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Tar, Bitumen and Asphalt

18.1 INTRODUCTION

Bitumen and bituminous materials have been known and used in construction works since ancient times, approximately 6000 B.C. Asphalts were used as cements to hold stonework together in boat building and as waterproofing in pools and baths. Some asphalt was mixed with stand and used to pave streets and palace floors. The Egyptians made use of asphalt in the mummification process and as a building material. The Greeks and Romans not only used asphalt as a building material but also used burning asphalt as a military weapon. The asphalt used by these ancient civilizations was *natural asphalt* formed when crude petroleum oils rose to the earth's surface and formed pools. The action of the sun and wind drove off the lighter oils and gases, leaving a heavy residue. The residue was asphalt with impurities such as water and soil present. Using crude distillation process, cementing and waterproofing materials were obtained.

The word bitumen comes from the original sanskrit word Gwitumen applied to native asphalts as fuel. Bitumens are mainly composed of a mixture of high-molecular hydrocarbons, methane, napthane and other aromatic series and their oxygen or sulphur derivatives. Tar and asphalt are the two varieties of bituminous materials. Tars are bituminous condensates obtained in the process of destructive distillation of coal, petroleum, wood and other organic materials at high temperature without access of air. They are composed of hydrocarbons and their sulphurous, nitrous and oxygen derivatives. Asphalt on the other hand is a naturally occurring bitumen which is a combination of an inorganic mineral matter either calcareous or siliceous and an organic matter—a chemical compound of carbon and hydrogen.

Bitumens and bituminous materials are being extensively used in damp proofing the basements, floors, roofs, damp proof courses; painting timber and steel structural elements;

as adhesives and caulking compounds, and tars are used as binders in road works. When combined with aggregate these are also used to provide floor surfaces. Bitumens are now more commonly used for building purposes than is tar.

18.2 BITUMEN

Bitumen is a noncrystalline solid or viscous material derived from petroleum, by natural or refinery process and substantially soluble in carbon disulphide. It is asphalt in solid state and mineral tar in semi fluid state. Bitumen is brown or black in colour.

The main constituent is petrolene—a yellowish oily substance, an excess of which makes bitumen to melt at low temperature and, asphaltene—hard black substance, an excess of which makes bitumen brittle and non-plastic. Its compositions is carbon 87 per cent, hydrogen 11 per cent and oxygen 2 per cent.

Bitumen is not affected by light, air or water individually, but in combination they can make it brittle, porous and susceptible to oxidation forming blisters and cracks. It becomes soft at temperatures between 30°–100° C (no sharp melting point), and therefore must be protected from exposure to heat. It is insoluble in water and fairly resistant to most acids. Although bitumen is combustible, composite products, such as mastic asphalt, are not readily ignited. Physical and chemical requirements of bitumen for use in buildings is given in Appendix II.

Forms

Bitumen emulsion is a liquid product containing bitumen to a great extent in an aqueous medium. The bitumen which is in a very finely divided state (globules of about 2 micron diameter) is kept suspended in the aqueous medium with the help of some suitable stabilizing agents. Depending upon the stability of the protective coating of the emulsifying agent, the emulsions are classed as rapid setting (RS), medium setting (MS) and slow setting (SS). These emulsions are always stored in air tight drums.

Blown bitumen is obtained by passing air under pressure at a higher temperature through the bitumen. It can be used as roofing and damp-proofing felts, in the manufacture of pipe asphalts and joint fillers, as heat insulating material, etc.

Cut-back bitumen is obtained by fluxing asphaltic bitumen in presence of some suitable liquid distillates of coal tar or petroleum. It is mainly used in road construction and in soil stabilization (2–4%). Cut-backs are commercially manufactured in the following three groups.

1. Rapid curing (RC) cut-backs containing naptha or gasoline.
2. Medium curing (MC) cut-backs containing kerosene.
3. Slow curing (SC) cut-backs containing light oils as fluxing agents.

Each of the above group of cut-backs is further subdivided into six categories from 0 to 5. The six different viscosities are named by numbers 0 to 5 in the increasing order of viscosity.

Plastic bitumen consists of bitumen, thinner and a suitable inert filler. The amount of inert filler is about 40 to 45 per cent. It is used for filling cracks in masonry structures, for stopping leakage, etc.

Straight run bitumen is the bitumen being distilled to a definite viscosity or penetration without further treatment.

Classification

Based on Source: Bitumens are classed as natural and petroleum bitumens.

