SYLLABUS

Subcode: 10CV763 **IA Marks: 25**
No of lecture hour/week: 04 **Exam hours: 03**
Total no of lecture hours: 52 **Exam marks: 100**

PART - A

PAVEMENT MATERIALS

UNIT - 1

AGGREGATES: Origin, classification, requirements, properties and tests on road aggregates, concepts of size and gradation – design gradation, maximum aggregate size, aggregate blending

to meet specification. 6 Hours

UNIT - 2

BITUMEN AND TAR: Origin, preparation, properties and chemical constitution of bituminous

road binders; requirements. 4 Hours

UNIT - 3

BITUMINOUS EMULSIONS AND CUTBACKS: Preparation, characteristics, uses and tests. Adhesion of Bituminous Binders to Road Aggregates: Adhesion failure, mechanism of stripping, tests and methods of improving adhesion. 8 Hours

UNIT - 4

BITUMINOUS MIXES: Mechanical properties, dense and open textured mixes, flexibility and brittleness, (no Hveem Stabilometer & Hubbar – Field Tests) bituminous mix, design methods using Rothfuch"s Method only and specification using different criteria- voids in mineral aggregates, voids in total mix, density, flow, stability, percentage voids filled with bitumen.

6 Hours

PART - B

PAVEMENT CONSTRUCTION

UNIT - 5

EQUIPMENT IN HIGHWAY CONSTRUCTION: Various types of equipment for excavation, grading and compaction – their working principle, advantages and limitations. Special equipment for bituminous and cement concrete pavement and stabilized soil road construction.

6 Hou

UNIT - 6

SUBGRADE: Earthwork grading and construction of embankments and cuts for roads. Preparation of subgrade, quality control tests. 6 Hours

UNIT - 7

FLEXIBLE PAVEMENTS: Specifications of materials, construction method and field control checks for various types of flexible pavement layers. 8 Hours

UNIT - 8

CEMENT CONCRETE PAVEMENTS: Specifications and method of cement concrete pavement construction; Quality control tests; Construction of various types of joints.

8Hours

LIST OF CONTENTS

Unit -1: AGGREGATES

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction.

1.1 Origin:

- Most of the aggregates are prepared from natural rock
- Gravel aggregates are obtained from river beds.
- Sand in fine aggregates from weathering of rock.
- Based on the origin, natural rocks are classified as igneous, sedimentary and metamorphic.

1.2 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.

1.3 Requirements:

Aggregates have to bear stresses occurring due to the wheel loads on the pavement. It has to resist wear due to abrasive action of traffic on the surface course.

It should resist disintegration due to the action of weather.

1.4 Properties of aggregates:

Strength:

- The aggregates should be strong to withstand the stresses due to traffic wheel load.
- Aggregates used in top layers of pavements I.e. wearing course have to be capable of withstanding high stresses in addition to wear and tear hence should posses resistance to crushing.

Hardness

- The aggregate used in surface course are subjected to constant rubbing or abrasion due to moving traffic.

- They should be hard enough the wear due to abrasive action of traffic.
- Heavy wheel loads can also cause deformation on some types of pavements.
- The mutual rubbing of stones is called attrition which also cause little wear in the aggregates.

Toughness

- Aggregates in pavements are subjected to impact due to moving wheel loads.
- Severe impact like hammering is seen when heavily loaded steel tyred vehicles move on WBM roads.
- Jumping of steel tyred wheels from one stone to another cause severe impact.
- The magnitude of impact increases with the roughness of load surface, speed of the vehicular characteristics.

Durability

- They should be durable and should resist disintegration due to action of weather.
- The property of the stones to withstand adverse action of weather is called soundness.
- The aggregates are subjected to physical and chemical action of rain and ground weather and hence road stones should be sound enough to withstand weathering action.

Shape of aggregates

- Flaky and elongated aggregates will have less strength compared with cubical, angular or rounded particles.
- Rounded aggregates are preferred in cement concrete mix due to better workability where as these materials are not preferred in granular base course, water bound macadam and bitumen construction. In such cases angular particles are used.
- Highly angular flaky and elongated aggregates have more voids in comparison with rounded aggregates.

Adhesion with Bitumen

The aggregates used in bituminous pavements should have less affinity with water or else bituminous coating on the aggregate will be stripped off in presence of water.

1.5 Test for road aggregates:

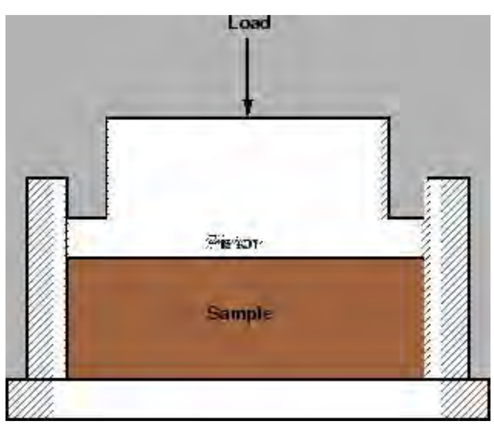
1. Crushing test
2. Abrasion test
3. Impact test
4. Soundness test
5. Shape test
6. Specific gravity and water absorption test
7. Bitumen adhesion test

1. Aggregate crushing test:

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 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.

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

Aggregate Crushing value= (W_1/W_2) X 100



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 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.

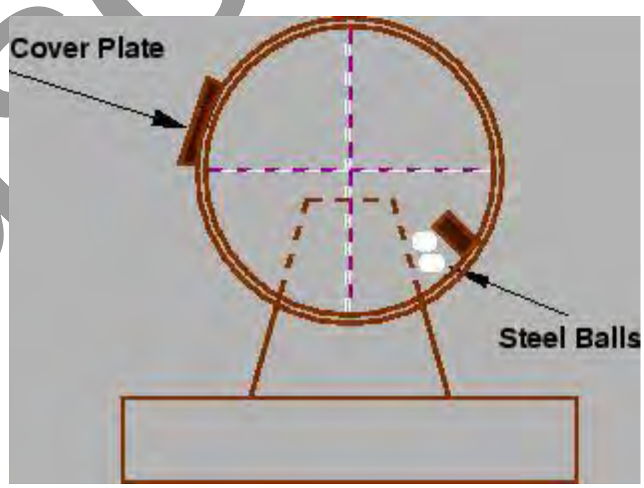


Figure 2: Los Angeles abrasion test setup

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).

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

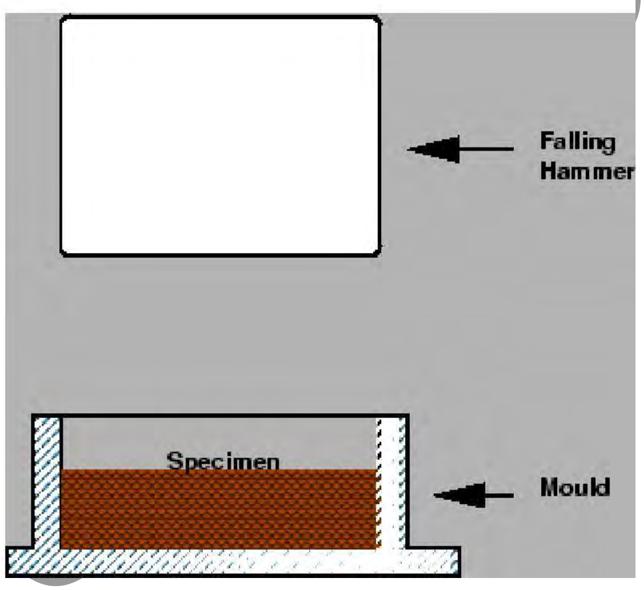


Figure 3: Impact test setup

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

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 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.

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)

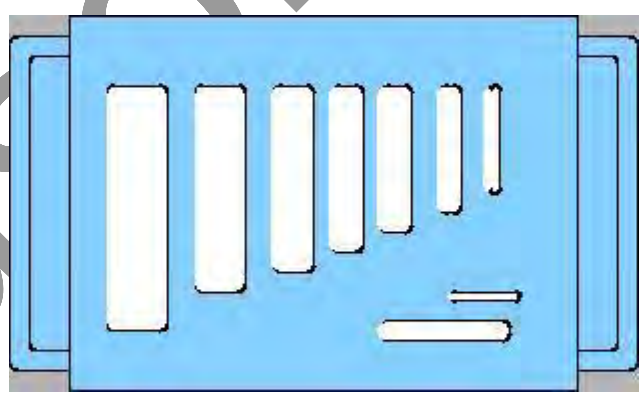


Figure 4: Flakiness gauge

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.

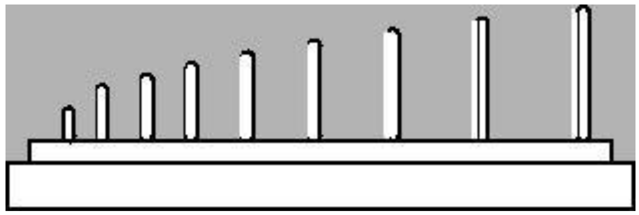


Figure 5: Elongation gauge

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 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

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

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

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

where, V_t 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

$$\text{water absorption} = \frac{M_W}{M_s} \times 100 \quad (3)$$

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.

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 $40^{\circ}C$ temperature for 24 hours. IRC has specified maximum stripping value of aggregates should not exceed 5%

1.6 Aggregate gradation

The properties of the bituminous mix including the density and stability are very much dependent on the aggregates and their grain size distribution. Gradation has a profound effect on mix performance. It might be reasonable to believe that the best gradation is one that produces maximum density. This would involve a particle arrangement where smaller particles are packed between larger particles, thus reducing the void space between particles. This create more particle-to-particle contact, which in bituminous pavements would increase stability and reduce water infiltration. However, some minimum amount of void space is necessary to:

- provide adequate volume for the binder to occupy,
- promote rapid drainage, and
- provide resistance to frost action for base and sub base courses. A dense mixture may be obtained when this particle size distribution follows Fuller law which is expressed as:

$$p = 100\,[d/D]^n$$

where, p is the percent by weight of the total mixture passing any given sieve sized, D is the size of the largest particle in that mixture, and n is the parameter depending on the shape of the aggregate (0.5 for perfectly rounded particles). Based on this law Fuller-Thompson gradation charts were developed by adjusting the parameter n for fineness or coarseness of aggregates. Practical considerations like construction, layer thickness, workability, etc, are also considered. For example Table 25:1 provides a typical gradation for bituminous concrete for a thickness of 40 mm.

