

Chapter 22

Pavement materials: Aggregates

22.1 Overview

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

22.2 Desirable properties

22.2.1 Strength

The aggregates used in top layers are subjected to (i) Stress action due to traffic wheel load, (ii) Wear and tear, (iii) crushing. For a high quality pavement, the aggregates should possess high resistance to crushing, and to withstand the stresses due to traffic wheel load.

22.2.2 Hardness

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic. The abrasive action is severe when steel tyred vehicles move over the aggregates exposed at the top surface.

22.2.3 Toughness

Resistance of the aggregates to impact is termed as toughness. Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyred wheels from one particle to another at different levels causes severe impact on the aggregates.

22.2.4 Shape of aggregates

Aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated 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 aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible.

22.2.5 Adhesion with bitumen

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

22.2.6 Durability

The property of aggregates to withstand adverse action of weather is called soundness. The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering action

22.2.7 Freedom from deleterious particles

Specifications for aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat or elongated pieces, dust, clay balls and other objectionable material. Similarly aggregates used in Portland cement concrete mixes must be clean and free from deleterious substances such as clay lumps, chert, silt and other organic impurities.

22.3 Aggregate tests

In order to decide the suitability of the aggregate for use in pavement construction, following tests are carried out:

- Crushing test
- Abrasion test
- Impact test
- Soundness test
- Shape test
- Specific gravity and water absorption test
- Bitumen adhesion test

22.3.1 Crushing test

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by IS:2386 part-IV and used to determine the crushing strength of aggregates. 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 (Figure 22:1). 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 (W_2) is expressed as percentage of the weight of the total sample (W_1) which is the aggregate crushing value.

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

A value less than 10 signifies an exceptionally strong aggregate while above 35 would normally be regarded as weak aggregates.

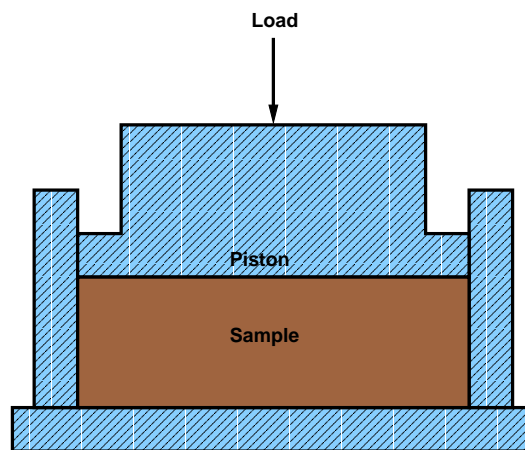


Figure 22:1: Crushing test setup

22.3.2 Abrasion test

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.

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 (see Figure 22:2). 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.

A maximum value of 40 percent is allowed for WBM base course in Indian conditions. For bituminous concrete, a maximum value of 35 is specified.

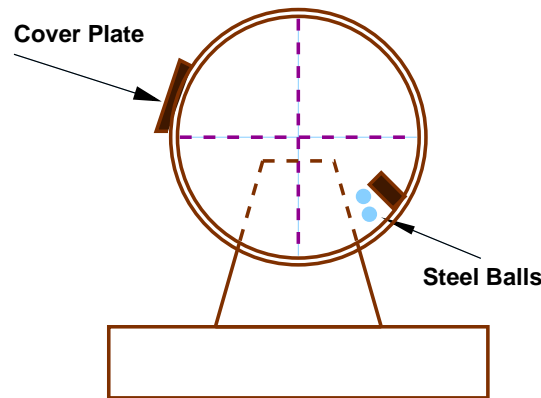


Figure 22:2: Los Angeles abrasion test setup

22.3.3 Impact test

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 number 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 number 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 (W_2) to the total weight of the sample (W_1).