Natural Bitumen: Pure natural bitumen occurs rarely. Limestones, sandstones and soils impregnated with bitumen are frequently found. It originates from the accumulation of petroleum in the top layers of earth crust through migration, filling pores and cavities of rocks, under the action of high temperature and pressure.

The natural bitumen is dark-brown in colour which on heating gradually softens and passes to liquid state and on cooling solidifies. It is insoluble in water but dissolves in carbon disulphide, chloroform, benzene and very little in gasoline. Natural bitumen may be extracted from bituminous rocks by blowing in kettles or dissolving in organic solvents (extraction).

Petroleum Bitumens are product of processing crude petroleum and its resinous residues. These are classified as residual asphaltums, oxidized, cracked and extracted bitumens.

Residual Asphaltums are black or dark-brown solid substances at normal temperatures, obtained by atmospheric-vacuum distillation of high-resin petroleum after topping of gasoline, kerosene and fractions.

Oxidized Bitumen are produced by blowing air through petroleum residues. Oxygen from air combines with hydrogen of the residues to give water vapour. The petroleum residues thicken because of polymerization and condensation.

Cracked Bitumen are obtained by the cracking—high temperature decomposition—of petroleum and petroleum oils allowing high yield of gasoline. Blowing of air through residues gives oxidized cracked bitumens.

Based on Consistency *(at 18° C):* These are classified as solid, semi-solid and liquid bitumens.

Based on Application: Bitumens are classified as road construction bitumen, building bitumen and roofing bitumen.

Uses Bitumen is used for manufacture of roofing and damp proofing felts, plastic bitumen for leak stops, waterproof packing paper, pipe asphalt, joint filler, bituminous filling compounds for cable boxes, for sealing accumulators and batteries. It is also used for fixing of roofing felts, dam proofing felts and for heat insulation materials for buildings, refrigeration and cold storage equipments.

Properties of Bitumen

The various properties are viscosity, ductility and softening point.

Viscosity depends greatly on temperature. At lower temperature, bitumen has great viscosity and acquires the properties of a solid body, while with increase in temperature the viscosity of bitumen decreases and it passes into liquid state.

Ductility depends upon temperature, group composition and nature of structure. Viscous bitumens, containing solid paraffins at low temperatures are very ductile.

Softening Point is related to viscosity. Bitumen needs sufficient fluidity before specific application.

Resilience Bitumen is resilient, non-rigid and as such it is capable of absorbing shocks and accommodate itself to the movement in structure due to temperature, settlement or shrinkage.

Bituminous Sheets

These are manufactured by running refined bitumen on to paper of different thicknesses and qualities. These sheets are used for damp proof courses. These can be bent without cracking. A lead sheet sandwiched between two layers of refined bitumen makes the sheet acid-proof.

Fluxed Bitumen

When bitumen is used in hot applications, the process is known as *hot mopping* in which case a suitable flux is added. Fluxing is essentially a softening process. The flux is usually a heavy oil added primarily to control the final setting hardness, but may also serve to reduce the temperature at which a hot applied bitumen becomes workable.

18.3 TAR

It is a dark (deep black) viscous liquid produced by destructive distillation of organic material such as coal, oil, lignite and wool. Depending upon the source of origin it is classified as coal tar, wood tar and mineral tar. Tar is restraint to petroleum-based solvents. It has very low bitumen content.

Coal Tar is obtained, as a by product in the destructive distillation of coal, or in the manufacture of coal gas. It is heavy, strong smelling and black. These generally have high specific gravities and viscosities, and good adhesive properties. On the further distillation of coal tar (from coal gas) coal naphtha, creosote oil, dyes, etc. are obtained, coal tars for road works are obtained by coking coal or melting together coal pitch with oils or dehydrated raw tar.

Composition A typical composition of coal tar from coke oven plant is true pitch 72 per cent, heavy oils 15 per cent, medium oil 6 per cent, light oil 6 per cent, moisture and ash 1 per cent.

Uses For coating of wooden poles, sleepers, iron-poles, latrine walls, etc.

Wood Tar is obtained by the destructive distillation of resinous wood (pine, etc.). It contains creosote and as such is a very strong preservative. On further distillation wood tar produces wood creosote. Compared to coal tar creosote, it is an inferior preservative for wood. The residue left after the distillation is known as pitch.

There are five grades of road tars:

- RT-1 : For surface painting under exceptionally cold weather conditions, hill roads at very high elevations.
- RT-2 : For standard surface painting under normal climatic conditions.
- RT-3 : For surface painting and renewal coats and is also used for premixing chips in top courses.
- RT-4 : For premixing tar macadam (base course).
- RT-5 : For grouting.

