coarser particle used sieve analysis is carried out.

Design Gradation

It is the gradation or distribution of particles or aggregates specified by the designer. The design gradation is obtained using a number of trials by mixing different size aggregate to satisfy the requirement of density and CBR value.

When the available aggregate sample does not satisfy the design gradation, the aggregates of different gradation are blended (mixed) using different trials or standard procedure suggested by Rothfuch's Method.

Maximum Aggregate Size

Maximum aggregate size is the sieve size or mean size of the smallest sieve through which 100% of material will pass. The maximum size and the grading of the aggregate are controlled by the specification which describes the distribution of particle sizes to be used of a particular work. The aggregates contain finer fraction (75μ) liquid limit and plastic limit of the particles finer than 425μ are to be determined. The aggregates containing more than 2% fines and greater than 5% fines can be used only for bituminous courses.

Aggregate Blending

Aggregate blending is a method of mixing the aggregates of different sizes to obtain or to satisfy the design gradation. There are several techniques used to blend the aggregates. The trial method is the one in which the aggregates are blended by several trials to get the design gradation and to meet the required specification.

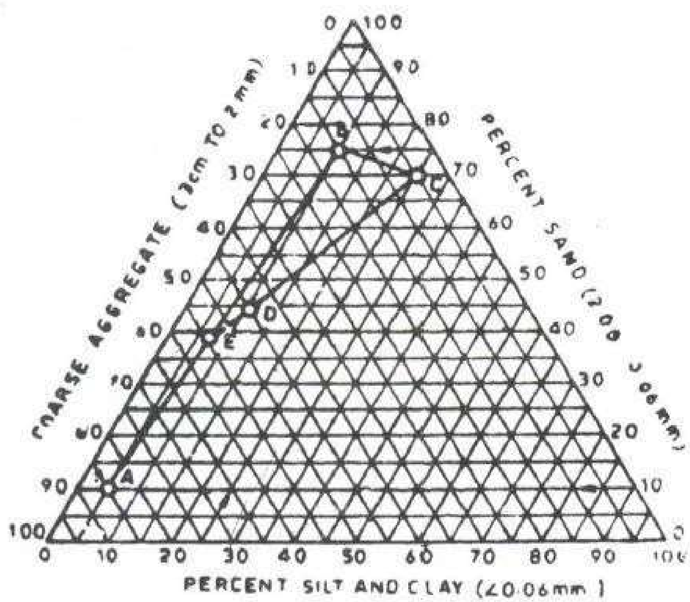
Two graphical methods in common use for proportioning/blending are:

1) Triangular Chart

2) Rothfuch's Method

➢ **Triangular Chart**

This method is applicable when three materials are to be mixed together to achieve a desired gradation (for maximum density). The materials may be conveniently divided on a triangular chart as shown in figure.



Suppose three materials A, B and C are available which are respectively coarse, medium and fine grained materials. Points A, B and C are plotted on the triangular chart knowing the grain size distribution (or proportion of coarse aggregate, sand and fines) of the three materials. Next step is to obtain the desired gradation D based on some gradation criteria or by using a gradation formula (Fuller equation). The point D is also plotted in the triangular chart representing the desired gradation. Now the graphical construction for obtaining the proportions A, B and C is made, by producing the line CD to meet the line AB at E.

The proportions of coarse aggregate, sand and fines are given by:

% coarse aggregate = (EB x DC / AB x EC) x 100

% Sand = (AE x DC / AB x EC) x 100

% Fines = (ED / EC) x 100

- **Rothfuch's Method**

This method is used when a number of materials have to be mixed together for obtaining a desired or design gradation. The desired gradation may be decided either based on recommended grain size distribution charts or tables or using the below Fuller's equation.

P = 100 (d/D) n

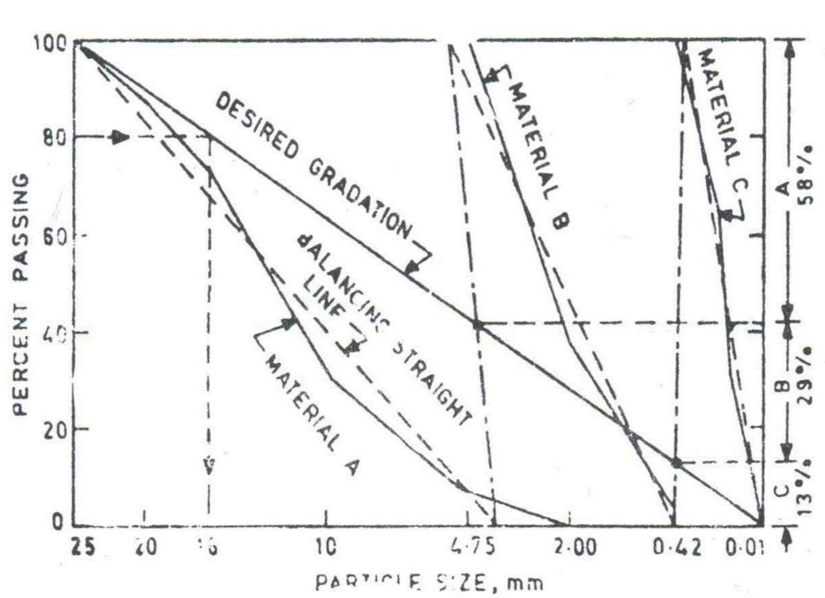
Where,

D = diameter of largest particle, mm

P = percent finer than diameter'd' (mm) in the material

n = gradation index, which have values ranging from 0.5 to 0.3 depending upon the shape.

On a graph paper, with Y-axis representing percent passing and X-axis representing particle size, as shown in figure. A diagonal line is drawn from point corresponding to (100 percent passing, maximum particle size of the material) to a point corresponding to (zero percent passing, smallest particle size of the materials)



1.8 . Introduction to bitumen & tar

Bituminous binders used in pavement construction works include both bitumen and tar. Both bitumen and tar have similar appearance, black in colour though they have different characteristics. Bituminous materials or asphalts are extensively used for road construction, primarily because of their excellent binding characteristics & waterproofing and relatively low cost. Bituminous mixtures are being used as structural layers & these materials are considered to be flexible from structural view point.

Origin

Naturally occurring deposits of bitumen are formed from the remains of ancient, microscopic algae and other once-living things. When these organisms died, their remains were deposited in the mud on the bottom of the ocean or lake where they lived. Under the heat and pressure of burial deep in the earth, the remains were transformed into materials such as bitumen or petroleum. Deposits at the La Brea Tar Pits are an example.

There are structural similarities between bitumen's and the organic matter in carbonaceous meteorites. However, detailed studies have shown these materials to be distinct. Asphalt or bitumen can sometimes be confused with "tar", which is a similar in colour (black), but it is a thermoplastic material produced by the destructive distillation of coal. During the early and mid 20th century when town gas was produced, tar was a readily available product and extensively used as the binder for road aggregates.

The addition of tar to macadam roads led to the word tarmac, which is now used in common parlance to refer to road-making materials. However, since the 1970s, when natural gas succeeded town gas, asphalt (bitumen) has completely overtaken the use of tar in these applications.

BITUMEN is a petroleum product obtained by the distillation of petroleum crude.

TAR is a thermoplastic material obtained from the destructive distillation.

The grade of bitumen used for pavement construction work of roads and airfields are called paving grades and used for water proofing of structures and industrial floors etc. are called industrial grades.

The paving bitumen available in India is classified into two categories

1) Paving bitumen from Assam petroleum denoted as A-type and designated as grades A35, A 90.etc.

2) Paving bitumen from other sources denoted as S-type and designated as grades S35, S90 etc.

The viscosity of bitumen is reduced some times by a volatile diluents this material is called **Cutback.**

The bitumen is suspended in a finely divided condition in an aqueous medium and stabilized with an emulsifier; the material is known as **Emulsion.**

- **Asphalt**

1) Rock Asphalt

a) It consists of limestone, sand stone naturally impregnated with bitumen.

b) The mineral matter will be about 90% and bitumen content of 10%.

2) Lake Asphalt

a) Mineral matter will be finely divided and dispersed through the bitumen

b) The whole mass is capable of flow

c) Type of lake asphalt used in road making in United Kingdom is Trinidad lake asphalt.

d) It is used in flexible road construction and also in rolled asphalt wearing courses.