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

Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent. For bituminous macadam the maximum permissible value is 35 percent. For Water bound macadam base courses the maximum permissible value defined by IRC is 40 percent

22.3.4 Soundness test

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 are 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 at $105 - 110^\circ C$ to a constant weight. After five cycles, the loss in weight of aggregates is determined by sieving

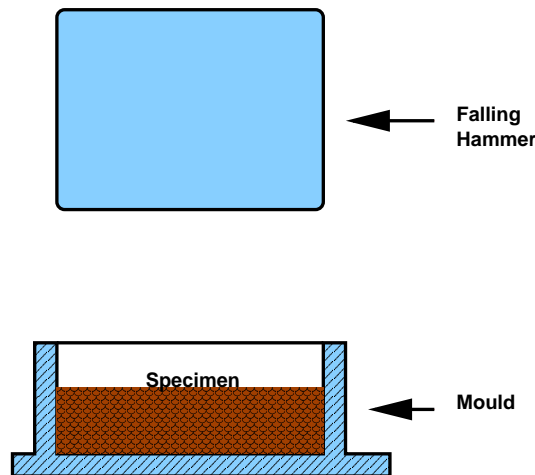


Figure 22:3: Impact test setup

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.

22.3.5 Shape tests

The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.

The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size. Test procedure had been standardized in India (IS:2386 part-I)

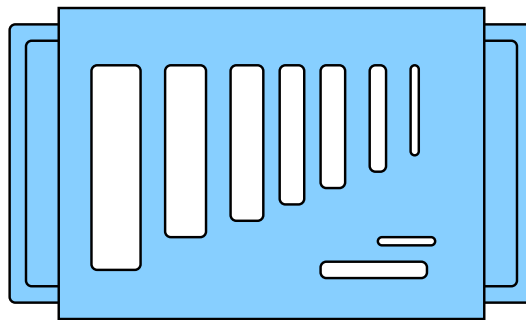


Figure 22:4: Flakiness gauge

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). However there are no recognized limits for the elongation index.

22.3.6 Specific Gravity and water absorption

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal

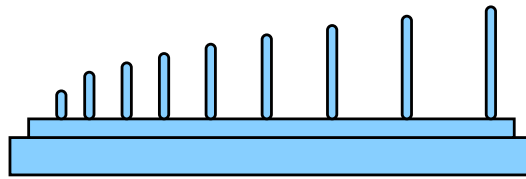


Figure 22:5: Elongation gauge

volume of distilled water at a specified temperature. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used: *apparent* specific gravity and *bulk* specific gravity.

- Apparent Specific Gravity, G_{app} , is computed on the basis of the net volume of aggregates i.e the volume excluding water-permeable voids. Thus

$$G_{app} = \frac{M_D/V_N}{W} \quad (22.1)$$

where, M_D is the dry mass of the aggregate, V_N is the net volume of the aggregates excluding the volume of the absorbed matter, W is the density of water.

- Bulk Specific Gravity, G_{bulk} , is computed on the basis of the total volume of aggregates including water permeable voids. Thus

$$G_{bulk} = \frac{M_D/V_B}{W} \quad (22.2)$$

where, V_B is the total volume of the aggregates including the volume of absorbed water.

- 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 M_W . M_W is the weight of dry aggregates minus weight of aggregates saturated surface dry condition. Thus

$$\text{water absorption} = \frac{M_W}{M_D} \times 100 \quad (22.3)$$

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

22.3.7 Bitumen adhesion test

Bitumen adheres well to all normal types of road aggregates provided they are dry and free from dust. In the absence of water there is practically no adhesion problem of bituminous construction. Adhesion problem occurs when the aggregate is wet and cold. This problem can be dealt with by removing moisture from the aggregate by drying and increasing the mixing temperature. Further, the presence of water causes stripping of binder from the coated aggregates. This problems occur when bitumen mixture is permeable to water. Several laboratory tests are conducted to arbitrarily determine the adhesion of bitumen binder to an aggregate in the presence of water. Static immersion test is one specified by IRC and is quite simple. The principle of the test is by immersing aggregate fully coated with binder in water maintained at 40°C temperature for 24 hours. IRC has specified maximum stripping value of aggregates should not exceed 5%.