Table 25:1: Specified gradation of aggregates for BC surface course of 40 mm

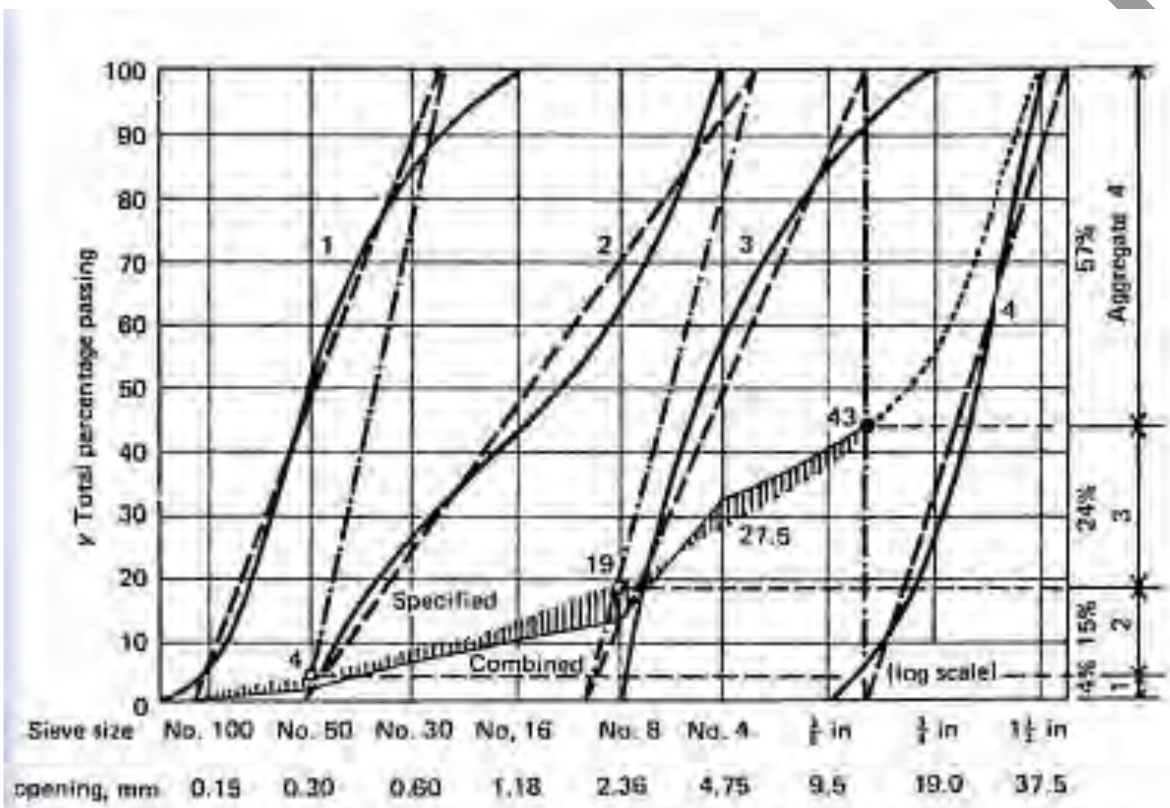
Sieve size (mm)	Wt passing (%) Grade 1	Wt passing (%) Grade 2
20	-	100
12.5	100	80-100
10.0	80 - 100	70 - 90
4.75	55 - 75	50 - 70
2.36	35 - 50	35 - 50
0.60	18 - 29	18 - 29
0.30	13 - 23	13 - 23
0.15	8 - 16	8 - 16
0.075	4 - 10	4 - 10
Binder*	5 - 7.5	5 - 7.5

* Bitumen content in percent by weight of the mix

1.6.1 Proportioning of aggregates

After selecting the aggregates and their gradation, proportioning of aggregates has to be done and following are the common methods of proportioning of aggregates:

1. **Trial and error procedure**: Vary the proportion of materials until the required aggregate gradation is achieved.
2. **Graphical Methods**: Two graphical methods in common use for proportioning of aggregates are, Triangular chart method and Rotfuch's method. The former is used when only three materials are to be mixed.



13.7: A graphical determination of the blending proportions needed for aggregates 1 to 4 to approximate ecified grading.

Unit -2: BITUMEN AND TAR

2.1Origin

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, kerogen, or petroleum. Deposits at the La Brea Tar Pitsare an example. There are structural similarities between bitumens 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 black, 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

2.2 Preparation 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.

2.1.1 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.

2.3 Properties

Bitumen's main property is that of a very strong and durable adhesive that binds together a very wide variety of other materials without affecting their properties. Its durability is essential to major engineering projects such as roads and waterways where it must do its job for 20 years or more.

Bitumen is insoluble in water but is soluble in numerous organic solvents. As it is highly waterproof, it can act as an effective sealant. It also resists action by most acids, alkalis and salts. It does not contaminate water so it can be used to line watercourses. It is a thermoplastic material: it softens and becomes liquid with the application of heat and hardens as it cools.

Bitumen can be spread relatively easily in the areas where it is required because it can readily be liquefied by one of three methods:

- applying heat
- dissolving it in petroleum solvents
- Dispersing with water (emulsification).

Bitumen gives controlled flexibility to mixtures of mineral aggregates which is why so much of the total annual production is used in road building. It is available at an economic cost virtually all over the world.

2.4 Requirements of Bitumen

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

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

2.6 Tar

When coal is heated without air, it does not burn but produces many by-products. This process of heating coal in the absence of air is called destructive distillation of coal.

The main by products are:

a. coke
b. coal tar
c. amino acid liquor
d. coal gas

Unit -3: BITUMINOUS EMULSIONS AND CUTBACKS

3.1 Introduction

An emulsion is an intimate mixture of two or more substances which normally do not mix together. Bitumen emulsion consists of a dispersion of tiny globules (4 to 10 microns in diameter) or bitumen in water, stabilized by the addition of an emulsifying agent.

The nature and quantity of the emulsifying agent controls the type and stability of the emulsion. Emulsions are manufactured by forcing the required proportion of bitumen, water and emulsifying agent into an homogenized, Where by the bitumen is broken up into the globules, dispersed and held in suspension by the emulsifying agent. The bitumen content of an emulsion can vary from 30% to 70% (usually 55-70%) by volume depending on the grade of emulsion required.

Emulsions are used primarily on maintenance work, surface enrichment, dust laying processes, slurry sealing, and in projects where weather conditions may prevent the use of hot bitumen or cutbacks.

"Breaking" of an emulsion is the term applied when the bitumen globule suspension breaks down resulting in complete separation of the bitumen and water components. Breaking normally occurs on the pavement surface after spraying whereby the water from the emulsion drains off or evaporates leaving behind a bitumen residue.

The surfaces of the suspended bitumen globules develop an ionic (electrical) charge. The type of charge depends on the emulsifying agent employed. The type of charge depends on the emulsifying agent employed. The presence of this charge is used to advantage to secure greater adhesion of the bitumen to the aggregate.

The basic types of bitumen emulsion are available:-

- Anionic emulsions
- Cationic emulsions.

The two types of bitumen emulsion are incompatible and should not be mixed under any circumstances otherwise premature breaking will occur. Some aggregates, particularly acidic types such as granite and quartzite, develop a negative ionic surface charge when wetted. If a cationic emulsion is used with such aggregate, the bitumen globules, which have a positive ionic surface charge, will be attracted electrochemically to the aggregate and a better bond will be established between the bitumen and the aggregate.

Similarly other aggregates, such as limestone, can develop positive surface charges and under these conditions an anionic emulsion containing bitumen globules with a negative ionic surface charge is best used

3.2 Procedure for Field Preparation of Cut Back Bitumen

Paving Bitumen 80/100 is heated at 100° to 110°in a bitumen boiler. The required quantity of distillate of specified type is taken in an empty drum. Hot bitumen from the boiler is added to the drum. After closing the lid of the drum containing distillate and hot bitumen, it is rolled on the ground to and fro till a uniform blend is obtained. The blend so prepared is transferred to a storage tank. Sufficient quantity of cut back bitumen has to be prepared before undertaking the road construction work. It may be ensured that the drum containing distillate is kept at a safe distance from bitumen boiler equipment

3.3 Tests for Cut-Back Bitumen:

1. VISCOSITY

   This is a standard test as specified in IS:1206-1978 Part-I. For Cut back Bitumen, a standard tar viscometer (STV) of 4 mm diameter orifice is used. The grade of Cut-back bitumen is designated by its viscosity value.

2. FLASH POINT

   This standard test is specified in IS : 1209-1978. For Cut back Bitumens, flash Point in ° C is determined by Pensky Martens closed cup apparatus. The value signifies the safe temperature to which cut-back bitumen can be heated.

3. DISTILLATION

   This is a standard test specified in IS:1213-1978. In this test volatile constituents Cut back bitumen are separated between different specified temperature ranges, from which the type of cut back bitumen can be identified. The type and quantity of distillate controls the curing time of cut back bitumen. For example, cut back bitumen RC-3 obtained by blending paving bitumen 80/100 with about 16 percent by weight of naphtha type distillate requires approximately 12 hours of curing time. A cut back bitumen is taken as cured when the float value at 50° C is more than 120 seconds. The details of float test are given in IS: 1210-1978. Residue obtained from the distillation test is tested for penetration and ductility to determine the nature of base bitumen used in preparation of cut-back bitumen

3.4 Adhesion of bituminous binders to road aggregates.

3.4.1 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 far can be regarded as an ideal adhesive but in general when proper precautions are exercised, both are adequate, there are occasions , however when the adhesive bond may fail and the durability of the bituminous material may be seriously affected. The adhesive of bituminous binder to road stone presents few problems in the absence of water, although excessive dust may create trouble. On the other hand because road stone are wetted more easily by water than by the bituminous binder, the presence of water can be lead to difficulties, either in the initial coating of damp or wet road stone or in maintaining an adequate bond between the binder and the 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.

3.5 Mechanism of stripping

Fundamental properties of the 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. Most sand stones have surfaces that are electrically changed for example silica , a common constituent of igneous rocks, possess a weak negative surface change resulting from the presence in the surface of oxygen atoms which are not fully saturated eclectically. Generally the constituents bituminous binder have little polar activity being largely composed of high molecular a weight hydrocarbons. The bond between bituminous binder and stone is therefore primarily due to relatively weak dispersion forces. The polar liquid water, on the other hand is strongly attracted to the changed road stone surfaces by orientation forces.