1.9 Difference between Bitumen and Tar

Sl No.	Bitumen	Tar
1	Bitumen is found in black to brown in colour	Tar is usually found in brown colour
2	Bitumen is obtained from fractional distillation of crude oil	Tar is obtained by destructive distillation of coal or wood
3	Bitumen is soluble in carbon disulphide and carbon tetra chloride	Tar is soluble in toluene
4	Molecular weight range for road bitumen is 400 to 5000	Molecular weight range for road tar is 150 to 3000
5	Bitumen consists of large amount of aromatic hydrocarbon	Tar consist of large amount of oily matter with lower molecular weight
6	Bitumen show resistance to coating road aggregate and also does not retain in presence of water	Tar coats more easily and retain it better in presence of water
7	Free carbon content is less	Free carbon content is more
8	It shows more resistance to weathering action	It shows less resistance to weathering action
9	Less temperature susceptibility	More temperature susceptibility

1.10 General properties of bitumen

1. They contain predominantly hydrocarbons, with small quantities of sulphur, oxygen, nitrogen and metals.
2. They are predominantly soluble in carbon disulphide, the portion insoluble in CS_2 being generally less than 0.1%.
3. Most bituminous are colloidal in nature.
4. Bitumen's are thermoplastic, i.e. they soften on heating and harden on cooling.
5. They have no specific melting point, boiling or freezing point, though a form of softening point (Ring and Ball) is used in their characterization.
6. Bitumen's are insoluble in water.
7. They are highly impermeable to the passage of water.
8. They are generally hydrophobic (water repellent), but may be made hydrophilic (water linking) by the addition of small quantity of surface active agents.
9. They are chemically inert.
10. They oxidize slowly.

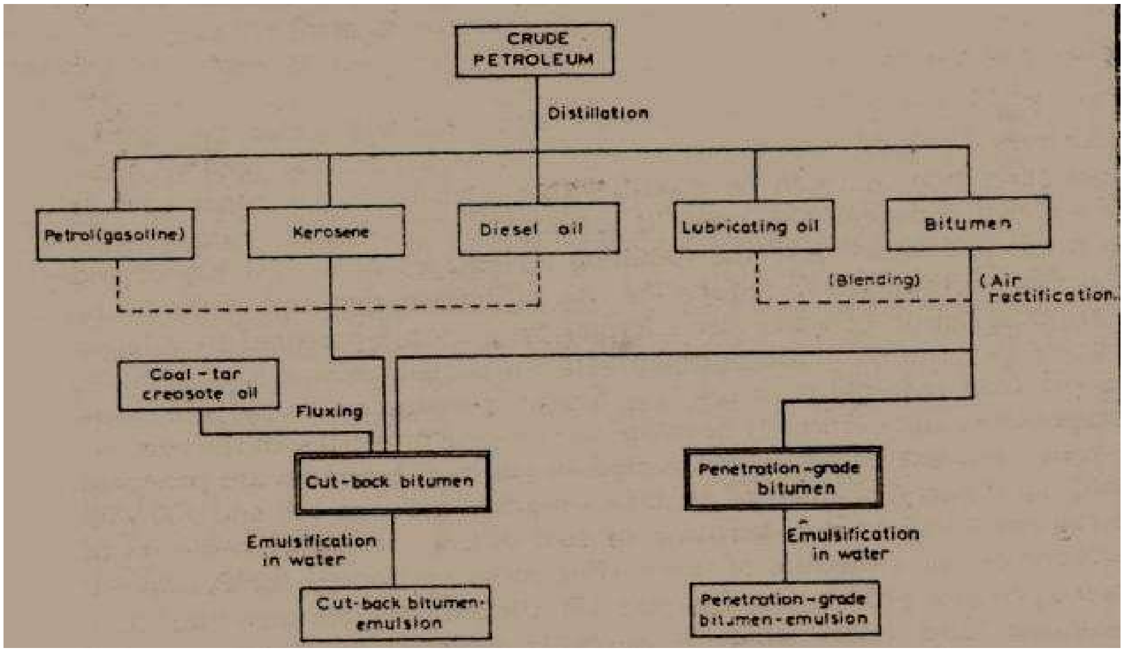
1.11 Desirable Properties of Bitumen

1. Viscosity: The viscosity of the bitumen at the time of mixing and compaction should be adequate. This is achieved by heating the bitumen and aggregate prior to mixing or by use of cutbacks or emulsions of suitable grade.
2. Temperature Susceptibility: The bituminous material shouldn't be highly temperature susceptible. During the hottest weather of the region the bituminous mix should not become too soft or unstable. During cold weather the mix should not become too hard and brittle, causing cracking. The material should be durable.
3. Adhesion Property: In presence of water the bitumen should not strip off from the aggregate. There has to be adequate affinity and adhesion between the bitumen and aggregate used in the mix.
4. It should be fluid enough at the time of mixing to coat the aggregates evenly by a thin film. Fluidity is achieved either by heating or by cutting – back with a thin flux or by emulsifying the bitumen.
5. The bitumen should have a good amount of volatiles in it, and it should not lose them excessively when subjected to higher temperature. This will ensure its durability.
6. The bitumen should be ductile and not brittle.
7. The bitumen should be capable of being heated to the temperatures at which it can be easily mixed with fire hazards.
8. The bitumen should have good affinity to the aggregates and should not be stripped off in the continued presence of water.

1.12 Preparation of Road Bitumen from Petroleum

The refining of petroleum is most complex procedure producing a tremendous range of products from the simplest hydrocarbon gas methane to the hardest bitumen with constituents of molecular weight of the order of several thousands.

The preparation of different forms of bitumen for road purposes from petroleum is illustrated in the above figure.



Flow chart: Preparation of road bitumen

a) Distillation of Petroleum

- Bitumen is produced from selected crude oils by a process of concentration by distillation.
- The distillate is obtained in the desired boiling point ranges by condensation in a fractionating column.
- It is first to heat the crude oil to a temperature lower than 350°C under atmospheric pressure & to drive off light fractions such as gasoline, kerosene and gas oil.
- Further heating above 400°C is necessary to drive off heavier oils.
- Refining of the topped crude is carried out by use of reduced pressures and steam injection in the fractionating column.
- The incoming crude is pumped through a continuous pipe-still similar to that used in tar-distillation plants, where it is raised to desired temperature (between 200 and 400° C).
- It is then injected into a fractionating column where at the reduced pressure volatile components flash into vapours.
- The vapours are condensed into fractions of decreasing boiling point by condensation at points at higher levels in the fractionating column.
- A flow diagram representing the distillation of topped oil in a modern refinery is given in figure below.

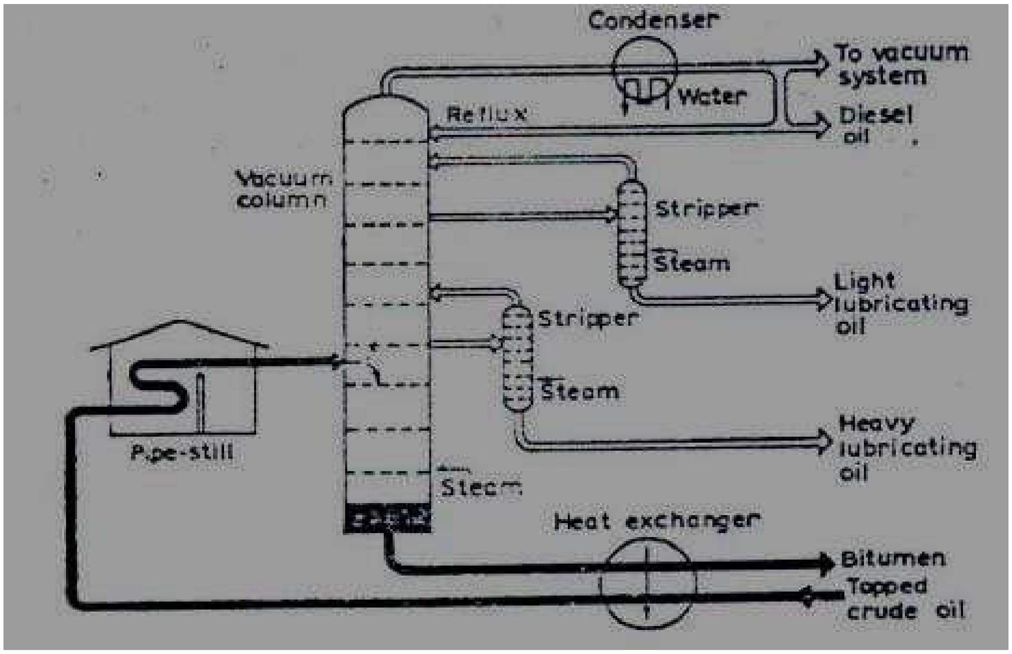


Fig: Bitumen Production

b) Air-Rectification of Refinery Bitumen

Bitumen produced by straight steam-refining from crude oils may be deficient in the components of high molecular weight which are insoluble in heptanes, asphaltenes fractions. It is common practice to increase the asphaltene content by oxidation of the hot straight-run bitumen by a current of air blown through it. These are bitumen of high softening point produced by an oxidation by air-blowing at high temperatures.