Mineral tar is obtained by the distillation of bituminous shales. Some examples are tarmac, tar paving and tar macadam.

Tarmac is ironstone slag impregnated with tar oils. It is impervious to water and used in road pavement.

Tar Paving is a composition of limestone and coaltar. It is heated before use.

Tar Macadam is used for road pavement. Soft rock materials such as limestones blast furnance cinder, etc. are heated in a furnace and then mixed with boiling coal tar, pitch and creosote oil. The mix is applied in road soon after cooling and rolled.

18.4 PITCH

Most pitches used in building are obtained either as the residue of the direct distillation of crude tar produced by the high temperature carbonization of coal as a waste product. However, by fluxing back such pitch residues with high boiling coal tar distillates the material can be suitably conditioned to give products of desired softening points for a number of particular uses.

Coal tar pitch is classified on the basis of softening point into four grades as given in Table 18.1.

Table 18.1 Requirements for Coal Tar Pitch

Grade	*Softening*	*Sp.gr.*	*Distillate per cent by wt. below 270°C (Max.)*	*300°C (Max.)*	*Matter insoluble in toluene as % by weight (Max.)*	*Ash % by weight (Max)*
Soft pitch	45–55°	1.20–1.30	4	8	25	0.50
Soft medium pitch	58–68°	1.22–1.32	4	8	28	0.50
Hard medium pitch	70–80°	1.22–1.32	3	4	30	0.75
Hard pitch	82–92°	1.28–1.38	–	–	35	0.80

Composition

Carbon	75%
Hydrogen	8%
Oxygen	16%
Nitrogen	1%
Ash and sulphur	Little

Uses Pitch is extensively used as ingredient in a number of water proofing, protective and binding compounds in masonry, timber and steel structures. It is also used in the manufacture of tar felt and flooring mastics, and as a base for coal tar paints designed mainly for cold applications. The pitch paints set by drying of the solvent.

18.5 ASPHALT

Asphalt is a natural or artificial mixture in which bitumen is associated with inert mineral matter. It is black or brownish black in colour. At temperature between 50–100°C it is in liquid state whereas at temperature less than this it remains in solid state. Because it is a thermoplastic material it softens as it is heated and hardens as it is cooled. It is the basic paving material in use today.

Natural Asphalt is also known as *native asphalt*. When obtained from lakes it is termed as *lake asphalt*. It is used for making pavements, for water proofing of structure, stopping vibrations in machine foundations, tunnels and subways, in manufacture of marine glue, and in lining trenches.

Rock Asphalt is a naturally occurring rock formation, usually limestone or sandstone intimately impregnated throughout its mass with 6–14% bitumen.

Refined Asphalt is obtained by heating pitch to drive off the water and to draw off the mineral matter by segregating the impurities.

Composition

Bitumen	52%
Inorganic matter	38%
Organic matter	10%

Mastic Asphalt is manufactured by adding pulverized natural rock gradually to molten refined bitumen, agitating the mixture for about 5 hours (200–250°) and placing it into moulds for cooling. The mass consolidates into hard elastic blocks which can be remelted when used for pavements. It is tough, durable, nonabsorbent, damp proof, noninflammable, and noiseless. When non-bituminous limestone is mixed with bitumen of residual type it is brown as synthetic mastic asphalt.

Liquid Asphalt is the viscous residue obtained by the distillation of asphaltic base crude oil to 425°C.

Cut-back Asphalt is derived by distillation of asphalt in a volatile solvent. It contains about 80 per cent asphalt and remainder the solvents.

Artificial Asphalt is the pitch residue obtained by evaporation of the volatile constituent of coal tar. It is formed of an admixture of coaltar, pitch, ground iron slag, sawdust, chalk, etc.

Composition

Bitumen	12%
Minerals and sand	87%
Organic matter	1%

Asphaltic Cement is prepared by oxidizing asphalt at a high temperature the lighter oils vapourize and are drawn off at their condensation temperature, leaving a residual material–aspaltic cement. It is used for flooring and water proofing and in expansion joints in concrete.

A comparison of tar and asphalt is given in Table 18.2.