Property of aggregate	Type of Test	Test Method
Crushing strength	Crushing test	IS : 2386 (part 4) -1963
Hardness	Los Angeles abrasion test	IS : 2386 (Part 5)-1963
Toughness	Aggregate impact test	IS : 2386 (Part 4)-1963
Durability	Soundness test- accelerated durability test	IS : 2386 (Part 5)-1963
Shape factors	Shape test	IS : 2386 (Part 1)-1963
Specific gravity and porosity	Specific gravity test and water absorption test	IS : 2386 (Part 3)-1963
Adhesion to bitumen	Stripping value of aggregate	IS : 6241-1971

Table 22:1: Tests for Aggregates with IS codes

22.4 Summary

Aggregates influence, to a great extent, the load transfer capability of pavements. Hence it is essential that they should be thoroughly tested before using for construction. Not only that aggregates should be strong and durable, they should also possess proper shape and size to make the pavement act monolithically. Aggregates are tested for strength, toughness, hardness, shape, and water absorption.

22.5 Problems

- IRC has specified the maximum value of stripping value of bitumen not to exceed
 - 2%
 - 3%
 - 4%
 - 5%
- Which property of aggregate is tested by conducting aggregate impact test?
 - Durability
 - Hardness
 - Toughness
 - Porosity

22.6 Solutions

- IRC has specified the maximum value of stripping value of bitumen not to exceed
 - 2%✓
 - 3%
 - 4%
 - 5%

2. Which property of aggregate is tested by conducting aggregate impact test?
- (a) Durability
 - (b) Hardness
 - (c) Toughness✓
 - (d) Porosity

Chapter 23

Pavement materials: Bitumen

23.1 Overview

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

23.1.1 Production of Bitumen

bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

23.1.2 Vacuum steam distillation of petroleum oils

In the vacuum-steam distillation process the crude oil is heated and is introduced into a large cylindrical still. Steam is introduced into the still to aid in the vapourisation of the more volatile constituents of the petroleum and to minimise decomposition of the distillates and residues. The volatile constituents are collected, condensed, and the various fractions stored for further refining, if needed. The residues from this distillation are then fed into a vacuum distillation unit, where residue pressure and steam will further separate out heavier gas oils. The bottom fraction from this unit is the vacuum-steam-refined asphalt cement. The consistency of asphalt cement from this process can be controlled by the amount of heavy gas oil removed. Normally, asphalt produced by this process is softer. As the asphalt cools down to room temperature, it becomes a semi solid viscous material.

23.2 Different forms of bitumen

23.2.1 Cutback bitumen

Normal practice is to heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the

bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate. Cutback bitumen is used for cold weather bituminous road construction and maintenance. The distillates used for preparation of cutback bitumen are naphtha, kerosene, diesel oil, and furnace oil. There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC). RC is recommended for surface dressing and patchwork. MC is recommended for premix with less quantity of fine aggregates. SC is used for premix with appreciable quantity of fine aggregates.

23.2.2 Bitumen Emulsion

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilised by suitable material. Normally cationic type emulsions are used in India. The bitumen content in the emulsion is around 60% and the remaining is water. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of setting depends upon the grade of bitumen. The viscosity of bituminous emulsions can be measured as per IS: 8887-1995. Three types of bituminous emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC). Bitumen emulsions are ideal binders for hill road construction. Where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface dressing work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

23.2.3 Bituminous primers

In bituminous primer the distillate is absorbed by the road surface on which it is spread. The absorption therefore depends on the porosity of the surface. Bitumen primers are useful on the stabilised surfaces and water bound macadam base courses. Bituminous primers are generally prepared on road sites by mixing penetration bitumen with petroleum distillate.