The oxidation is more extensive and the blown bitumens have rubbery qualities required for certain industrial purposes and not used as binders for road aggregates.

1.13 Chemical Constitution of Bitumen

Bitumen although formed from distillation process causes some changes which are closely related in chemical nature to its primary source i.e., the crude petroleum oil. Bitumen is completely soluble in carbon-di-sulphide but most of them divide the bitumen soluble in carbon-di-sulphide into 3 fractions:

a) **Carbenes:** Fraction insoluble in carbon tetrachloride.

b) **Asphaltenes**: Fraction insoluble in light aliphatic hydrocarbon solvent such as petroleum ether.

c) **Maltenes:** Fraction soluble in light aliphatic hydrocarbon solvent**.**

The molecular weight of asphaltene fraction is estimated between 1800 and 1, 40,000 and maltenes have molecular weight between 370 and 710.

The hydrocarbons in petroleum are of four basic forms:

a) Saturated aliphatic groups or paraffins.

b) Naphthenic groups or cycloparaffins.

c) Aromatic ring compounds.

d) Aliphatic groups with olefin double bonds.

Aliphatic group normally does not present in road bitumen. The approximate proportions of the other three groups in the molten groups can be obtained from modified Waterman analysis. Many properties of bitumen, particularly the non-Newtonian flow properties suggest that bitumen is a colloidal system. The colloidal nature of bitumen is due to the presence of asphaltenes in association with high molecular weight material from the maltenes fraction, form a disperse phase. This complex is normally referred as ‘micellar phase’.

On the basis of flow properties, bitumen can be divided into two types, ‘sol’ type, in which there is little interaction between micelles or a ‘gel’ type in which interaction of micelles are great enough to cause a loose structure formation. Most of the distilled road bitumens are sol type, blowing leads to gel type structures.

1.14 Requirements of Bitumen

The desirable properties of bitumen depend on the mix type and construction.

a) Mixing: type of materials used, construction method, temperature during mixing, etc.

b) Attainment of desired stability of the mix

c) To maintain the stability under adverse weather conditions

d) To maintain sufficient flexibility and thus avoid cracking of bituminous surface and

e) To have sufficient adhesion with the aggregates in the mix in presence of water

1.15 Tar

Tar is the viscous liquid obtained when natural organic materials such as wood and coal carbonized or destructively distilled in the absence of air. Based on the materials from which tar is derived, it is referred to as wood tar or coal tar. It is more widely used for road work because it is superior.

There are five grades of roads tar: RT-1, RT-2, RT-3, RT-4 and RT-5, based on their viscosity and other properties.

RT-1 has the lowest viscosity and is used for surface painting under exceptionally cold weather as this has very low viscosity.

RT-2 is recommended for standard surface painting under normal Indian climatic conditions.

RT-3 may be used for surface painting, renewal coats and premixing chips for top course and light carpets.

RT-4 is generally used for premixing tar macadam in base course.

RT-5 is adopted for grouting purposes, which has highest viscosity among the road tars.

<u>The various tests carried out on road tars are:</u>

- Specific gravity test
- Viscosity test on standard tar viscometer
- Equiviscous temperature (EVT)
- Softening point
- Softening point of residue
- Float test
- Water content
- Phenols, percent by volume
- Naphthalene, percent by weight
- Matter insoluble in toluene, percent by weight
- Distillation fraction on distillation upto 200°C, 200°C to 270°C and 270°C to 330°C

1.16 Preparation of Tar

There are three stages in the production of road tar:

- Carbonization of coal to produce crude tar
- Refining or distillation of crude tar
- Blending of distillation residue with distillate oil fractions to give desired road tar.

(A) High-Temperature Carbonization of Coal

The carbonization or destructive distillation of coal consists essentially of heating a thin layer of coal enclosed in a chamber of refractory brick-work for several hours at temperature about 1000° C.

Majority there are two major methods for carbonization, they are:

- Carbonization in Coke-ovens
- Carbonization in gas-works retorts

<u>Carbonization in Coke-Ovens:</u>

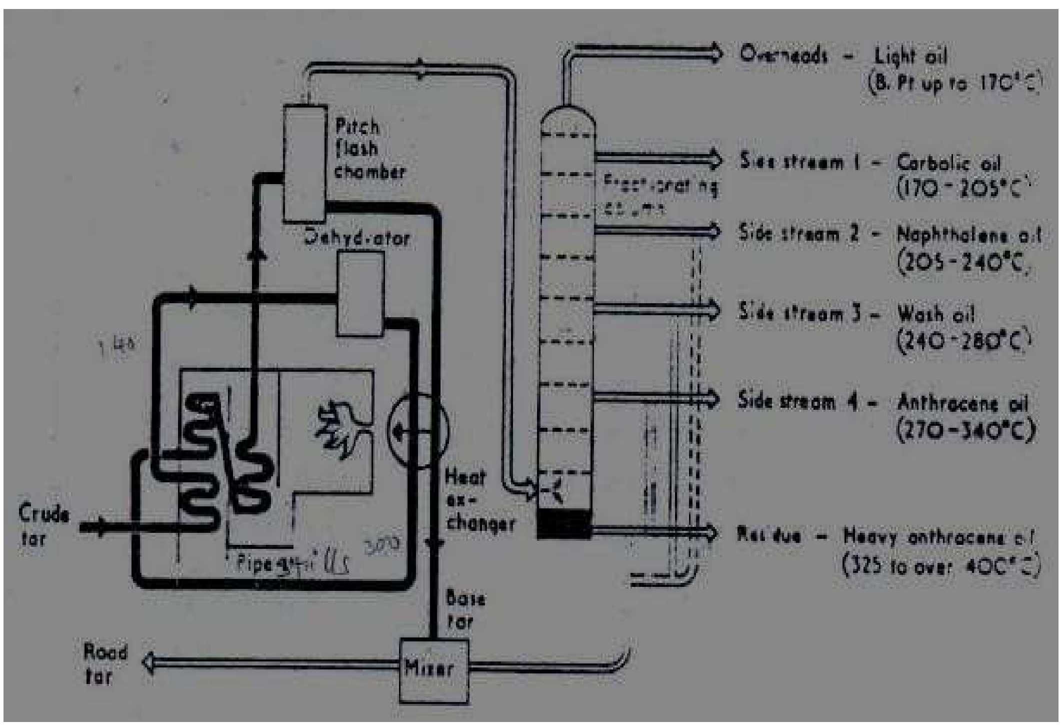
A batch of about 16 tons of coal is loaded into a coke-oven.

Coke oven consists of large thin box lined with brick, 40 feet long, 14 feet high and 1 ½ feet wide.

The charge of coal is heated for 18 hours at a temperature of 1200° C.

Each ton of coal yields 8 gallons of crude tar.

(B) Distillation of Crude Tar



The crude tar obtained by the condensation of the vapours emitted from coal in the course of carbonization is subjected to distillation process.

The distillation or refining of tar is carried out by tar distillers. The process consists, first heating the crude tar to remove water and some light oils (Benzole), then heating further and condensing the heavier vapour in a fractionating column.