A very rough indication of the difference in the strength of the bond is given by heats of wetting of a silica surface by water and benzene, which are 600 and 150 ergs/ sq. cm respectively. The aliphatic hydrocarbon will have even lower heats of watering on a silica surface than is found with benzene. The heat of wetting is an expression of the tendency of a liquid to wet a solid surface and the greater it is the greater is energy released during wetting and stronger is the bond between the solid and the liquid although both water and the hydrocarbon such as bitumen and tar will adhere to a stone surface, the forces of attraction are appreciably greater in the case of water. The stone surface thus possesses so called Hydrophilic properties.

Conclusions follow from this act are

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

If a stone is already coated with a binder, it is possible for water to strip the binder from the stone. The conditions existing when solid is already wetted by water and a bituminous binder is brought into the system is shown in diagram below.

If the angle of contact between the three phases is and the energies of the solid/ binder, solid/ water and binder/water interfaces are respectively r_{sb}, r_{sw} and r_{bw} . Then the work of displacing water from unit area of stone is given by

$W= r_{sb}+ r_{bw} - r_{sw}$

Wow for equilibrium to be reached young and dupre‟ s equation must be satisfied.

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

This theoretical treatment is not rigorous because it has been simplified by the omission of one form into e equation the surface pressure of the adsorbed layer of water. However it is adequate to give an understanding of the problems involved. Displacement of the water by the binder will be made easier if the interfacial energy (binder/water) is reduced and if θ is increased. In case of a normal bituminous binder , θ is always less then 90 and so the factor (1+ cos θ) is always > 1 .

i.e an appreciable amount of work is required to make the binder displace the water and as a result the binder tends to collect in drops on the surface.

The values of r_{bw} and θ vary with the type of binder. The variations of θ on a polished glass surface given by three bituminous binders.

The variations in the case are ascribed to the differing quantities of polar bodies such as phenols in the binders. The r_{bw} and θ can both be altered by adding certain chemicals to the system. A striking effect on the interface is obtained by adding a little calcium hydroxide to the water the interfacial energy is reduced from 18.5 ergs/sq.cm for a tar/ water interface to about 3 ergs/ sq.cm when lime water is substituted for distilled water.

There is one danger implicit in the use of a chemical additive to reduce the energy of the water / binder to form an emulsion in water is increased.

3.6 Adhesion tests

It is desirable that there should be a reliable method of determining in the laboratory whether or not a bituminous binder will adhere will to an aggregate in the presence of water. Studies of the physio chemical properties of the binder/ stone/ water system have so far not proved sufficient conclusion to develop a rational approach of testing the materials.

This has led to develop arbitrary tests which may be used to examine the various combinations of road stones and binder used in bituminous road construction. Such tests may also be used to study the effect of an particular variable on the behavior of the binder/ stone/ water system.

Several tests have been described most of which fall into six basic types, they are.

Static immersion tests.

Dynamic immersion tests

Chemical immersion tests

Immersion mechanical tests

Immersion trafficking tests

Coating tests

Static immersion tests

In this type of tests aggregate coated with binder is immersed in water and degree of stripping is estimated. The method consists of single sized chipping which are coated with a constant quantity of binder under carefully controlled conditions and the coated stone is then immersed in distilled water and allowed to stand at a controlled temperature for up to 48 hours. The percentage of stripped surface is estimated visually. The results obtained in this test are not standardized and leads to poor reproducibility. In order to improve the test several agencies have tried to adopt other methods of assessing the degree of stripping. One approach is to measure the quantity of light reflected by the sample of coated aggregate before and after immersion in water. Another is to coat the aggregate with a solution of a radio- active calcium salt before it is coated with binder so that, when stripping occurs, the salt dissolves in water and the rise in radio activity of the water may be followed.

This method is fundamentally -------- because the interface which is studied is no longer between binder and stone but instead between binder and calcium salt. It is known that small amounts of materials such as calcium salts may sometimes have a effect on stripping of binders from the aggregate. When studied by a static immersion test. Though the test gives difficulties with reproducibility the test frequency gives some idea of how a mixture of aggregate and binder may behave on the road.

Dynamic immersion tests

This type of test is similar in general principle to the static immersion test., but the sample is agitated mechanic ally by shaking or kneading. The method of assessing the degree of stripping in such tests may involve visual estimation which again is usually not very satisfactory or determination of the quantity of uncoated aggregate which separates from the original sample.

The Nicholson wash test is typical of several dynamic immersion tests. In this coated aggregate is shaken in water for a known time and then the amount of stripping is estimated usually.

Chemical immersion tests

The Best known example of this type of test is that described by Riedel and Weber, but others of similar type also exist. In the Riedel and Weber test sand coated with binder is boiled successively in distilled water and if necessary, in solutions of gradually increasing concentrations of sodium carbonate. The strength of the solution of sodium carbonate in which stripping in first observed is used as a measure of the adhesively. Attempts have been made to improve this test, for example by reducing the temperature and using larger stone, or by measuring the amount of uncoated aggregate which separates from the coated mass. The artificial conditions of the test make it of doubtful value in reproducing road performance although it has been widely used probably because it gives a numerical answer and is very easily carried out.

Immersion mechanical tests

Immersion mechanical tests are in essence static immersion tests in which the degree of stripping of the binder from the aggregate is observed indirectly by measuring the change in a specified mechanical property of a sample of bituminous material after it has been immersed in water . In order that a mechanical test can be used it is necessary to employ a graded aggregate rather than single sized stone.

The mechanical properties which may be measured include shear strength, tensile strength, flexural strength, compressive strength, resistance to penetration of a cone and resistance to abrasion. In this test a number of identical cylindrical specimens of bituminous mixture to be tested are prepared. After a few hours of curing some are used to determine the compressive strength of the mixture under a constant rate of strain. The reminder 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. One of the major criticisms which may be leveled at most of this immersion mechanical test is that, although much work has been carried out in laboratory, little is known about correlation between the test and the actually road performance of the mixtures which are tested. With some of the materials which have been examined by means of these tests, it is even doubtful whether an important practical problem really exists.

Unit -4: BITUMINOUS MIXES

4.1 Introduction

Bituminous mixes (some times called asphalt mixes) are used in the surface layer of road and Airfield pavements. The mix is composed usually of aggregate and asphalt cements. Some types of bituminous mixes are also used in base course. The design of asphalt paving mix, as with the Design of other engineering materials is largely a matter of selecting and proportioning constituent materials to obtain the desired properties in the finished pavement structure.

4.2 Desirable properties

1. Resistance to permanent deformation: The mix should not distort or be displaced when subjected to traffic loads. The resistance to permanent deformation is more important at high temperatures.

2. Fatigue resistance: the mix should not crack when subjected to repeated loads over a period of time.

3. Resistance to low temperature cracking. This mix property is important in cold regions.

4. Durability: the mix should contain sufficient asphalt cement to ensure an adequate film thickness around the aggregate particles. The compacted mix should not have very high air voids, which accelerates the aging process.

5. Resistance to moisture-induced damage.

6. Skid resistance.

7. Workability: the mix must be capable of being placed and compacted with reasonable effort.

8. Low noise and good drainage properties: If the mix is to be used for the surface (wearing) layer of the pavement structure.

4.3 Marshall Mix design

The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) as a result of the loading.

The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. The important steps involved in marshal mix design are summarized next.

4.3.1 Specimen preparation

Approximately 1200gm of aggregates and filler is heated to a temperature of 175oC to 190oC. Bitumen is heated to a temperature of 121 125oC with the first trial percentage of bitumen (say 3.5 or 4% by weight of the material aggregates) to the heated aggregates and thoroughly mixed at temperature of 154oC to 160oC. The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at temperature of 138oC to 149oC. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by +0:5% and repeat the above procedure. Number of trials is predetermined. The prepared mould is loaded in the

4.3.2 Determine the properties of the mix

The properties that are of interest include the theoretical specific gravity Gt, the bulk specific gravity of the mix Gm, percent air voids Vv, percent volume of bitumen Vb, percent void in mixed aggregate VMA and percent voids filled with bitumen VFB.

5.3.3 Theoretical specific gravity of the mix Gt

Theoretical specific gravity Gt is the specific gravity without considering air voids, and is given by:

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}}$$

where, W1 is the weight of coarse aggregate in the total mix, W2 is the weight of aggregate in the total mix, W3 is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, G1 is the apparent specific gravity of coarse aggregate, G2 is the apparent specific gravity of fine aggregate, G3 is the apparent specific gravity of filler and Gb is the apparent specific gravity of bitumen,

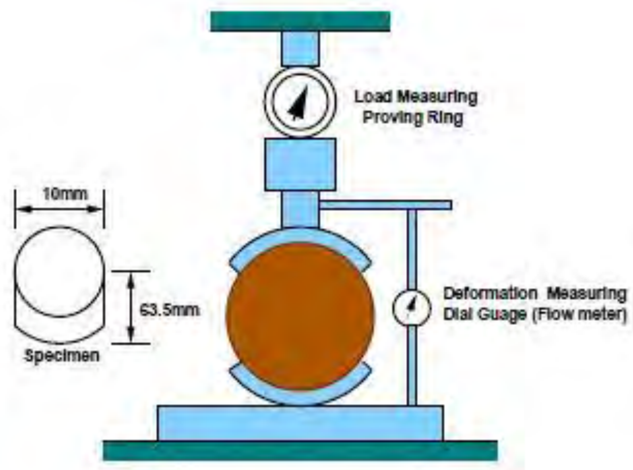


Figure 26:1: Marshall Mould

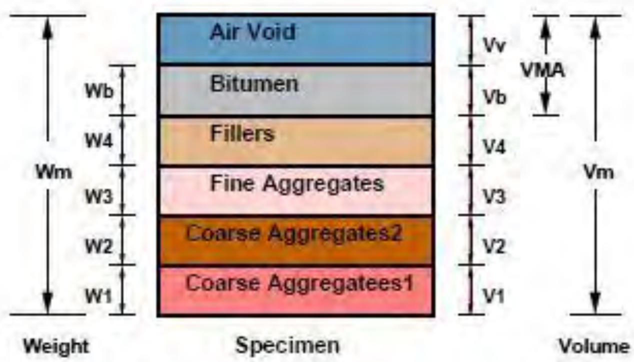


Figure 26:2: Marshall Mould

5.3.4 Bulk specific gravity of mix Gm

The bulk specific gravity or the actual specific gravity of the mix Gm is the specific gravity considering air void sand is found out by:

$$G_m = \frac{W_m}{W_m - W_w}$$

where, Wm is the weight of mix in air, Ww is the weight of mix in water,

5.3.5 Air voids percent Vv

Air voids Vv is the percent of air voids by volume in the specimen and is given by:

$$V_v = \frac{(G_t - G_m)100}{G_t}$$

where Gt is the theoretical specific gravity of the mix, given by equation 1. and Gm is the bulk or actual specific gravity of the mix given by equation 2.