23.2.4 Modified Bitumen

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

- Lower susceptibility to daily and seasonal temperature variations
- Higher resistance to deformation at high pavement temperature
- Better age resistance properties
- Higher fatigue life for mixes
- Better adhesion between aggregates and binder
- Prevention of cracking and reflective cracking

23.3 Requirements of Bitumen

The desirable properties of bitumen depend on the mix type and construction. In general, Bitumen should possess following desirable properties.

- The bitumen should not be highly temperature susceptible: during the hottest weather the mix should not become too soft or unstable, and during cold weather the mix should not become too brittle causing cracks.
- The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing.
- There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

23.4 Tests on bitumen

There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials.

1. Penetration test
2. Ductility test
3. Softening point test
4. Specific gravity test
5. Viscosity test
6. Flash and Fire point test
7. Float test
8. Water content test
9. Loss on heating test

23.4.1 Penetration test

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardised the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25° C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred. The Figure 23.4.1 shows a schematic Penetration Test setup.

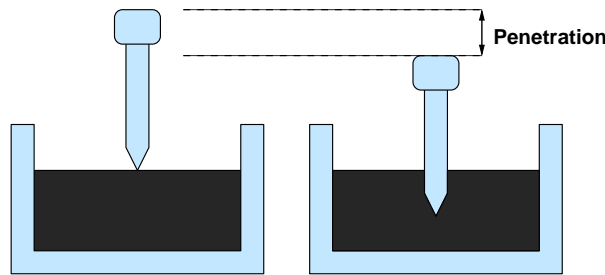


Figure 23:1: Penetration Test Setup

23.4.2 Ductility test

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27° C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS. Figure 23.4.2 shows ductility moulds to be filled with bitumen.

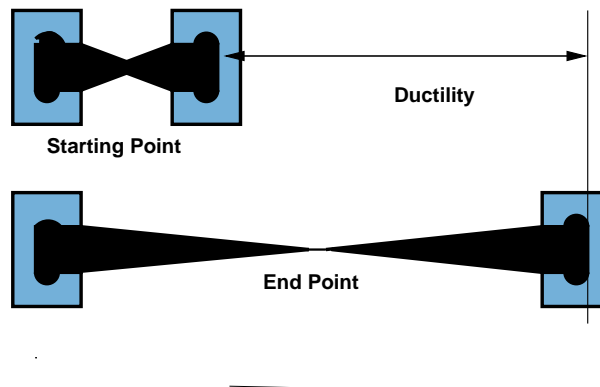


Figure 23:2: Ductility Test

23.4.3 Softening point test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5° C per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher

softening point indicates lower temperature susceptibility and is preferred in hot climates. Figure 23.4.3 shows Softening Point test setup.

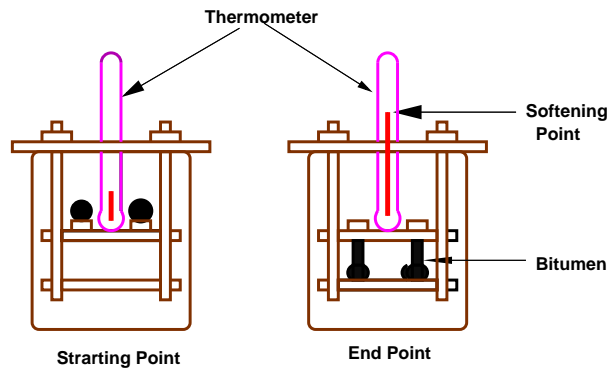


Figure 23:3: Softening Point Test Setup

23.4.4 Specific gravity test

In paving jobs, to classify a binder, density property is of great use. In most cases bitumen is weighed, but when used with aggregates, the bitumen is converted to volume using density values. The density of bitumen is greatly influenced by its chemical composition. Increase in aromatic type mineral impurities cause an increase in specific gravity.

The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known content to the mass of equal volume of water at 27° C. The specific gravity can be measured using either pycnometer or preparing a cube specimen of bitumen in semi solid or solid state. The specific gravity of bitumen varies from 0.97 to 1.02.