The operation is carried out in two stages:

In the first stage, the tar passes through the tubes in the cooler part of the furnace at a temperature of 140°C.

It is then passed to a dehydration chamber where the pressure is released and water and light oil is released.

The remaining tar is then passed to the second stage of the pipe-still at a temperature of 300°C.

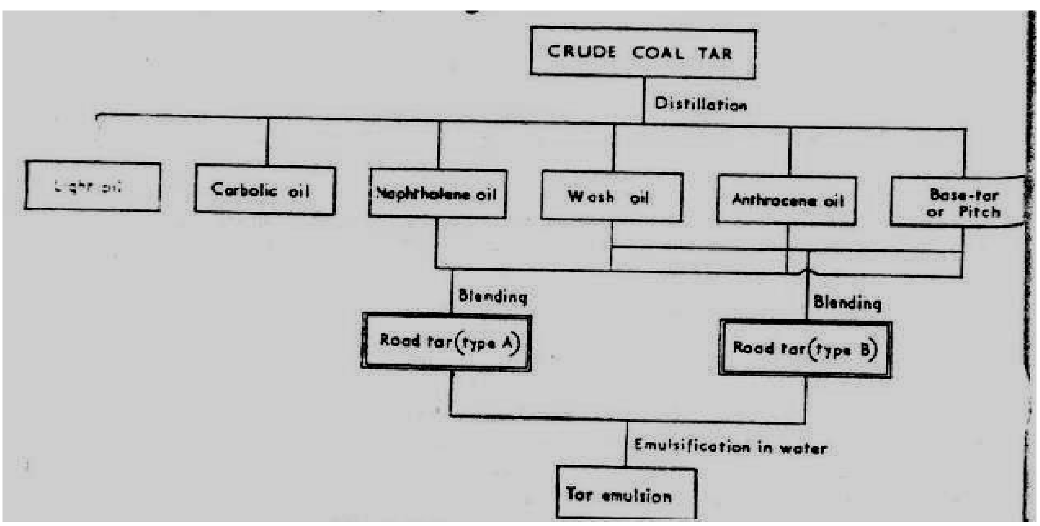
From pipe-still, tar passes to a chamber at a lower pressure where vaporization takes place.

The vapours are condensed in a fractionating column which forms fractions of different boiling point ranges.

The residue which is not distilled is base-tar or pitch.

In order of increasing boiling points they may be classified as light oil, carbolic oil, naphthalene oil, wash oil, anthracene oil.

(C) Blending of Tar-Distillation Fractions to Produce Road Tar



Preparation of road tar layout

Type A = Base tar + Naphthalene oil
Type B = Base tar + Wash oil + Anthracene oil

It is evident from the above that a tar of a suitable viscosity for use on the roads could be left as residue simply by stopping the distillation at the appropriate point.

Road tar 1 and 2, on the basis of viscosity, having viscosities of 10 to 40 and 40 to 125 seconds at Standard Tar Viscosity (STV) at 30°C.

Type-A having high softening point is used for surface dressings and base courses. Type-B is used for wearing courses and carpets.

1.17 Chemical Constitution of Tar

It is estimated that there are over 10,000 compounds in tar. Out of this 300 have been separated. The distillate oils consist largely of aromatic hydrocarbons, with one or more methyl groups attached to the nucleus, with smaller quantities of aromatic hydroxyl compounds, paraffinic hydrocarbons and heterocyclic compounds with oxygen, nitrogen or sulphur in the ring.

Dickinson developed a method called 'solvent fractionation' which uses n-hexane, benzene and pyridine as solvents to give five fractions. He divided up in this way tars produced from vertical-retort, horizontal-retort and coke-oven crudes and by measurement of mean molecular weights. Typical structures for the solvent fractions have been suggested by spectroscopic examination on the basis of molecular weight and C/H ratio.

The differences in chemical structure between tars from different carbonization processes are reflected in different in their properties. Tars produced by carbonization in coke-ovens or horizontal retorts have more purely aromatic hydrocarbons compared to vertical retorts.

Thus, where as in coke-oven tar distillate oils over 90 percent may consist of aromatic hydrocardon of benzene, naphthalene, anthracene and phenanthrene series, similar oils from vertical retort tars contain up to 25% of phenolic material and the same amount of paraffins, this is because temperature reached in coke-ovens and horizontal retorts will be higher than continuous vertical retorts and the vapours evolved during carbonization are in contact with hot coke for a longer period.

Vertical-retort tars are often referred as low-aromatic tars while coke-oven and horizontal-retort tars as high-aromatic tars. In general, the high-aromatic class is distinguished by wider molecular weight range, higher specific gravity, higher pitch content and low phenolic content.

Further reading & Reference

1. Highway Engineering- Khanna, S.K., and Justo, C.E.G.: Nem Chand and Bros. Roorkee.
2. RRL, DSIR, 'Bituminous Materials in Road Construction', HMSO Publication.

MODULE-2

BITUMINOUS EMULSIONS & CUTBACKS

Structure

1.1 Objective

The objective of the present module is to expose students to different materials which are used in pavement construction, impart knowledge about the engineering properties required.

1.1 Emulsions

An emulsion is a two-phase system consisting of two immiscible liquids (unmixable or unbendable). The dispersed or internal phase is the liquid that is broken up into globules and the surrounding liquid is known as the continuous or external phase. Oil-in-water emulsions have the oil as the dispersed phase and water as the continuous phase. The reverse occurs when the emulsion is of water-in-oil type. Oil phase consisting of bitumen or tar.

In the preparation of emulsion of asphaltic bitumen or tar, emulsifiers have to be added in small proportions both to facilitate the formation of dispersion and to keep the globules of dispersed binder in permanent suspension.

If no emulsifier is present, a dispersion of oil droplets in water brought about by stirring will rapidly separate into 2 layers. With emulsifier present, an adsorbed film of the emulsifier is formed round each globule in the emulsion.

1.2 Classification of the Emulsions based on setting time

Emulsion is classified in to 3 types based on setting time:

1. Rapid setting: If the bitumen emulsion is intended to break rapidly, the emulsion is said to possess rapid-set quality and this type is used in surface dressing & penetration macadam.

2. Medium setting: Emulsion which does not break spontaneously on contact with stone but break during mixing or by fine mineral dust are MC. Used in premixing with coarse aggregate.

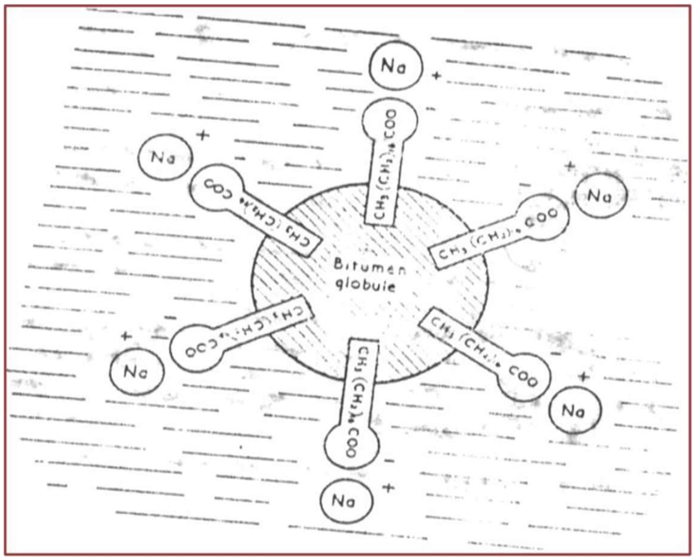
3. Slow setting: When specified type of emulsifying agent is used to make the emulsion relatively stable, they are called slow setting grade. Used in surface course along with the coarse aggregate.