5.3.6 Percent volume of bitumen Vb

The volume of bitumen Vb is the percent of volume of bitumen to the total volume and given by:

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}}$$

where, W1 is the weight of coarse aggregate in the total mix, W2 is the weight of _ne aggregate in the total mix, W3 is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, Gb is the apparent specific gravity of bitumen, and Gm is the bulk specific gravity of mix given by equation 2.

5.3.7 Voids in mineral aggregate VMA

Voids in mineral aggregate VMA is the volume of voids in the aggregates, and is the sum of air voids and volume of bitumen, and is calculated from

VMA = Vv + Vb

where, Vv is the percent air voids in the mix, given by equation 3. and Vb is percent bitumen content in the mix, given by equation 4. (26.4).

5.3.8 Voids filled with bitumen V FB

Voids filled with bitumen V FB is the voids in the mineral aggregate frame work filled with the bitumen, and is calculated as:

where, Vb is percent bitumen content in the mix, given by equation 4. and VMA is the percent voids in the mineral aggregate, given by equation 5.

5.4 Determine Marshall stability and flow

Marshall stability of a test specimen is the maximum load required to produce failure when the specimen is preheated to a prescribed temperature placed in a special test head and the load is applied at a constant strain (5 cm per minute). While the stability test is in progress dial gauge is used to measure the vertical deformation of the specimen. The deformation at the failure point expressed in units of 0.25 mm is called the Marshall flow value of the specimen.

5.5 Prepare graphical plots

The average value of the above properties are determined for each mix with different bitumen content and the following graphical plots are prepared:

1. Binder content versus corrected Marshall stability

2. Binder content versus Marshall flow

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

4. Binder content versus voids filled with bitumen (V FB)

5. Binder content versus unit weight or bulk specific gravity (Gm)

5.6 Determine optimum bitumen content

Determine the optimum binder content for the mix design by taking average value of the following three bitumen contents found form the graphs obtained in the previous step.

1. Binder content corresponding to maximum stability

2. Binder content corresponding to maximum bulk specific gravity (Gm)

3. Binder content corresponding to the median of designed limits of percent air voids (Vv) in the total mix (i.e. 4%)

The stability value, flow value, and V FB are checked with Marshall mix design specification chart given in Table below. Mixes with very high stability value and low flow value are not desirable as the pavements constructed with such mixes are likely to develop cracks due to heavy moving loads.

Table 26:2: Marshall mix design specification

Test Property	Specified Value
Marshall stability, kg	340 (minimum)
Flow value, 0.25 mm units	8 - 17
Percent air voids in the mix V_v%	3 - 5
Voids filled with bitumen VFB%	75 - 85

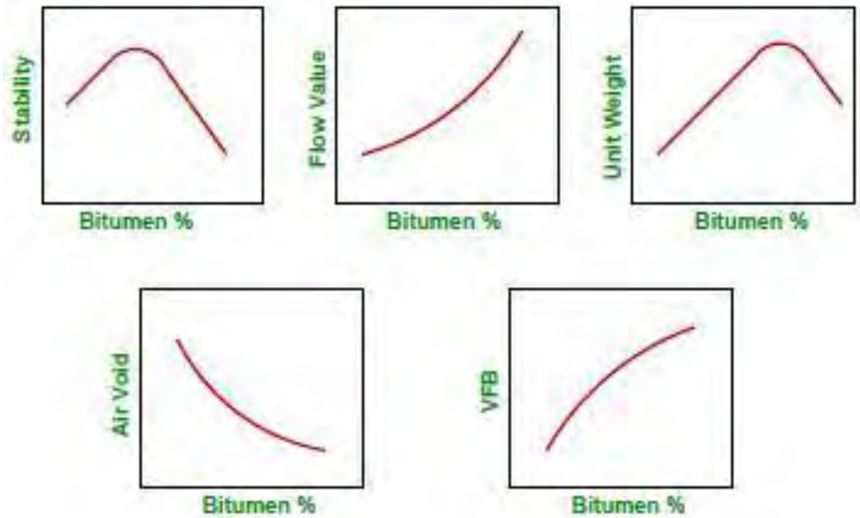


Figure 26:3: Marshal graphical plots

Problem

The specific gravities and weight proportions for aggregate and bitumen are as under for the preparation of Marshall mix design. The volume and weight of one Marshall specimen was found to be 475 cc and 1100 gm. Assuming absorption of bitumen in aggregate is zero, find V_v, V_b, VMA and VFB;

Item	A_1	A_2	A_3	A_4	B
Wt (gm)	825	1200	325	150	100
Sp. Gr	2.63	2.51	2.46	2.43	1.05

$$
\begin{aligned}
G_t &= \frac{825+1200+325+150+100}{\frac{825}{2.63}+\frac{1200}{2.51}+\frac{325}{2.46}+\frac{150}{2.43}+\frac{100}{1.05}} \\
&= \frac{2600}{1080.86} \\
&= 2.406 \\
G_m &= \frac{1100}{475} \\
&= 2.316 \\
V_v &= \frac{2.406-2.316}{2.406}\times 100 \\
&= 3.741\ \% \\
V_b &= \frac{100}{1.05}\times\frac{2.316}{1100} \\
&= 20.052\ \% \\
VMA &= (3.741+20.05) \\
&= 23.793\ \% \\
VFB &= \frac{20.052}{23.793}\times 100 \\
&= 84.277\ \%
\end{aligned}
$$

Unit -5: EQUIPMENT IN HIGHWAY CONSTRUCTION

5.1 Introduction

5.2 Earth Moving Equipment:

Dozer

Wheel Loader

Hydraulic Excavator

Vibratory Compactor

5.3 Road Making Equipment:

Roller

Road Paver

Asphalt Concrete Plant

5.4 Concreting Equipment:

Batching Plants

Mixers

Concrete Pumps

Transit Mixers

Dumpers

Concrete Placers

5.5 Stabilized soil road construction

Soil stabilization is required to upgrade the low cost roads to higher specification without involving appreciable wastage & the construction cost can be decreased by selecting local materials for construction of lower layers, if local soil is not adequate for supporting wheel beds, the properties are improved by soil stabilization techniques.

Soil Stabilization Methods -

i. Mechanical Soil Stabilization.
ii. Soil – Cement Stabilization.
iii. Soil – Lime Stabilization.
iv. Soil – Bitumen Stabilization.

5.6 Mechanical Soil Stabilization –

Correctly proportional materials when adequately compacted to get a mechanically stable layer, the method is called mechanical stabilization.

Two basic principles are

a) Proportioning
b) Compaction

a) Properties of Soil – Aggregate Mixture –

3 typical states in which compacted soil – aggregates mixes are formed.

The desirable properties of soil aggregates are strength, incompressibility, less changes in volume, stability, good drainage, less frost, ease of compaction. Stability is increase by increasing dry density & hence proportioning is done to increase MDD.

Fig (a) shows state when the aggregates without fines. This gives mass which is stable only when confined, highly permeable, no frost action. It is not easy to compact such a granular material.

Fig (b) shows state when the voids just filled with compacted binder thus retaining frictional component of mass due to grain to grain contact of aggregate. There is increase stability even when unconfirmed due to higher cohesion.

Fig (c) shows state when it is mixed with excess fines & compacted. As the aggregate have lost their contacts with each other & they float in binder oil, stability is decreased & mix is less desirable with poor drainage.

b) **Factors affecting Mechanical Stability** –

1) Mechanical Strength of aggregates
2) Gradation
3) Properties of soil
4) Presents of salts, mica, etc.,
5) Compaction.

c) Mix Design in Mechanical Stabilization –

The factors to be considered are gradation, density, index properties & stability.

1) Gradation – The particle size distribution that give max density. The theoretical gradation for maximum density is given by $P = 100 (d/D)^n$ where p = percent finer than diameter „d" (mm), D= diameter of largest particle mm & n = Gradation index, value ranging from 0.5 to 0.3

Proportioning is very much necessary to get highest density. Two graphical methods use for proportioning are triangular chart method & Rothfutch" s method.

2) Density – At least 95% standard dry density is aimed at field compaction.
3) Index Proprties – L.L & P.I for material passing 0.425mm sieve

	Base Course	Surface Course
Liquid Limit	25% Max	35% Max
Plasticity Index	6% Max	5 – 10% Max

4) Stability – Any method is adopted but soaked C.B.R test is commonly used.

d) Construction Procedure

1) Materials – Construction materials are collected from borrow pits & stacked in desired proportions.
2) Equipment – Roller is need for compaction.
3) Construction Steps –

i. Subgrade should be prepared.
ii. The materials are mixed to proportions by design in terms of volume.
iii. The existing moisture content is tested.
iv. The wet mix is spread & compacted by rollers till adequate compaction is achieved.
v. Field Control tests – Determination of moisture content before compaction & density during & after compaction.

Stabilized roads are opened to traffic after layers hardened by drying.

5.7 Soil Cement Stabilization –

a) Principles & Application –

Soil – cement is a mix of soil, cement & water is well compacted to form strong base course.

In granular soil, the mechanism of stabilization is due to bond between hydrated cement & compacted soil particles at the points of contact. In fine grained soil, is due to reduction is plasticity. Degree of stabilization depends on nature of soil, proportion of cement compacting moisture cement & the dry density of the mix.