23.4.5 Viscosity test

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting paving mixes. Low or high viscosity during compaction or mixing has been observed to result in lower stability values. At high viscosity, it resists the compactive effort and thereby resulting mix is heterogeneous, hence low stability values. And at low viscosity instead of providing a uniform film over aggregates, it will lubricate the aggregate particles. Orifice type viscometers are used to indirectly find the viscosity of liquid binders like cutbacks and emulsions. The viscosity expressed in seconds is the time taken by the 50 ml bitumen material to pass through the orifice of a cup, under standard test conditions and specified temperature. Viscosity of a cutback can be measured with either 4.0 mm orifice at 25° C or 10 mm orifice at 25 or 40° C.

23.4.6 Flash and fire point test

At high temperatures depending upon the grades of bitumen materials leave out volatiles. And these volatiles catch fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade. BIS defined the flash point as the temperature at which the vapour of bitumen momentarily catches fire

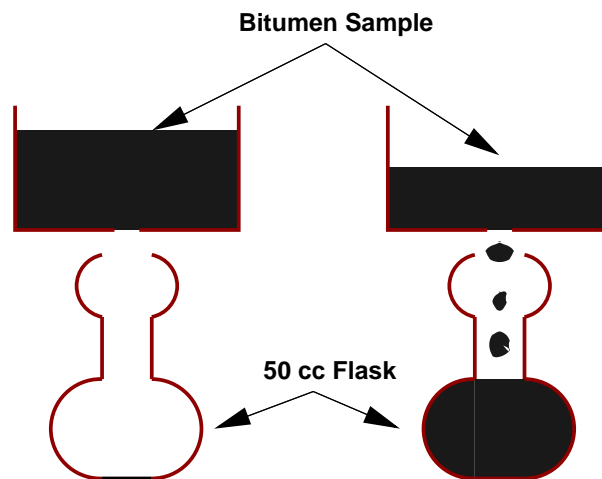


Figure 23:4: Viscosity Test

in the form of flash under specified test conditions. The fire point is defined as the lowest temperature under specified test conditions at which the bituminous material gets ignited and burns.

23.4.7 Float test

Normally the consistency of bituminous material can be measured either by penetration test or viscosity test. But for certain range of consistencies, these tests are not applicable and Float test is used. The apparatus consists of an aluminum float and a brass collar filled with bitumen to be tested. The specimen in the mould is cooled to a temperature of 5°C and screwed in to float. The total test assembly is floated in the water bath at 50°C and the time required for water to pass its way through the specimen plug is noted in seconds and is expressed as the float value.

23.4.8 Water content test

It is desirable that the bitumen contains minimum water content to prevent foaming of the bitumen when it is heated above the boiling point of water. The water in a bitumen is determined by mixing known weight of specimen in a pure petroleum distillate free from water, heating and distilling of the water. The weight of the water condensed and collected is expressed as percentage by weight of the original sample. The allowable maximum water content should not be more than 0.2% by weight.

23.4.9 Loss on heating test

When the bitumen is heated it loses the volatility and gets hardened. About 50gm of the sample is weighed and heated to a temperature of 163°C for 5 hours in a specified oven designed for this test. The sample specimen is weighed again after the heating period and loss in weight is expressed as percentage by weight of the original sample. Bitumen used in pavement mixes should not indicate more than 1% loss in weight, but for bitumen having penetration values 150-200 up to 2% loss in weight is allowed.

Table 23:1: Tests for Bitumen with IS codes

Type of test	Test Method
Penetration Test	IS: 1203-1978
Ductility test	IS: 1208-1978
Softening Point test	IS: 1205-1978
Specific gravity test	IS: 1202-1978
Viscosity test	IS: 1206-1978
Flash and Fire Point test	IS: 1209-1978
Float Test	IS: 1210-1978
Determination of water content	IS: 1211-1978
Determination of Loss on heating	IS:1212-1978

23.5 Summary

Requirements of bitumen as a binding material and its different forms were discussed. Various tests are conducted on bitumen to assess its consistency, gradation, viscosity, temperature susceptibility, and safety. Standard test procedures on bitumen were also covered in this chapter.