Emulsifiers for road emulsions may be divided into four main groups:

- Anionic emulsifiers
- Cationic emulsifiers
- Non-ionic emulsifiers
- Colloidal emulsifiers

Anionic Emulsifiers

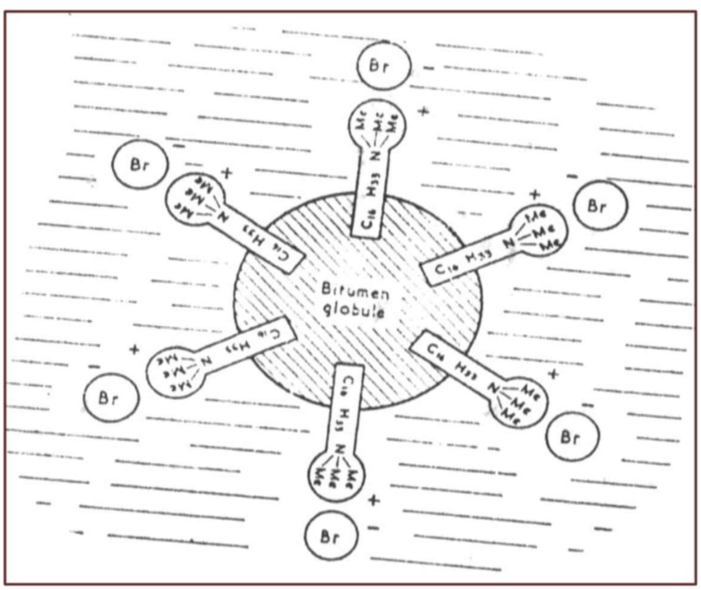
It is characterized by having a large organic anion forming a salt with an alkali. A typical example of sodium stearate $CH_3(CH_2)_{16}COONa$. When dissolved in water, this dissociates into the (negative) stearate anion $CH_3(CH_2)_{16}COO^-$ and the (positive) sodium cation Na^+. The long-chain fatty-acid stearate anion is soluble in bitumen, the carboxylic group (COO^-) which carries the negative charge being the least soluble part. Each bitumen globule is surrounded by stearate ions with negative charge on the surface and it becomes much more difficult for the globules to combine because all have surface negative charges and tend to repel each other.



Anionic Emulsifier

Cationic Emulsifiers

These are compounds in which it is the cation which is the large organic fraction soluble in bitumen. Typical example is cetyl trimethyl-ammonium bromide $C_{16}H_{33}(CH_3)_3NBr$ dissociates in water into the (positive) cetyl trimethyl-ammonium cation and the (negative) bromine anion Br^-. The cation is soluble in bitumen and when this compound is present in a system of globules of bitumen in water is established, so that each globule of bitumen is surrounded by a positively charged layer.



Cationic Emulsifier

Non-Ionic Emulsifiers

The non-ionic emulsifiers do not ionise in aqueous solution, are limited in use. They comprise esters and ethers of fatty acids and alcohols.

Colloidal Emulsifiers

It includes naturally occurring fine powders which are used for industrial purpose than for road emulsions. Examples of these are casein and gelatine and fine powders such as clays and bentonites.

1.3 Preparation of Emulsion

Materials

Almost all grades of bitumen can be emulsified, from hard penetration grades to softer grades. Harder grades of bitumen are used for industrial purposes.

Methods of Making Road Emulsion

a) Colloid mill method

b) High-speed mixer method

The main difference between the methods is that with the colloid mill the emulsion is produced continuously where as with the high-speed mixer a number of separate batches are produced.

a) Colloid Mill Method

In the colloidal mill the emulsion is produced continuously. Power requirement is more to give continuous production.

Equipment/ machinery:

Rotor: The method consists of high speed rotor which revolves in a stator, the clearance between the rotor and the stator being approximately 15 to 20 thousands of an inch. The rotor speed produces velocity of 10,000 ft per min. The main emulsifying agent depends upon the hydraulic shearing forces exerted by the rotating surfaces upon the particles of bitumen in the presence of aqueous emulsifying liquids.

Method: A hot solution of the emulsifiers in water and the heated bitumen are fed separately at a constant rate into the machine in the appropriate constant proportions so that an emulsion of uniform binder content is continuously produced. It has been shown that the degree of hardness of the water used has an influence on the degree of dispersion and water-softening plants may need to be installed in areas of very hard water.

- The colloidal mill must be driven so that it will run at a constant speed and the bitumen and emulsifier solution must be maintained at a constant temperature so that the viscosity of the liquids passing through the machine is constant.
- Road emulsions can be continuously produced in colloid mills at rates of up to 2500 gallons per hour.

b) High-Speed Mixer Method

This method is not widely used because it is a batch process and therefore more labour is required. The procedure is to run appropriate amount of water at just below boiling point into a 200/300-gallon mixer, the diameter of which is equal to depth of liquid it is proposed to mix. The mixer is fitted with a high-speed propeller type. Stirrer mounted off-center to avoid the production of a vortex. Alkali is added to the water in the mixer and bitumen at about 100°C is slowly run in with continuous stirring. Dispersions obtained by this method are not as uniform as those obtained in a colloidal mill. After emulsification by either method, the material is pumped into storage tanks where it is allowed to cool.

1.4 Properties of Emulsion

The following are the properties pertaining largely to the constitution of emulsion before use.

a) Residue on sieving

b) Stability to mixing with coarse-graded aggregate

c) Stability to mixing with cement

d) Water content

e) Viscosity

f) Coagulation at low temperature

g) Sedimentation

h) Stability on long-period storage

Residue on Sieving

Practically all road bitumen and tars are slightly heavier than water and the globules of binder will tend to sediment in emulsion; the rate at which it sediments depends on the size of the particle. Hence percentage of large particles should be controlled and hence is to ensure that no more than 0.25% by weight of emulsion consists of particles greater than 0.006 inch in diameter.

Stability to Mixing with Coarse-Graded Aggregate

When mixing bitumen emulsions with coarse aggregates break down of the emulsion and coating off the aggregates with bitumen should not take place too early in the mixing cycle. Stable emulsions should have sufficient mechanical and chemical stability for all purposes involving mixing with fines and cement.

Stability to Mixing with Cement

Stable emulsions should have sufficient mechanical and chemical stability for all purposes involving mixing with aggregates including those containing large proportions of fines. Cement is used as a standard fine aggregate.

Water Content

Road emulsions may contain up to 65% of water. It is essential to know this percentage if the quantity of bituminous binder actually used in the surfacing is to be measured accurately. The water content of an emulsion is often varied to suit particular forms of application.

Viscosity

It is determined by the proportion of bitumen or tar in the emulsion and by the particle-size distribution. The viscosity of the emulsion should be low enough to spray through conventional jets or to coat stone. It is measured by Engler out flow viscometer.

Coagulation at Low Temperature

All emulsions contain water they are affected by extremes of heat and cold. Exposure to temperatures below 0°C will result in freezing and the degree of recovery on thawing depends on type of emulsion.

Sedimentation

Some sedimentation may occur when a drum of emulsion is left standing before use; provided however the sediment redisperses on agitation, the emulsion can be used satisfactory.

Stability on Long-Period Storage

When stored in drums under normal atmospheric conditions, the emulsion should not separate in a form which cannot be redispersed by agitation.

1.5 Classification of Emulsions based on breaking

Bitumen emulsions are divided into 3 main classes depending on the rates at which they break. The classes are sub-divided, depending on the bitumen contents and viscosity ranges of the emulsions.

- **Class-1: Labile or Quick-Breaking**

This class embraces emulsions characterized by rapid breakdown on application and suitable for surface-dressing and grouting work. They are normally unsuitable for mixing with aggregate and subdivided into following classes: 1A, 1B, 1C.

- **Class-2: Semi-Stable**

These are emulsions of sufficient stability to permit mixing with certain grades of aggregate before breakdown occurs. They contain more stabilizer than the labile emulsions and are sub-divided as class 2A, 2B.

- **Class-3: Stable**

These are emulsions with sufficient mechanical and chemical stability for all purposes involving mixing with aggregates including fines like cement, hydrated lime, etc.

1.6 Uses of Emulsions:

- They are more tolerant than penetration grade bitumen, of the presence of dampness, although they should not be used in the presence of free water on the road surface or on aggregate.
- Because emulsion is of relatively low viscosity at normal temperature, they eliminate the need to heat the aggregate and binder and thus they conserve energy.
- They can be used when the weather is relatively cold.
- They are ideal for patching and repairing work, particularly they do not require heating before use.
- They are used for surface dressing, grouting, pre-mixing, sealing, and soil stabilization with cement.

1.7 Disadvantages

- Emulsions are however, costly.
- Since they contain a substantial quantity of water, the transportation coat is higher.