Soil cement is used as sub base or base course of all types of pavements. A bituminous wearing course is placed over the base course.

b) Factors influencing properties of soil – cement –

i. Soil – The physical properties like particle size distribution, clay content, specific surface, liquid limit and plasticity index affect the properties of soil cement. Also surface chemical factors, organize matter & sulphate content after the properties & durability.
ii. Cement – Increase in cement generally increases the strength and durability.
iii. Pulverisation & Mixing – Better the pulverization & degree of mixing higher the strength.

iv. Compaction – If dry density increases amount of compaction increases hence strength of and durability of soil cement also increases.

v. Curing – Higher temp of curing accelerates the rate of gain in strength.

vi. Additives – Lime, Sodium hydroxide, Sodium carbonate, Calcium chloride.

c) Design of Soil Cement –

- There are various methods for design of mix, the most commonly known are British Method or PLA Method.
- In British Method, of mix design compressive strength of specimen is found for 7 days cured specimen.
- In PCA method, it is base on durability or ability of the soil cement specimens to withstand the specified wet – dry cycles & freeze that cycles.

d) Construction of Soil – Cement Base Course –

1) Materials –Passing 4.75mm Sieve > 50%

Passing 0.075mm Sieve	< 50%
Liquid Limit	< 40%
Plasticity Index	< 18%

2) Construction Steps –

i. Preparation of subgrade or sub base
ii. Pulverization of soil
iii. Application of cement & dry mixing
iv. Addition of spraying water & remixing
v. Spreading & grading
vi. Compaction
vii. Curing the soil – cement layer
viii. Joint with old work
ix. Field control tests

5.8 Soil – Bitumen Stabilization –

a) Principles & Applications –

The basic principle are water proofing & binding. By water proofing the inherent strength & other properties of soil is retained. In case of cohesion soil the binding action is also important.

In granular soil the coarser grains are individual coated by thin film of bituminous material. In fine grained soil, it plugs up the voids between small soil clods.

Most commonly used materials are cutback & bitumen. Bituminous stabilized layer may be used as sub – base or base course of roads and also as surface course.

b) Factors affecting properties of soil & bitumen –

1) Soil – The particle size, shape & gradation of soil influence the properties of soil – bitumen mix.
2) Type of Bituminous material – Cutbacks of different grades give different stability values for a soil. Emulsions generally gives slightly inferior results than cut back.
3) Amount of Bitumen – Increasing proportion of Bitumen cause or decrease in max dry density but stability increases water absorption decreases with increase bitumen content. The optimum binder content ranges from 4 to 6%.
4) Mixing – Improved type of mixing period is adopted. It is suggested first to mix soil with water before adding cut back. Mixing temperatures also affects the properties of mix, depending on the type & grade of cut back and soil type.
5) Compaction – Better the compaction, higher the stability and resistance to absorb water. It is depends on compacting moisture content & temperature, a eration of the mix before compaction & the amount & type of compaction.
6) Curing – By curing, the water & volatiles are allowed to evaporate there by allowing the bitumen to be effective to import binding & water proofing actions it depends on curing temperature, relative humidity and soil type.
7) Additives – Anti stripping & reactive chemical additives improve the properties of mixed. Porland cement is used.

c) Design of soil – Bitumen mix –

- There is no standard of mix design.

- (BR & modified Hubband field test are considered suitable for evaluating the stability and water proofing effects.
- Other tests like low bearing value test & cone penetration test are also done.

d) Construction of Soil – Bitumen Layer

1) Materials - Passing 4.75mm < 50%

Passing 0.425mm	35 – 100%
Passing 0.075mm	10 – 50%
Liquid Limit	< 40%
Plasticity Index	< 18%

2) Construction Steps

i. The soil to be stabilized is pulverized.

ii. Water is added to soil and is mixed.

iii. Cut back or emulsion is added and the most soil is remixed for proper distribution of Bitumen.

iv. The mix is spread, grade & compacted.

v. The compacted layer is allowed to cure when the moisture evaporates.

vi. Field control tests for moisture content & compaction.

5.9 Soil – lime Stabilization

a) Principles & Applications – Soil Lime is widely used either as a modified for claycy soil or a binder. When claycy soil with high plasticity are treated with lime the plasticity index is decreased and the soil becomes friable and easy to be pulverized.

b) Factors affecting soil lime are soil type, lime content, types of lime, compaction, curing, additives.

c) Design of soil lime mix has no standard design but compressive strength of soil specimens is obtained for the design mix.

d) Construction of soil lime – Preparation of subgrade, pulverizing the soil, Addition of lime, Allowing for toning the soil, adding rest of lime, spreading to desired grade and compacting and field control tests.

Unit -6: SUBGRADE

1.1 Preparation of Subgrade

Construction Procedure –

- **Setting out** – After the site has been cleared, the work should be setout. The limits of embankment are marked by fixing batter pegs on both sides at regular intervals. The subgrade should be wider than the design dimension so that surplus material may be trimmed.
- **Dewatering** – If the foundation of the embankment is in area with stagnant water, it is feasible to remove it by bailing out or pumping.
- **Stripping & Storing top soil** – In localities where most of the available embankment materials are not conductive to plant growth, the top soil from all areas of cutting shall be stripped to specified depths not exceeding 150mm & stored in stock piles of height not exceeding 2m for covering embankment slopes.
- **Compacting ground supporting embankment / subgrade** – where necessary, the original ground shall be leveled to facilitate placement of first layer of embankment, scarified, mixed with water and then compacted by rolling so as to achieve minimum dry density as given in table. In case difference in subgrade level and ground level is less than 0.5m & the ground does not have 97% relative compaction, the ground shall be loosened upto a level 0.5m below the subgrade level, watered & compacted in layers to not less than 97% of dry density.

Table 1 – Density requirements of embankment & subgrade materials

Sl. No.	Type of Work	Max lab dry unit weight when tested as per IS – 2720
1	Embankment upto 3m height, not subjected to extensive flooding	Not less than 15.2 KN/cum
2	Embankment exceeding 3m height or embankments of any height subject to long period of inundation.	Not less than 16.0 KN/cum
3	Subgrade & earthern shoulders / verger / backfill	Not less than 17.5 KN/cum

Table 2 – Compaction requirements for embankment & subgrade

Sl. No.	Type of Work	Relative Compaction s % of max lab dry density
1	Subgrade & earthern shoulders	Not less than 97
2	Embankment	Not less than 95
3	Expansive soils Subgrade & 500mm portion just below the subgrade. Remaining portion of embankment.	Not allowed. Not less than 90.

In high embankments, resting of suspect foundation as reveled by borehole logs shall be carried out in a manner and to the desired depth.

➢ **Spreading material in layers & bringing to appropriate moisture content –**

a. The embankment & subgrade material shall be spread in layers of uniform thickness not exceeding 200mm compacted thickness over the entire width of embankment by mechanical means, finished by a motor grader & compacted.

b. Moisture content of the material shall be checked at this site of placement prior to commencement of compaction, water shall be sprinkled from a water tanker filled with sprinkler capable of applying water uniformly.

c. Moisture content of each layer should be checked with respect to table – 1 in accordance with IS – 2720.

d. Clods or hard lumps of earth shall be broken to have max size of 75mm when placed in embankment & max size of 50 mm when placed in subgrade.

e. Embankments & other areas of unsupported fills shall not be constructed with steeper side slopes, or to greater widths.

f. Whenever fills is to be deposited against the face of a natural slope, steeper than 1 verticle on 4 horizontal, such faces shall be benched.

➢ **Compaction –**

a. Smooth wheeled, vibratory, pneumatic tyred, sheep foot or pad foot rdlers of suitable size and capacity should be used for different types & grades of materials.

b. Mostly compaction will be done with vibratory roller of 80 to 100KN static weight or heavy pneumatic tyred roller.

c. Each layer of the material shall be thoroughly compacted to the densities in table – 1, subsequent layers should be laid only after the finished layer has been tested.

d. The measurement of field dry density is recorded by nuclear moisture / density guage.

e. When density measurement revel any soft areas in embankment, further compaction is carried out.

➢ **Drainage –** The surface of embankment at all times during construction shall be maintained at such across fall as will shed water and prevent pending.

➢ **Repairing of damages caused by rain / spillage of water –**

a. The soil in the affected portion shall be removed in such areas before next layer is laid & refilled in layers & compacted using small vibratory roller, plate compactor or power rammer to achieve the required density.

b. Tests shall be carried out to ascertain the density requirements of the repaired area.

➢ **Finishing operations –**

a. It shall include the work of shaping & dressing the shoulders / verge / road bed & side slopes to conform to alignment, levels, cross sections & dimensions.

b. Both the upper & lower ends of side slopes shall be rounded off & to merge the embankment with adjacent terrain to improve appearances.

c. The top soil, removed & conserved earlier shall spread over the fill slopes, before spreading the slopes should be roughened and moistened slightly to provide bond and is provided t a depth of 75mm to 150mm for plant growth.

d. When earthwork is completed, the road area shall be cleared of all debris & ugly scars.

1.2 Quality Control Tests

Quality control tests for Embankment, Subgrade construction.

Sl. No.	Type of test	Frequency of tests
1	Sand content	2 tests per 3000 cubic meter of soil.
2	Plasticity test	2 tests per 3000 cubic meter of soil.
3	Density test	2 tests per 3000 cubic meter of soil.
4	Deleterious content	As & when required.
5	Moisture content	1 test for 250 cubic meter of soil.
6	CBR test [soaked & unsoaked]	1 test per 3000 cubic meter of soil.

a) **Compaction Control** – Atleast one measurement of density for each 1000sqm of compacted area, test locations should be chosen with random sampling techniques. Control should be based on the mean value of 5 – 10 density determinations. The number of tests in one set of measurements shall be 6. For earth work in shoulders at least one density measurement for every 500sqm for the compacted area should be made and the number of tests in each set shall be atleast 10.

Unit -7: FLEXIBLE PAVEMENTS

7.1 Introduction

This chapter provides a general overview of construction procedures such as specification of materials, surface preparation, compaction and quality control tests are also discussed

7.2 Granular sub base layer

A. Specification of material –

- The materials to be used for the work shall be natural sand, moorum, gravel, crushed stone or combination depending on grading requirement.
- The materials shall be free from organic or deleterious constituents & should conform to one of the three gradings given in table 400-1.
- The gradings in Table 400 – 1 are in respect of close graded granular sub base materials, & Table 400 – 2 for coarse graded materials.

Table 400 – 1 – Grading for close graded granular sub – base materials.