23.6 Problems

The minimum ductility value specified by BIS for bitumen is

1. 50 cm
2. 25 cm
3. 75 cm
4. 100 cm

The allowable maximum water content in bitumen should not be more than

1. 2%by weight
2. 0.2% by weight
3. 2.5% by weight
4. 5% by weight

23.7 Solutions

The minimum ductility value specified by BIS for bitumen is

1. 50 cm
2. 25 cm
3. 75 cm ✓

4. 100 cm

The allowable maximum water content in bitumen should not be more than

1. 2% by weight
2. 0.2% by weight ✓
3. 2.5% by weight
4. 5% by weight

Chapter 24

Bituminous mix design

24.1 Overview

The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical. The requirements of the mix design and the two major stages of the mix design, i.e dry mix design and wet mix design will be discussed.

24.2 Evolution of road surface

- Unsurfaced earthen roads, or cart-track
- Unsurfaced earthen roads upgrades with natural soil from borrow pits and attention to drainage, and compaction is by traffic
- Dry aggregate and sand-clays mix, in which the the former act as wear resistant and the latter as natural binder
- Water-bound macadam, the above constituents, mixed together (pre-mix or in-situ) with water and compacted to improve the strength
- Oiled roads, introduced to reduce dust by bitumen stabilized soils
- Seal coat: the base course is protected from traffic and moisture by sealing the surface with a thin film of bitumen aggregate mix, which is structurally strong surface for pneumatic-tyred traffic. This is provided on firm and smooth base course after a tack coat using cutback bitumen or bitumen emulsions with a penetration of 5 mm.
- Asphaltic concrete: Traffic and the axle configuration are increasing very much which raises demand for the new type of pavement which can meet the above requirements. The asphaltic concrete is one which is the high dense graded premix and it is termed as the highest quality pavement surface course.
- Bitumen mix or asphalt mix overlays of minimum 20 - 40 mm to as high as 300 - 500 mm or even more.

24.2.1 Objectives of mix design

The objective of the mix design is to produce a bituminous mix by proportionating various components so as to have:

1. sufficient bitumen to ensure a durable pavement,
2. sufficient strength to resist shear deformation under traffic at higher temperature,
3. sufficient air voids in the compacted bitumen to allow for additional compaction by traffic,
4. sufficient workability to permit easy placement without segregation,
5. sufficient flexibility to avoid premature cracking due to repeated bending by traffic, and
6. sufficient flexibility at low temperature to prevent shrinkage cracks.

24.2.2 Constituents of a mix

- **Coarse aggregates:** Offer compressive and shear strength and shows good interlocking properties. E.g. *Granite*
- **Fine aggregates:** Fills the voids in the coarse aggregate and stiffens the binder. E.g. *Sand, Rock dust*
- **Filler:** Fills the voids, stiffens the binder and offers permeability. E.g. *Rock dust, cement, lime*
- **Binder:** Fills the voids, cause particle adhesion and gluing and offers impermeability. E.g. *Bitumen, Asphalt, Tar*

24.2.3 Types of mix

- **Well-graded mix:-** *Dense mix, bituminous concrete* has good proportion of all constituents and are called dense bituminous macadam, offers good compressive strength and some tensile strength
- **Gap-graded mix:-** Some large coarse aggregates are missing and has good fatigue and tensile strength.
- **Open-graded mix:-** Fine aggregate and filler are missing, it is porous and offers good friction, low strength and for high speed.
- **Unbounded:-** Binder is absent and behaves under loads as if its components were not linked together, though good interlocking exists. Very low tensile strength and needs kerb protection.