1.8 Tests for Road Emulsions

a) Determination of Water Content

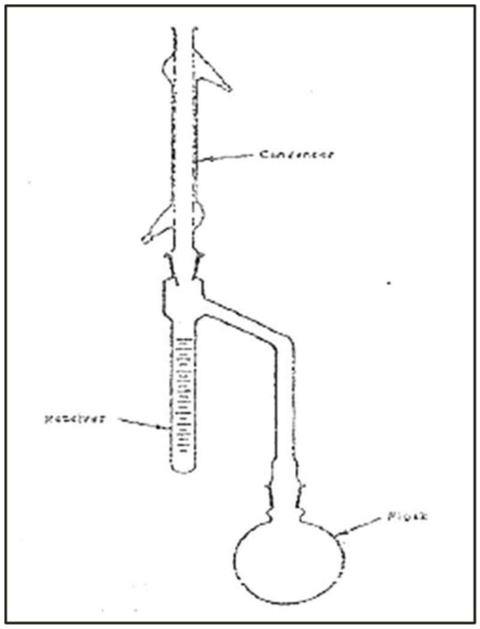


Fig: **APPARATUS FOR DETERMINATIONN OF WATER CONTENT**
(Dean-and-Stark Method)

Road emulsions may contain up to 65% of water and it is essential to know this percentage. The determination is made by Dean and Stark method. The sample is placed in a round-bottomed flask fitted with a graduated receiver (Dean and Stark tube) and a condenser. An organic liquid immiscible with water. Ex: Benzene and xylene, white spirit or solvent naphtha is added and the flask is heated. The organic liquid distils into the receiver, carrying with it, water which then separates into lower layer. The excess carrier liquid over flows into the flask.

b) Measurement of Viscosity

The viscosity of an emulsion is a measure of flow properties of emulsion itself and has no relation to the viscosity of the bitumen or tar and it is determined by means of Engler viscometer.

Emulsions are available having viscosities in the range 5 to 20°Engler. The viscosity must be chosen so that the emulsions is sufficiently fluid to flow and coat the stone but at the same time is viscous enough not to drain from the stone.

It is first calibrated by filling to the level with distilled water which is adjusted to 20°C by the surrounding water bath. The time in seconds for 200 ml to run out is recorded. The viscometer is dried and the test is repeated using emulsion. The viscosity in Engler degrees is the ratio of the times of flow for emulsion and water.

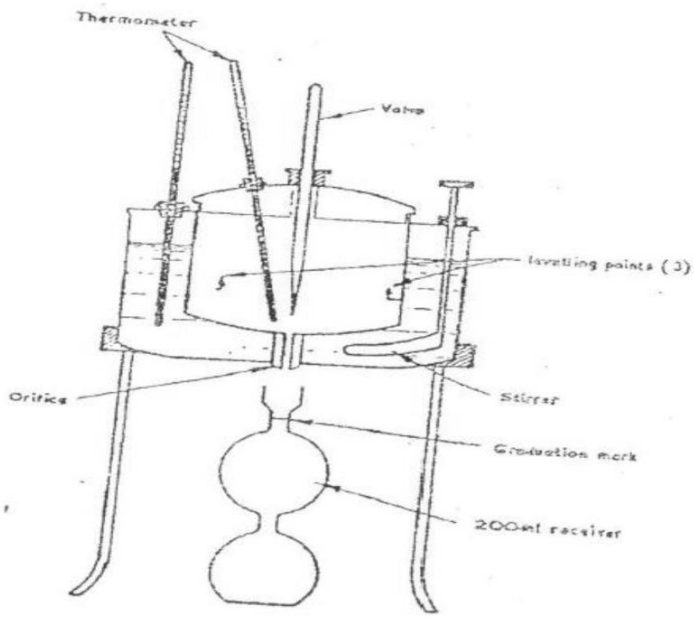


Fig: ENGLER VISCOMETER

c) Determination of Residue on Sieving

This test determines the amount of binder present in a bituminous road emulsion in particles large enough to be retained on a gauge of specified mesh. Emulsions must not give more than 0.25 g of residue per 100 ml of emulsion when passed through appropriate sieve.

The appropriate sieve is washed, dried, weighed and moistened. 100 ml of emulsion are poured through and the sieve is washed with distilled water, after drying in a vacuum desiccators, the residue is weighed.

d) Coagulation on Storage (Short-Period Test)

This test indicates the tendency of the particles of binder in an emulsion to agglomerate when the emulsion is stored or transported in ordinary commercial containers. Not more than 0.1 g of coagulain per 100 ml of emulsion should be produced under the conditions of test.

100 ml of sieved emulsion are allowed to stand for 7 days in a stoppered measuring cylinder. At the end of this period the emulsion is again sieved and the residue weighed after washing and drying. The weight of residue is reported as coagulated binder per 100 ml of emulsion.

e) Long-period storage stability

This method indicates the tendency of the binder in a bituminous road emulsion stored in drums to separate in a form which cannot be redispersed by agitation. An emulsion should not possess more than 2% of water content difference between before and after storage.

A drum of emulsion is selected and the water content is determined by Dean and Stark method. The emulsion is transferred to a clean drum leaving 5% air space. The drum is sealed and left for 3 months at temperature range 5 to 30°C. At the end of storage period, the test portion is sieved and the water content determined. The difference between the water content of the emulsion before and after storage is reported as storage stability.

f) Coagulation at Low Temperature

This test is intended to show if any coagulation of the binder occurs on exposure to low temperatures. This emulsion is first sieved and preheated to 60°C and it is then cooled in a series of baths to a temperature of -3° to -4°C. After remaining quiescent for 30 minutes. The temperature of the emulsion is allowed to regain air-temperature, when the emulsion is sieved. Any coagulated binder will be retained; the emulsion fails the test if any coagulation occurs.

g) Sedimentation

Some sedimentation may occur when a drum of emulsion is left standing before use. 10 g of bitumen emulsion is weighed into a glass tube which is then centrifuged for five minutes to sediment the emulsion. 30 ml of 1 % soft soap is added and tube is stoppered. The tube is then rotated end-over-end at one complete inversion per second, after each five turns the table is allowed to drain towards the stopper for ten seconds to observe if any sediment remains. The number of inversions until the sediment disperses is noted and should not be less than 50 for the emulsion.

1.9 Cutback Bitumen

Cutback bitumen is defined as the bitumen, the viscosity of which has been reduced by volatile diluents. For use in surface dressings, some type of bitumen macadam and soil-bitumen stabilization, it is necessary to have a fluid binder which can be mixed relatively at low temperatures. Hence to increase the fluidity of the bituminous binder at low temperatures the binder is blended with volatile solvent. After the cutback mix is used in construction work, the volatile gets evaporated and the cutback develops the binding properties. The viscosity of cutback and rate of which it hardens on the road depend on the characteristics and quantity of both bitumen and volatile oil used as the diluents.

1.10 Types of Cutback Bitumen and Uses

Cutback bitumen is available in three types, namely:

a) Rapid Curing (RC)

b) Medium Curing (MC)

c) Slow Curing (SC)

This classification is based on the rate of curing or hardening after the application.

- **Rapid Curing Cutbacks (RC)**

These are bitumen's, fluxed or cutbacks with a petroleum distillate such as naphtha or gasoline, which will rapidly evaporate after using in construction, leaving the bitumen binder. The grade of the RC cutback is governed by the proportion of the solvent used. The penetration value of residue from distillation up to 360°C of RC cutback bitumen 80 to 120.

- **Medium Curing Cutbacks (MC)**

This bitumen fluxed to greater fluidity by blending with an intermediate boiling-point solvent like kerosene or light diesel oil. MC cutbacks evaporate relatively at slow rate because the kerosene-range solvents will not evaporate rapidly as the gasoline-range solvents used in the manufacture of RC cutbacks.

MC products have good wetting properties and so satisfactory coating of fine grain aggregate and sandy soils is possible.

- **Slow Curing Cutbacks (SC)**

These are obtained either by blending bitumen with high-boiling-point gas, oil or by controlling the rate of flow and temperature of the crude during the first cycle of refining. SC cutbacks or wood soils hardens or set way slowly as it is a semi volatile material.