IS Sieve Designation	Percentage by weight passing the IS sieve		
	Grading – I	Grading – II	Grading – III
75.0mm	100	-	-
53.0mm	80 – 100	100	-
26.5mm	55 – 90	70 – 100	100
9.5mm	35 – 65	50 – 80	65 – 95
4.75mm	25 – 55	40 – 65	50 – 80
2.36mm	20 – 40	30 – 50	40 – 65
0.425mm	10 – 25	15 – 25	20 – 35
0.075mm	3 – 10	3 – 10	3 – 10
(BR Value min)	30	25	20

Table 400 – 2 – Grading for coarse graded Granular sub – base materials.

IS Sieve Designation	Percentage by weight passing the IS sieve		
	Grading – I	Grading – II	Grading – III
75.0mm	100	-	-
53.0mm	-	100	-
26.5mm	55 – 75	50 – 80	100
9.5mm			
4.75mm	10 – 30	15 – 35	25 – 45
2.36mm			
0.425mm			
0.075mm	< 10	< 10	< 10
(BR Value min)	30	25	20

B. Physical requirements –

a) The material shall have 10% finer value of 50KN or more.

b) If the water absorption value for coarse aggregates exceeds 2%, soundness test is carried out.

c) The material passing 425 micron sieve for all 3 gradings shall have liquid limit & plasticity Index not more than 25 & 6%.

C. Construction Operations –

a) **Preparation of sub grade –** Before laying sub base, the sub grade should be prepared by removing vegetation & extraneous matter, lightly sprinkled with water if necessary & rolled with two passes of 80 – 100KN smooth wheeler roller.

b) **Spreading & Compacting –**

- The sub base material should be spread on prepared sub grade with help of motor grader, its blades having controls for maintaining the required slope & grade.
- When sub – base material have combination of materials, mixing is done mechanically. Manual mixing is permitted where the width of laying is small for mechanical operations.

  The equipment used for min – in place construction is rotavator.
- Moisture control of loose material shall be checked with IS – 2720 & suitably adjusted by sprinkling water from truck mounted or trailer mounted water tank.
- At the time of compaction, water content should be from 1% above to 2% below the optimum moisture content.
- After adding water it is processed by horrows, rotavators until the layer is uniformly wet.
- Immediately rolling will start, if the thickness of compacted layer does not exceed 100mm, a smooth wheeled roller is used. For a compacted single layer upto 225mm,

  vibratory roller or heavy pneumatic tyred roller of min 200 to 300KN wt is used.
- Rolling will start from lower edge & proceed towards upper edge longitudinally to achieve super elevation & unidirectional cross fall & should start at both edges &

  progress towards centre for portions having cross fall on both sides.
- Each pas of roller shall uniformly overlap not less than one third of track made in preceding pass. The speed of roller shall not exceed 5km per hour.
- Rolling is continued till the density is achieved atleast 98% of MDD for the material determined.
- The surface of any layer of material on completion of compaction shall be will closed, free from movement under compaction equipment & from compaction planes, ridges,

  cracks or loose materials. If so happens it should be re – compacted.

Surface Finish & Quality control of work – The surface finish of construction & control on the quality of materials & works shall be in accordance with section 900, the tests to be conducted are as below –

D. QUALITY CONTROL TESTS ON GRANULAR SUB – BASE

Sl. No.	Type of Test	Frequency [Min]
1	Gradation	One test per $200m^3$
2	Atterberg limits	One test per $200m^3$
3	Moisture content prior to compaction	One test per $250m^3$
4	Density of Compacted Layer	One test per $500m^3$
5	Deleterious Constituents	As required.
6	CBR	As required.

7.3 Water Bound Macadam

I. <u>Specification of materials –</u>

a) **Coarse aggregates –** It can be either crushed or broken stone, crushed slag, over burnt rick aggregates or naturally occurring aggregates such as Kankar & Laterite. The aggregates shall conform the physical requirements said in table 400 – 6. If the water absorption is greater than 2% the soundness test shall be carried out.

Table 400 – 6 physical requirements of coarse aggregates for water bound Macadam for sub base / base courses.

Sl. No.	Type of Test	Test Method	Requirements
1	Los angles abrasion value or Aggregate Impact Value	IS – 2386 IS – 2386 or IS – 5640	40% (Max) 30% (Max)
2	Combined flakiness & Elongation Indices	IS – 2386	30% (Max)

i. **Crushed Slag –** It is made from air cooled blast furnace slag. It should be angular shape, reasonably uniform in quality & density. The weight of crushed slag shall not be less than 11.2 KN/m^3 & percentage of glossy material shall not be more than 20 water absorption should not be more than 10% sulphur content should not exceed 2%.

ii. **Crushed or Broken Stone –** It should be hard, durable & free from excess flat, clongated, soft & disintegrated particles, dirt & other deleterious material.

iii. **Over burnt (Jhama) bick aggregates –** It should be made from over burnt bricks or brick bats & be free from dust & deleterious materials.

iv. **Grading requirement of coarse aggregates –** The coarse aggregates shall conform to one of the gradings given in table 400 – 7, the use of Grading No – 1 shall be restricted to sub – base courses only.

Grading No	Size Range	IS Steve Designation	Percent by weight passing
I	90mm to 45mm	125mm	100
		90mm	90 – 100
		63mm	25 – 60
		45mm	0 – 15
		22.4mm	0 – 5
II	63mm to 45 mm	90mm	100
		63mm	90 – 100
		53mm	25 – 75
		45mm	0 – 15
		22.4mm	0 – 5
III	53mm to 22.4 mm	63mm	100
		53mm	95 – 100
		45mm	65 – 90
		22.4mm	0 – 10
		11.2mm	0 – 5

The compacted thickness for a layer with Grading – I shall be 100mm while for layer with other gradings 2 & 3 should be 75mm.

v. **Screenings –** It is used to fill voids in coarse aggregates which consists of same material as the coarse aggregate. Such as non plastic materials like moorum or gravel is used provided liquid limit & plasticity Index are below 20 & 6 respectively & fraction passing 75 micron sieve does not exceed 10%. Screenings should conform to the grading serial in table 400 – 8. It should be omitted in case of soft aggregates such as brick metal, kankar, laterites etc as they get crushed under rollers.

Table 400 – 8 Grading for Screenings –

Grading Classification	Size of Screenings	IS Sieve Designation	Percent by weight passing the IS Sieve
A	13.2mm	13.2mm	100
		11.2mm	95 – 100
		5.6mm	15 – 35
		180micron	0 – 10
B	11.2mm	11.2mm	100
		5.6mm	90 – 100
		180micron	15 – 35

vi. **Binding Material –** It is used as a filler material for WBM having PI value less than 6, the quantity of binding material to be used depend on type of screening. Generally, the quantity required for 75mm compacted thickness will be 0.06 – 0.09$m^3/10m^2$ & for 100mm compacted thickness it will be around 0.08 – 0.10$m^3/10m^2$.

II. Construction Operations –

a) **Preparation of Base –**

The surface of subgrade / sub base to receive WBM coarse shall be prepared to specified lines & cross fall & made free of dust & other materials.

Levelling course is used to correct the irregularities in the profile.

Laying of WBM over thick bituminous layer is avoided due to the internal drainage of the pavement at the interface of 2 courses.

Where the intensity of rain is low & the interface drainage facility is efficient WBM can be laid over the existing thin bituminous surface by cutting 50mm X 50mm furrows at an angle of 45^{o} to the centre line at one metre interval.

b) **Invented Choke –**

If WBM is to be land directly over subgrade, a 25mm coarse of screening B or coarse sand is spread before application of aggregates.

In case of find sand or silty or clayey subgrade, it is advisable to lay 100mm of screening or coarse sand on top of fine grained soil.

As an alternative to inverted choke, geo synthesis are used for separation & drainage over the prepared subgrade.

c) **Spreading Coarse Aggregates –**

The coarse aggregates shall be spread uniformly & evenly upon the prepared subgrade in thickness not more than 100mm for Grading – I & 75mm for Grading – II & III.

The spreading shall be done from stockpiles along the side of road way ro directly from vehicles. No segregation between aggregates is allowed & it must be of uniform gradation with no fine material.

The surface of the aggregates shall be checked carefully by removing or adding aggregates at high or low spots & it is checked with a straight edge.

The coarse aggregates should not normally be spread more than 3 days.

d) **Rolling –**

Rolling is started immediately after spreading by three wheeled power rollers, or tandem or vibratory rollers 80 to 100KN static weight.

Except on superelevated portions where the rolling will proceed from inner edge to outer & it begins from edges gradually progressing towards centre.

During rolling, slight sprinkling of water may be done if necessary.

Rolling is not done when subgrade is soft or yielding or when it cause a wave like motion in the subgrade or sub base course.

The rolled surface shall be checked transversely & longitudinally with templates & corrected or re – rolled to derived camber & grade.

Materials getting crushed during compaction should be removed & replaced. Shoulders are built up simultaneously along with WBM courses.

e) **Application of Screenings –**

After the coarse aggregate has been rolled, screenings are applied to fill the voids.

There shall not be damp or wet at the time of application. Dry rolling shall be done while the screenings are being spread so that it will settle into voids.

The screenings are spread uniformly in thin layers by hand shovels or by mechanical spreaders or from dipper.

The screening is applied at a slow & uniform rate so as to ensure filling of voids accompanied by dry rolling & brooming with mechanical or hand brooms or both.

These operations shall continue until no more screenings fills voids of aggregates. The spreading, rolling & brooming of screenings could be completed in one day.

f) **Sprinkling of water and grouting –**

After the screenings are applied, the surface should be sprinkled with water, swept & rolled. Hand brooms are used to sweep & distribute wet screenings evenly. It is continued until coarse aggregate has been thoroughly keyed, well bonded & firmly set in full depth & a grout has been formed of screenings.

g) **Application of Binding Material –**

After application of screening, binding material is applied in 2 or more thin layers at a slow & uniform rate. After each application water is sprinkled & swept with brooms to fill the voids & rolled. This is continued till a wave head of the wheels of the moving roller is formed on slurry.

h) **Setting & drying –**

After final compaction of WBM course, the pavement is allowed to dry overnight

Next morning spots be filled with screenings or binding materials & lightly sprinkled with water & rolled.

No traffic shall be allowed on the load until the macadam has set.

The compacted WBM course should be allowed to completely dry & set before the next pavement course is laid over it.