24.2.4 Different layers in a pavement

- **Bituminous base course** Consist of mineral aggregate such as stone, gravel, or sand bonded together by a bituminous material and used as a foundation upon which to place a binder or surface course.
- **Bituminous binder course** A bituminous-aggregate mixture used as an intermediate coarse between the base and surface courses or as the first bituminous layer in a two-layer bituminous resurfacing. It is sometimes called a leveling course.
- **Asphaltic/Bituminous concrete** Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through fine filler that is smaller than 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix is *effectively impervious* and will have acceptable dissipative and elastic properties.

Table 24:1: Aggregate gradation for BC

Sieve size		Passing (%)
26.5	mm	- 100
19.	mm	90 - 100
9.5	mm	56 - 80
4.75	mm	35 - 65
2.36	mm	23 - 49
300	micron	5 - 19
75	micron	2 - 8

24.3 Requirements of Bituminous mixes

24.3.1 Stability

Stability is defined as the resistance of the paving mix to deformation under traffic load. Two examples of failure are (i) *shoving* - a transverse rigid deformation which occurs at areas subject to severe acceleration and (ii) *grooving* - longitudinal ridging due to channelization of traffic. Stability depend on the inter-particle friction, primarily of the aggregates and the cohesion offered by the bitumen. Sufficient binder must be available to coat all the particles at the same time should offer enough liquid friction. However, the stability decreases when the binder content is high and when the particles are kept apart.

24.3.2 Durability

Durability is defined as the resistance of the mix against weathering and abrasive actions. Weathering causes hardening due to loss of volatiles in the bitumen. Abrasion is due to wheel loads which causes tensile strains. Typical examples of failure are (i) *pot-holes*, - deterioration of pavements locally and (ii) *stripping*, lost of binder from the aggregates and aggregates are exposed. Disintegration is minimized by high binder content since they cause the mix to be air and waterproof and the bitumen film is more resistant to hardening.

24.3.3 Flexibility

Flexibility is a measure of the level of bending strength needed to counteract traffic load and prevent cracking of surface. Fracture is the cracks formed on the surface (hairline-cracks, alligator cracks), main reasons are shrinkage and brittleness of the binder. Shrinkage cracks are due to volume change in the binder due to aging. Brittleness is due to repeated bending of the surface due to traffic loads. Higher bitumen content will give better flexibility and less fracture.

24.3.4 Skid resistance

It is the resistance of the finished pavement against skidding which depends on the surface texture and bitumen content. It is an important factor in high speed traffic. Normally, an open graded coarse surface texture is desirable.

24.3.5 Workability

Workability is the ease with which the mix can be laid and compacted, and formed to the required condition and shape. This depends on the gradation of aggregates, their shape and texture, bitumen content and its type. Angular, flaky, and elongated aggregates workability. On the other hand, rounded aggregates improve workability.

24.3.6 Desirable properties

From the above discussion, the desirable properties of a bituminous mix can be summarized as follows:

- Stability to meet traffic demand
- Bitumen content to ensure proper binding and water proofing
- Voids to accommodate compaction due to traffic
- Flexibility to meet traffic loads, esp. in cold season
- Sufficient workability for construction
- Economical mix

24.4 Summary

Bituminous mixes should be stable, durable, flexible, workable and should offer sufficient skid resistance. The mix consists of coarse and fine aggregates, filler and binder. It may be well graded, open graded, gap graded or unbounded as per the requirements. As far as possible, it should be economical also.

24.5 Problems

1. Granite is an example for
 - (a) Coarse aggregate
 - (b) Fine aggregate
 - (c) Filler
 - (d) none of these
2. Grooving is
 - (a) deterioration of pavements locally
 - (b) exposure of aggregate due to losing of bitumen
 - (c) longitudinal ridging due to channelization of traffic
 - (d) none of these

24.6 Solutions

1. Granite is an example for
 - (a) Coarse aggregate ✓
 - (b) Fine aggregate
 - (c) Filler
 - (d) none of these
2. Grooving is
 - (a) deterioration of pavements locally
 - (b) exposure of aggregate due to losing of bitumen
 - (c) longitudinal ridging due to channelization of traffic ✓
 - (d) none of these