1.11 Tests on Cutback Bitumen

Various tests carried out on cutback bitumen are:

- Viscosity test: Same as bitumen at specified temperature using specified size orifice.

- Penetration test, ductility test and test for matter soluble in carbon-disulphide on residue from distillation up to 360°C.
- Flash point test on cutback using Pensky Martens's closed type apparatus.
- Distillation test to find distillation fractions, up to specified temperature and to find the residue from distillation up to 360° C.

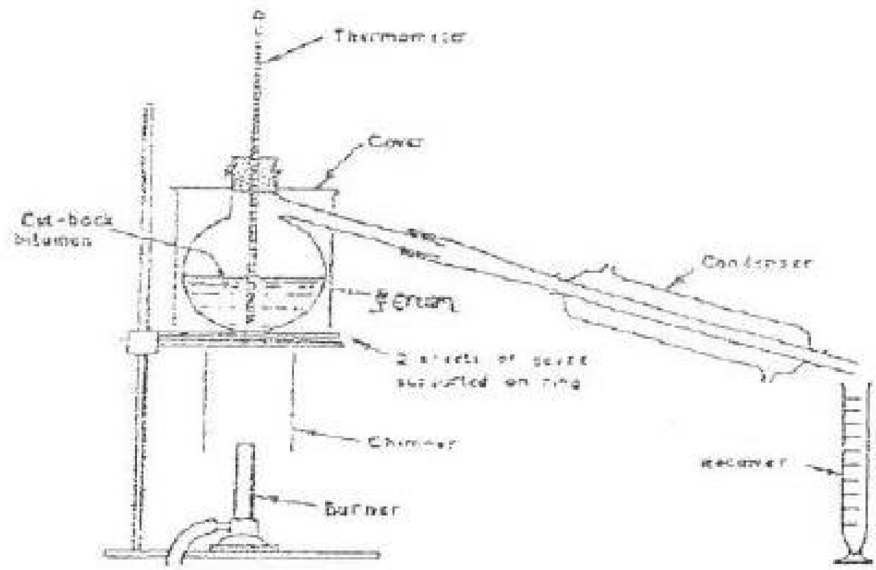


Fig: CUT-BACK BITUMEN DISTILLATION APPARATUS

The apparatus is as shown in figure. 22 ml of cutback bitumen is introduced into flask and the apparatus is assembled, note that the thermometer reaches almost to the bottom of flask. Heat is applied so that the distillation commences in 5 to 15 minutes and the distillation is continued at a rate of 50 to 70 drops per minute. The volume of distillate is observed at 175°C and at 25°C intervals thereafter up to 325°C; the heat source is removed when the temperature reaches 360°C. The total volume of oil is observed after draining the condenser. The bitumen residue is poured immediately into an open tin and allowed to cool below its fuming point.

1.12 Adhesion of Bituminous Binders to Road Aggregates

Introduction

One of the principal functions of a bituminous binder is, as its name suggests, acting as an adhesive either between road stones or between road stone and the underlying road surface. Neither bitumen nor tar can be regarded as an ideal adhesive but in general when proper precautions are exercised, both are adequate.

Road stones are wetted can lead to difficulties, either in the initial coating of damp road stone in maintaining an adequate bond between the binder and stone. Failure of a bond already formed is commonly referred to as 'stripping' which is brought about by the displacement of the bituminous binder from the stone surface by water. The greater the viscosity, the less readily and the more slowly does the binder wet the stone. The problems with water mixing in two ways, firstly due to aggregates being wet before laying, secondly due to effect of rain after it has been laid.

1.13 Types of Adhesion Failure

A) <u>Wet-Weather Damage to Surface Dressings</u>

Wet chippings are frequently used for surface dressing. With untreated stone and binder, adhesion will not take place until the stone dries out. In good weather, this process is rapid but with high atmospheric humidity the chippings may remain wet for several hours or even days. Rain may cause displacement of the binder from stone. Once the chippings have been removed, the binder is carried by vehicle tyres and extensive damage may be expected.

In other words, under the higher atmospheric humidity condition, the surface dressing materials will be generally in wet condition. These chips will be loosened under the wheel loads, resulting in extensive damages.

B) <u>Stripping in Pre-Mixed Bituminous Materials</u>

The problem of stripping is experienced only with bituminous mixtures which are permeable in water. If the material is really impermeable such as with rolled asphalt, then stripping is most improbable.

Permeable bituminous surfacing materials are widely used and an average life of five or six years is commonly obtained from bitumen-macadam wearing courses before surface treatment of some kind is required. The binder displaced from the stone surface generally moves upwards under the action of traffic and collects in the surface forming 'fat patches'.

If the stripping becomes extensive, the strength of the bituminous mixture is impaired and deformation takes place under traffic.

It is characteristic of stripping failures of pre-mixed surfacing that the stripping is found only in those parts of the road subjected to medium or heavy traffic.

In other words; it is the stripping of the bituminous mixtures which are permeable too water. It is the displacement of the binder from aggregate. The process is popularly explained by the theory or mechanism of stripping.

1.14 Mechanism of Stripping

Stripping is the displacement of the binder from the surface of aggregates by water. The process of displacement depends on the viscosity of the binder. The binders of high viscosity resist displacement by water than those of low viscosity.

It has been shown practically that water may penetrate through a film of binder and reach the stone surface. The transfer of water to the stone surface may occur with water in liquid or vapour form.

The speed with which water can penetrate and detach the binder depends on:

a) Type and viscosity of the binder

b) Thickness of binder film

c) Nature of road stone

Stripping was found throughout the length of the surface but failure was observed only on the parts of the flexible base. If the failure occurs it may be due to the following ways:

a) The binder is undetached and hence unstripped

b) The binder is partially detached but unstrapped

c) The binder is attached but unstripped

d) The binder is detached and stripped leading to the disintegration and failure.

1.15 Fundamental Properties of Binder/Stone/Water System

The displacement of one liquid by another on a solid surface arises from the physic-chemical forces acting in the system. Road stones have surfaces that are electrically charged. For example, silica possesses weak negative surface charge. Constituents of bituminous binders have little polar activity. The bond between bituminous binder and stone is therefore primarily due to relatively weak 'dispersion' forces. The polar liquid water is strongly attracted to charged road stone surfaces by 'orientation' forces.

Both water and hydrocarbon such as bitumen or tar will adhere to a stone surface, the forces of attraction are appreciably greater in the water. The stone surface possesses hydrophilic properties. Two important conclusions follow from this at once:

a) If a stone is already coated with water, it is impossible for a normal bituminous binder to displace the water and adhere to the stone.

b) A stone is already coated with a binder; it is possible for water to 'strip' the binder from the stone.

The indication of strength of bond for heat of wetting between silica surface by water and by benzene which gives 600 and 150 ergs/sg.cm respectively shows that water is more attracted to aggregates than a bitumen product. Again heat of wetting is an expression of tendency of a liquid to wet a solid surface. Greater is the heat of wetting, greater is the energy released and stronger is the bond between solid and liquid. Hence if an aggregate is already coated by water it is impossible for a normal binder to displace the water where as if an aggregate is already coated by bitumen is possible for water to strip binder from road stone.

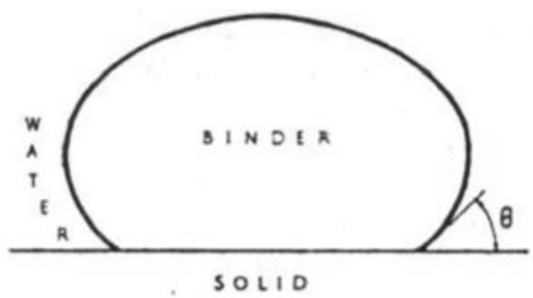
If the angle of contact between the 3 phases is 'θ' and the energies of solid/binder, solid/water and binder/water interfaces are γsb, γsw, γbw respectively, then the work displacing water from unit area of stone is given by:

$W = \gamma sb + \gamma bw - \gamma sw$ -------------------------------(i)

For equilibrium, Young and Dupre's equation

$\gamma sb = \gamma sw + \gamma bw \cos \theta$ --(ii)

$W = \gamma bw (1+\cos \theta)$



DIAGRAMMATIC ILLUSTRATION OFF A DROP OF BITUMINOUS BINDER PLACED ON A SOLID SURFACE UNDER WATER

Hence the work required to displace water by binder is directly proportional to interfacial energy between binder and water and it is also related to the angle of contact.