III. Quality control tests on Water Bound Macadam Course –

Sl. No.	Type of Test	Frequency (min)
1	Aggregate Impact value	1 test per 200m^3 of aggregate
2	Grading	One test per 100m^3
3	Flakiness Index & Elongation Index	One test per 200m^3 aggregate
4	Atterberg limits of binding materials	One test per 325m^3 of binding material

The evaluation of density results & acceptance criteria for compaction control shall be on lines similar to those subgrade / embankment as we discussed earlier.

7.4 Wet Mix Macadam layer

I. **Specification of Materials –**

a) Physical requirements of aggregates – Coarse aggregates shall be crushed stone & it should conform to the physical requirements said in Table – 400 – 10.

Sl. No.	Type of Test	Test Method	Requirements
1	Los Angeles abrasion value or Aggregate Impact Value	IS – 2386 IS – 2386	40% (Max) 30% (Max)
2	Combined flakiness & Elongation Indices (Total)	IS – 2386	30% (Max)

If the water absorption value of aggregates is greater than 2%, soundness test is carried out.

b) Grading requirements for WMM is given in table below 400 – II.

IS Sieve Designation	% by weight passing he IS Sieve
53.00mm	100
45.00mm	95 – 100
26.50mm	-
22.40mm	60 – 80
11.20mm	40 – 60
4.75mm	25 – 40
2.36mm	15 – 30
0.60mm	8 – 2
0.075mm	0 – 8

Materials finer than 425micron shall have plasticity Index not more than 6.

II. Construction Operations –

a) Preparation of base – It is done us the same as WBM layer as we have discussed earlier.

b) Provision of lateral confinement of aggregates – while constructing WMM, arrangement shall be made for lateral confinement of wet mix. This shall be done by laying in adjoining shoulders along with WMM.

c) Preparation of mix – WMM is prepared in mixing plant where pug mill or pan type mixer of concrete batching plant is used. Optimum moisture for mixing is determined at the time of compaction, water in the WMM should not vary from optimum value. The mixed material should be uniformly wet & no segregation is permitted.

d) Spreading of mix –

- Immediately after mixing it is spread uniformly & evenly on prepared subgrade / subbase / base. In no case it should be dumped in heaps.
- The mix may be spread by paver finisher or motor grader.

- The motor grader is cable of spreading the material uniformly so as to achieve the specified slope & grade.
- No segregation of large & fine particles should be allowed.

e) Compaction –

- After the mix has been laid to required thickness, grade & crossfall the same shall be compacted uniformly to the full depth by roller.
- If the thickness is 100mm single layer, smooth wheel roller is used. For compacted single layer upto 200mm vibratory roller is used.
- Same kind off rolling as in WBM is done as we discussed before.
- Along forms, kerbs, walls or other inaccessible places for rollers, mechanical tampers or plate compactor is used.
- Rolling should not be done when the subgrade in soft.
- If irregularities develop during rolling which exceed 12mm when tested with 3m straight edge, the surface should be loosened & premixed material added or removed.
- Rolling shall be continued till the density achieved is atleast 98% of the max dry density for the material.
- After completion, the surface of any finished layer is well closed, free from movement under compaction equipment or any compaction planes, ridges, cracks & loose material.
- All loose, segregated area shall be made good to the full thickness of layer & recompacted.

f) Setting & Drying – After final compaction of wet mix macadam course, the rolad shall be allowed to dry for 24 hours.

g) Opening to traffic – Preferably no vehicular traffic or any kind should be allowed on finished WMM surface till it has dried & the wearing course is laid.

7.5 Penetration Macadam and Built up Spray Grout

Penetration Macadam – Bituminous penetration macadam is used as base or binder course. The course aggregates are first spread & compacted well. The hot bitumen is sprayed at top, it penetrates in voids & binding some stone aggregates together. Depending on quantity of bitumen spread & extent of penetration, it is called „full grout‟ & „semigrout‟ when depth is full or half & is adopted in heavy & moderate rain fall regions respectively.

Built up spray grout [BSG] – it consists of 2 layer composite construction of compacted crushed aggregates with application of bituminous binder after each layer with key aggregates at top to provide a total thickness, 75mm. It is used for strengthing of existing bituminous pavement. A suitable wearing course is invariably provided over this & opened to traffic.

I. Construction procedure for penetration Macadam –

a) Preparation of existing surface – The underlying course is prepared to uniform grade & is lightly scarified & prime coat may be applied if required.

b) Spreading the coarse aggregate –
   - It is spread with proper edge protection by mechanical spreader or hand.
   - A template cut to camber profile is used to achieve cross section.

c) Rolling –
   - Aggregates are dry rolled with 10 – tones roller.
   - Rolling is commence from edge & proceeded to centre, the overlap being 30cm.
   - Dry compacted aggregate are checked for desired profile using 3m straight edge.

d) Bitumen Application –
   - The binder is spread uniformly either with pressure distributor or mechanical hand sprayer.
   - The quantity of bitumen being 50 & 68kg per $10m^2$ for 50 & 7mm compacted thickness respectively.

e) The key aggregates are spreaded & rolled & cross profile is checked.

f) Seal Coat – It is applied if another surfacing course is not constructed immediately & traffic is to allowed. The pavement is again rolled.

g) Finishing – The constructed pavement section is checked for its cross profile with template & longitudinal profile by straight edge.

h) Opening to traffic – The finished surface is opened to traffic after a period of 24 hours.

II. Construction procedure for Built up spray grout –

a) Preparation of existing base – The depressions & pot holes are filled and the surface is brought to required grade and prime coat may be applied.

b) Tack Coat – Heated bituminous binder is applied at a rate of 7.5 to 10 km on WMB surface & 6 to 8 kg on black top surface per $10m^2$ area.

c) Coarse aggregates are spread at a rate of $0.5m^3$ per $10m^2$ area.

d) The aggregates are rolled using 8 to 10 tonnes roller.

e) The second layer of coarse aggregates is spread at $0.5m^3$ per $10m^2$ & rolled thoroughly stating from edges.

f) Second application of binder is done at 12.5 to 15kg per $10m^2$.

g) Key aggregates are applied & spread at $0.13m^3$ per $10m^2$ & rolled.

h) Surface Finish – The surface unevenness is checked with 3m straight edge. Longitudinal profile should not have undulations exceeding 12mm. BSG should not be exposed to traffic before providing surface.

7.6 Bituminous Macadam layer

I. Specification of Materials –

- The grades of bitumen used 30/40, 60/70, 80/100 penetration. Road tar RT – 4, cutback & emulsion are used. Binder content 3 – 4.5% by weight of mix is used.
- Aggregates –

i.	Los Angles abrasion value	50% Max
ii.	Aggregate Impact value	30% Max
iii.	Flakiness index	15% Max
iv.	Stripping @ 40^oC	25% Max
v.	Loss with Sodium Sulphate	12% Max

For binder coarse, abrasion & impact value are 40 & 30% respectively.

vi. Grading for 75mm compacted thickness for base coarse & binder coarse

Percent passing **Sieve size (mm)**	**Base Course**		**Base or Binder Course**
	Grading I	**Grading II**	**Grading III**
63.0	100	100	-
50.0	-	90 – 100	-
40.0	35 – 70	35 – 65	100
25.0	-	20 – 40	70 – 100
20.0	0 – 15	-	50 – 80
12.5	-	5 – 20	-
10.0	-	-	25 – 50
4.75	-	-	10 – 30
2.36	0 – 5	0 – 5	5 – 20
0.075	0 – 3	0 – 5	0 – 4
Binder Content	3 – 4.5	3 – 4.5	3 – 4.5

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vii. Grading for 50mm compacted thickness for base course & binder

Percent passing Sieve size (mm)	Base Course		Base or Binder Course
	Grading I	Grading II	Grading III
50	100	100	-
40	-	90 – 100	-
25	35 – 70	50 – 80	100
10	-	-	70 – 100
12.5	0 – 15	10 – 30	35 – 60
4.75	-	-	15 – 35
2.36	0 – 5	-	5 – 20
0.075	0 – 3	0 – 5	0 – 4
Binder Content	3 – 4.5	3 – 4.5	3 – 6.0

The quantity of aggregates required for 10m^2 of BM are 0.60 to 0.75m^3 & 0.9 to 1m^3 respectively for 50 & 75mm compacted thickness.

II. Construction Procedure –

a) Preparation of existing layer – The existing layer is properly profiled & even & cleaned.

b) Tack Coat or Prime Coat application – A tack coat is applied of thin layer of bitumen binder using sprayer or pouring can.

c) Premix Preparation – The bitumen binder & aggregates are separately heated and then placed in mixer & is mixed till a homogenous mixture is formed & carried to site by transporter or wheel borrow.

d) Placement – Paving mixture is placed in a desired location & is spread with rakes to pre – determined thickness. The camber profile is checked with template.

e) Rolling & finishing the Paving Mix – The rolling is done using tandem roller. The rolling is commenced from edge of pavement to centre. The finished surface should not show separate lines of markings the roller wheel are kept damp. A variation of 6mm over 3m length is allowed in the cross profile. The number of undulations exceeding 10mm should not be less than 30 in 300m length of pavement.

7.6 Dense Bituminous Macadam

layer I. Specification of Materials –

a) Bitumen – Grade S65 or A65 (60 / 70), S90 (80 / 100) may be used.

b) Coarse aggregates –

1) Los Angles Abrasion Value	40% Max
2) Aggregates Impact Value	30% Max
3) FI & EI	30% Max
4) Stripping	Minimum retained
5) Loss with sodium sulphate	12% Max
6) Water absorption	2w% Max

c) Fine Aggregates – should be the fraction passing 2.36mm sieve & retained on 75m sieve.

d) Filler - IS Sieve % Passing by weight

600M	100
300M	95 – 100
75M	85 – 100

e) Aggregate Gradation –

Sieve Size	% Passing by weight
37.5mm	100
26.5mm	90 – 100
13.2mm	56 – 80
4.75mm	29 – 59

2.36mm	19 – 45
300micron	5 – 17
75micron	1 – 7

Requirement of Mix –

a.	Marshall stability	820Kg
b.	Marshall flow	2 – 4
c.	% air voids	3 – 5
d.	VMA	10 – 12%
e.	VFB	65 – 75
f.	Binder Content	Not less than 4%

Construction Procedure –

a. Preparation of Base – The surface should be swept clean using mechanical broom & is prepared to uniform grade. Prime coat may be used & tack coat are applied over base.

Preparation of mix is same as BM as discussed earlier.

b. Spreading – It is spread by self propelled paver for spreading, tamping & finishing the mix to desired grade, lines.

In restricted areas & narrow widths, manual laying of mix or mechanical paver are used.

Temperature is $120^o – 160^oC$ at the time of laying.

c. Rolling –

- It is compacted initially by smooth wheeled roller, intermediate rolling by vibratory roller or pneumatic roller & finishing rolling is done by tandem roller.
- The rollers shall not be allowed to stand on pavement which has not been full compacted & temperature is more than 70^oC.
- The wheels of roller shall be kept moist to prevent adhesion.
- Rolling with start from edge to centre line of pavement, both directions.
- Each pass of roller shall overlap one by half the width of rear wheel.
- Rolling shall be continued till the density achieved is atleast 98%.
- It is completed in all respects before the temp of mix falls below 100^oC.

d. Opening to traffic –

- Traffic may be allowed after completion of the final rolling is done.
- DBM is provided with proper wearing course before opening to normal traffic or rain.

7.7 Bituminous Concrete –

I Specification of Materials –

1) Bitumen – Same as DBM

Bitumen, Fine aggregates, Filler, Coarse aggregate are all same as DBM but Grading changes.

IS Sieve (mm)	% passing the Sieve by Weight
26.5	100
19.0	90 – 100
9.5	56 – 80
4.75	35 – 65
2.36	23 – 49
0.3	5 – 19
0.075	2 – 8

Mix Design –

1)	Marshall Stability	820Kg (Min)
2)	Marshall Flow	2 – 4
3)	# air voids	3 – 5
4)	VMA	11 – 13%
5)	VFB	65 – 75

6)	Binder Content	Min 45
7)	Water Sensitivity	Min 75%
8)	Swell Test	1.5% Max

II. Construction Operations –

- Preparation of Base – The base on which bituminous concrete is to be laid shall be prepared, shaped & conditioned to the specified levels, grade and crossfall (Camber).
- The surface shall be thoroughly swept clean free from dust and other matter using mechanical broom and dust removed by mechanical means or blown off by compressed air. In portions where mechanical means cannot reach, other approved method is used.
- Applying tack coat, preparation of mix, spreading, rolling are same as DBM layer as we have discussed earlier.
- Opening to Traffic – Traffic may be allowed immediately after completion of final rolling when the mix has cooled down to surrounding temperature.

7.8 Semi Dense Bituminous Concrete –

I. Specification of Materials –

a) Bitumen – Same as BM (30/40 to 80/100) grade materials are almost same as BM & DGBM course layers which we have discussed earlier.

b) Coarse aggregates, fine aggregates, filler same specification as dense grade bituminous macadam.

c) Mix Design

1)	Marshall Stability	820Kg
2)	Marshall flow	2 – 4
3)	# air voids in mix	3 – 5
4)	VMA	13 – 15
5)	VFB	65 – 75
6)	Binder Content	44%

d) Grading –

Sieve Size (mm)	% by weight passing		
	Grading I	Grading II	Grading III
22.4	-	100	100
13.2	100	85 – 100	79 – 100
11.2	88 – 100	70 – 92	68 – 90
5.6	42 – 64	42 – 64	33 – 55
2.8	22 – 38	22 – 38	22 – 38
710M	11 – 24	11 – 24	6 – 22
355M	7 – 18	7 – 18	4 – 14
180M	5 – 13	5 – 13	2 – 9
90M	3 – 9	3 – 9	0 – 5

II. Construction Operation –

Construction is similar to Dense BM as discussed earlier.

a) Preparation of Base – The base on which SDBC is to be laid shall be prepared, shaped & conditioned to the specified lines, grades and cross sections. Tack Coat, prepration of mix, rolling is same as DBM.

Opening to traffic – Traffic may be allowed after completion of final rolling when the mix has cooled down to surrounding temperature.

7.9 Seal Coat

a) Scope – This work shall consist of application of seal coat for sealing the voids in bituminous surface.

b) Specification of Materials –

- Binder – Suitable grade appropriate to region, traffic, rain fall & other environmental conditions.
- Stone chippings for type (A) & type (B) seal coat – It should consists of angular fragments of clean, hard, durable, tough and free from dust, soft or flaky elongated material, organic matter. It should be 6.7mm size and 0.18mm size respectively.

c) Purpose – a) To seal the surfacing against the ingress of water. b) To develop skid resistance texture. c) To enliven an existing dry or weathered bituminous surface.

7.10 Surface Dressing –

a) Scope – This work shall consists of the application of one coat or 2 coats of surface dressing, each coat consisting of a layer of bituminous binder sprayed on base followed by cover of chippings rolled to form wearing course.

b) Specification of Materials -

- Binder – It should be of suitable grade appropriate to region, traffic, rainfall.
- Stone Chipping – The stone polishing value should not be less than 55 & water absorption restricted to 1%.
- Quantities of Materials – For single coat or the first coat of 2 coat surface dressing, 13.2mm size where it passes 100% 22.4mm & retained on 11.2mm IS Sieve. For second coat, 11.2mm passing 100% 13.2mm Sieve & retained on 5.6mm Sieve.

c) Purpose –

- To serve as a thin wearing course of pavement & to protect the base course.
- To water proof the pavement surface and to prevent infiltration of water.
- To provide dust – free pavement surface in dry weather & mud – free pavement in wet weather.

7.11 Mastic Asphalt –

It is a mixture of bitumen, fine aggregates & filler in suitable proportions which yields a voidless & impermeable mass. Though the ingredients in mastic asphalt when cooled results in hard, stable & durable layer suitable to withstand heavy traffic. This material also can absorb vibrations and has a property of self – healing of cracks without bleeding. It is suitable surfacing materials for bridge deck slap. The filler, bitumen binder & aggregate are taken in suitable proportion & to make the mix.

Unit -8: CEMENT CONCRETE PAVEMENTS

8.1 Specification of Materials

For concrete slabs cement, coarse aggregates, fine aggregates and water are required. If reinforcement is provided, steel wire fabric are used & for construction of joints, joint filler & sealer are used.

1. Cement – Ordinary Portland cement is used. In case of urgency rapid hardening cement is used.
2. Coarse Aggregates – The max size should not exceed 1/4th slab thickness. The gradation may range from 50 – 4.75 or 40 – 4.75. The aggregates should be free from iron, purities, cola, mica, clay, alkali, etc., For Physical properties desire limits are –
   a) Aggregate Crushing Value : 30% Max
   b) Aggregate Impact Value : 30% Max
   c) Los Angeles abrasion Value : 30% Max
   d) Soundness for sodium sulphate : 12% Max
3. Fine aggregates – Natural sands, crushed stones etc., are used.
4. Proportioning of Concrete – It is proportioned so as to obtain a minimum modulus of rupture of 40Kg/cm^2 on field or to develop minimum compressive strength of 280 Kg/cm^2 at 28 days.

8.2 Construction method

a) Preparation of subgrade and sub base –
   - No soft pots are present in subgrade or sub base.
   - It should extent atleast 30cm on either side of width to be connected.
   - Subgrade is properly drained; minimum modulus of subgrade reaction is 5.54Kg/Cm^2.
   - The layers should be kept moist when cement concrete is placed.
   - Water proof paper may also be used when CC is laid directly.

b) Placing of Forms –
   - The steel or wooden forms are used.

- The steel forms are M.S. Channel sections and their depts. Is equal to thickness of pavement and length atleast 3m except on curves < 45m radius.
- Wooden forms are dressed on side, these have minimum base width of 100n for slab thickness or 20cm.
- The forms are jointed neatly and are set with exactness to the required grade and alignment.

c) Batching of Material & Mixing –

- The proportioned mixture is placed into holper in weigh batching plant.
- All batching of material is done on the basis of one or more whole bags of cement, wt of one bag is 50 kg or unit wt of cement is taken as 1440Kg/m^3.
- The mixing of concrete is done in batch mixer. So that uniform distribution, uniform is color and homogenous mix is obtained.
- The batch of cement, fine aggregate and coarse aggregate is led together into the mixer. Water for mixing is introduced into the drum within fifteen seconds of mixing.

d) Transportation & Placing of Concrete –

- The cement concrete is mixed in quantities required for immediate use.
- It should be seen that no segregation of materials results while transporting.
- Spreading is done uniformly; certain amount of redistribution is done with shovels.

e) Compaction & Finishing –

- The surface of pavement is compacted either by means of power driven finishing machine or by vibrating hand screed.
- Areas where width of slab is small, hand consolidation and finishing is adopted.
- The concrete is further compacted by longitudinal float. It is help parallel to carriage way and passed gradually from one site to other.
- The slab surface is tested for its grade and level with straight edge.
- Just before the concrete becomes hard, the surface is belted with two ply canvas belt.
- Broom finish is given with fibre broom brush and it is done perpendicular to centerline of pavement.
- Before concrete develop initial set, the edges of slab are carefully finished with an edging tool.

f) Curing of cement concrete –

- Initial curing – The surface of pavement is entirely covered with burlap cotton or jute mats prior to placing it is saturated with water and wet side is placed on pavement.
- Final curing – Curing with wet soil exposed edges of slabs are banked with soil berm. A blanket of sandy soil free from stones is placed. The soils is thoroughly kept saturated with water for 14 days.

In impervious membrane method, use of impervious membrane which does not impart a slippery surface to the pavement is used. Liquid is applied under pressure with a spray nozzle to cover the entire surface with a uniform film. It hardness within 30 minutes after its application. The liquid applied immediately after surface finishing.

When the concrete attains the required strength or after 28days of curing the concrete road is opened to traffic.

8.3 Quality Control Tests

A) Quality control tests for materials used –

1	Cement	Physical & Chemical Tests	One for each source of supply and occasionally
2	Coarse aggregates & fine aggregates	(i) Gradation (ii) Deleterious constituents	One test for every day work of each fraction of coarse aggregate and fine aggregate.

B) Quality control tests for levels, alignment and texture -

1	Level Tolerance	+5mm
2	Width of pavement & position of paving edges	-6mm +-10mm
3	Alignment of joints, widths, depths of dowel groves	To be checked @ one joint per 400m length
4	Surface regularity both transversely	Once a day or one day‟s work
5	Alignment of dowel bars and tie bars	To be checked in trail length.