1.16 Adhesion Test

Numerous tests have been described, most of which fall into 6 basic types. A sample of aggregates is coated with a bituminous binder and then immersed in water under controlled conditions. The degree of stripping of binder from the aggregate after a known period of time is measured. Six types of tests are:

a) Static Immersion Test

b) Dynamic Immersion Test

c) Chemical Immersion Test

d) Immersion Mechanical Test

e) Coating Test

a) Static Immersion Test

- In this type of test, aggregate coated with binder is immersed in water and the degree of stripping is estimated.
- Single-sized chippings are coated with a constant quantity of binder under controlled conditions.
- Coated stone is immersed in distilled water for 48 hours.
- The percentage of stripped surface is estimated visually.
- One more approach is to measure the quantity of light reflected by sample of coated aggregate before and after immersion in water.

b) Dynamic Immersion Test

- It is similar to static immersion test but the sample is agitated mechanically by shaking or kneading.
- Coated aggregates are shaken in water for a known time and then the amount of stripping is estimated visually.

c) Chemical Immersion Test

- Stone coated with binder is boiled in distilled water and if necessary, solutions of sodium carbonate are added.
- The strength of the solution of sodium carbonate in which stripping is first observed is used as a measure of the adhesivity.
- Attempts have been made to improve this test, for example by reducing the temperature and using larger stone or by measuring the amount off uncoated aggregate which separates from coated mass.

d) Immersion Mechanical Test

- Degree of stripping of the binder from aggregate is observed indirectly by measuring the change in a specified mechanical property of a bituminous material after it has been immersed in water.

- In this test, a number of identical cylindrical specimens of the bituminous mixture to be tested are prepared.
- After few hours 'curing' some are used to determine the compressive strength under constant rate of strain.
- The remainder are immersed in water for some days and then tested similarly.
- The reduction in strength gives an indication of the extent of any damage by water that has occurred.

e) Coating Test

- In this test an attempt is made to obtain adhesion between an aggregate and binder when water is also present.
- Test involves immersion of tray of binder in water and then the application of chippings to the surface of the binder. It is known as Immersion tray test.
- No adhesion is obtained under these conditions with normal road stones and binders but the test is helpful for examining how surface-active agents improve adhesion between binders and aggregates in surface dressing under wet conditions.

Immersion Tracking Test

Traffic may plan an important role in stripping. A number of tests have been described in which the bituminous sample is subjected not only to the action of water but also to stresses produced by some form of traffic.

These tests may be carried out on circular track machines or on machines where traffic simulated by reciprocating wheels which passes over the specimens while it is immersed in water.

Wheel Tracking Test:

This consists of three solid tyred wheels each 8 inch in diameter and 2 inch wide which traverse three specimens of road material.

The wheels travel with a reciprocating motion of frequency 25 cycles/minute and stroke of about 11 inches. Each wheel is coated to give a total weight of 30 lb per sq. inch bearing on the specimen.

The Specimens are contained in perforated metal moulds 1½ inch deep, 12 inch long and 4 inch wide, maintained horizontally in water level is well above the top of the specimens. The road material is compacted in moulds under standardized conditions and cured for short time before immersion. The temperature of the water bath is 40° C. The test machine is shown in diagram below.

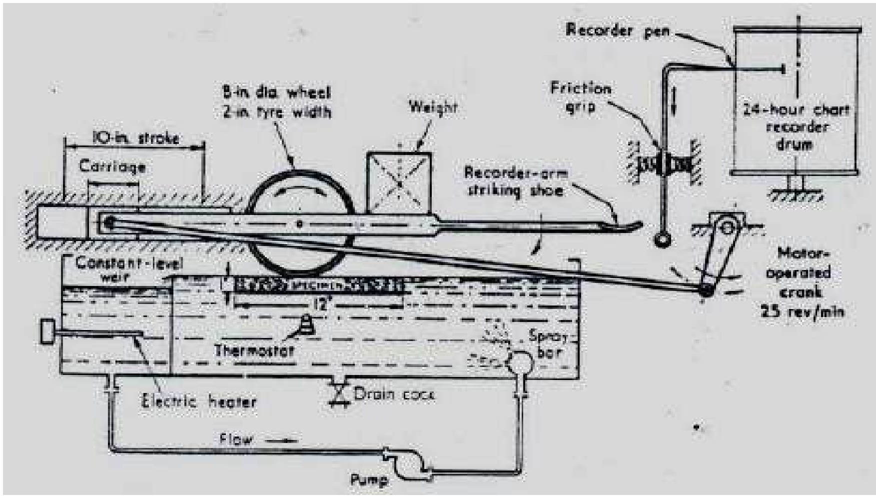
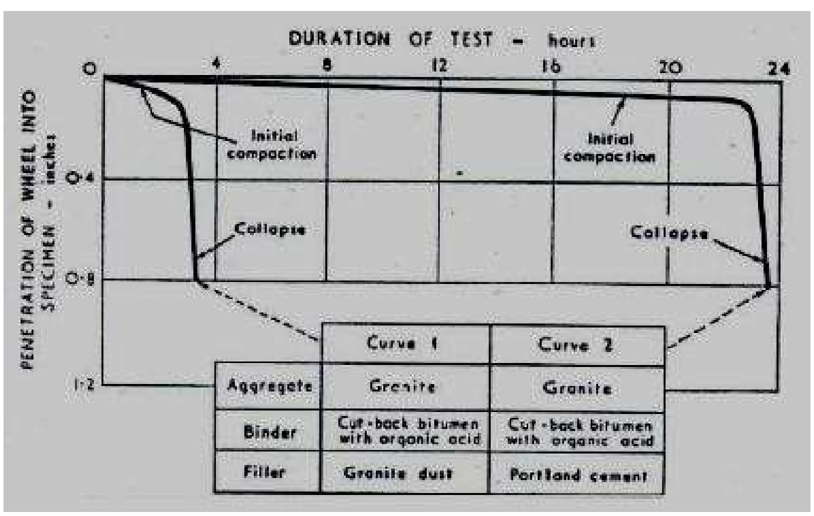


Fig: **TEST MACHINE FOR IMMERSION WHEEL-TRACKING TEST**

The criterion which is adopted to measure stripping is that of the time necessary to produce failure, if the depth of penetration of the wheels, in the specimen of road material is recorded with time, it is found that, at first there is a small and steady compaction of the specimen under the loaded wheels and then suddenly there is a sharp break in the curve where the wheels penetrate into the Specimen at a greater rate.



FAILURE RECORDS OBTAINED FROM IMMERSION WHEEL-TRACKING TEST

1.17 Methods of Improving Adhesion

1) Binder of high viscosity resists stripping more readily than those of low viscosity & hence there is an advantage that the viscosity of the binder should be as high as possible.
2) It is usually necessary to compromise between the lower viscosity needed to give the best initial coating on the aggregate & the higher viscosity desirable to give better protection against stripping.
3) Addition of filler to a mixture increases the viscosity of the binder & hence it will control the rate of stripping.
4) There is certain fillers, hydrated lime & Portland cement which when added to bituminous mixture in 1 to 2% weight of total mix will reduce or even completely prevent stripping.
5) Chemically active fillers are also used in the mixing of cold & wet aggregate with bituminous binders.
6) Organic acids present in binders react with filler to form calcium naphthalene or calcium phenate to improve adhesion.
7) Addition of up to 10% of road tar to bitumen improves adhesion in some coated macadam wearing courses.
8) By adding surface-active chemicals to the binder, it has been claimed that some soaps of metals (Ca, Pb, and Fe) may improve adhesion.
9) Additives which show cationic surface activity such as cetyl pyridinium bromide & cetyl trimethyl ammonium bromide increases the adhesive bond.
10) Powerful agents like organic amines which have high molecular weight are sprinkled on the surface dressing to increase adhesion.

Further reading & Reference

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2. RRL, DSIR, 'Bituminous Materials in Road Construction', HMSO Publication.