Table 18.2 Properties of Tar and Bitumen

S.No.	*Property*	*Asphalt*	*Tar*
1.	Colour	Brownish-black	Brownish-black
2.	Viscosity	Viscous	Viscous
3.	Sp.gr.	0.92–1.02	1.08–1.24
4.	Manufacture	Fractional distillation of crude petroleum	Fractional distillation of organic material

5.	Affinity to water	Does not weather well in presence of water	Greater surface tension and the tar coatings remain intact even in the presence of water
6.	Temperature changes and softening	Has a wider range of temperature for hardening	More susceptible to temperature changes
7.	Durability	High	Loses volatile matter very fast
8.	Hardening	Slow	Quicker
9.	Toxicity	Not	Toxic and used as preservative
10.	Solubility	Soluble in CS_2	Insoluble in CS_2

18.6 THE CHOICE OF PRODUCT

The choice of product will depend upon the use to which it is put; a broad classification of typical uses can be made as follow:

Fluxed bitumen and pitch Damp proof membranes; adhesives for wood block flooring; adhesive for cork slabs and insulating lining; saturants and adhesives for felts.

Asphalt mastic Tanking; damp proof courses; joint less flooring; tiled flooring; roofing.

Pitch mastic Joint less flooring.

Pitch and bitumen ("tar base") paints Floor paints; water proofing and decoration (external); isolating layers under plasters, etc., adhesive for linoleum and also (in emulsion form) for wood block flooring; caulking compounds (containing fillers); pipe wrappings; protection of metals against corrosion and decay; and protection of brickwork (as in factory chimneys).

18.7 GENERAL PROPERTIES

All bituminous substances have general property of resisting the passage of water. Other factors being equal, those products containing the highest percentage of the base material—*i.e.*, pitch or bitumen—will give the greatest protection. Pigmented products, light in colour, are therefore less efficient in this respect than those in which the quantity of pitch or bitumen necessitates a dark colour.

In general the hot applied material and those constituted with solvent—*i.e.*, not an emulsion—are more likely to withstand pressure: on other hand, emulsions are satisfactory when their purpose is to shed water from vertical or near vertical surface.

Durability Bituminous materials are known to have a long life—some asphalt mastic roofs are 100 years old—but they may be affected by sunlight and by other agencies such as acid, fats, etc. and also by mechanical damage. Defects due to natural weathering may be overcome by periodic maintenance and renewal of the top dressing. Effects of acid, mechanical damage etc. may be overcome by choosing the correct type and grade of material.

The decision as to choice of material is one for which the architect must rely very largely on the manufacturer, but in so far as it is possible to generalize, those product incorporating principally natural bitumens are thought to be superior to those incorporating derivative bitumens.

The Effect of Sunlight Exposure to sunlight over a long period is known to affect bituminous material adversely, and the degree to which they are affected will depend upon the type of material used. Experience indicates that bitumen is likely to be more durable in this respect than pitch, and its use is recommended for permanent roofing work.

Effect of Heat Bituminous material will revert to a plastic condition upon heating, and when used on roof or in exposed positions are liable to soften from the effect of the sun's heat, especially if insulation is provided between the surface of the structure and the covering. It is important to choose a grade of material best suited to withstand this, and to ensure that in all vertical application an adequate key is provided in order to prevent the material from flowing. Similar softening will occur if the material is applied near hot air exhausts, near radiators or other heat sources.

On roofs, a secondary effect of solar heating is the formation of blisters. These occur when the protective covering does not adhere uniformly to the substructure and the air entrapped below the covering expands upon heating. The defect may be overcome by laying the bituminous material on a sheathing felt to which it will readily adhere, thus isolating it from the surface of the structure. The likelihood of failure in this respect can be further reduced by providing a top surface which is light in colour and which reflects the sun's ray. This may be done simply by lime washing or by covering the roof with light coloured chippings; and oil paint must not be used for this purpose.

Resistance to Fire Mastic asphalt and pitch mastic are not readily combustible and entail no increase in the fire hazard.

Appearance The appearance of floors composed of bituminous material is reasonably good, though they are necessarily dark in colour and are usually limited to reds and browns. However, they have to be well maintained.

Bituminous paints may be obtained in a wider range of colours and tones, some of which are comparatively light. The paints can be manufactured to produce a high gloss if required.

Noise Floors composed of bituminous materials are moderately noisy.

Slipperiness Floors of bituminous material are reasonably non-slip, but frequent polishing increase their slipperiness.

Effect of Physical Loading When used under load, there is always a tendency for bituminous material to flow. The effect is sometimes to be seen in damp proof course squeezing out, and in floors which have become indented by point loads such as chair and table legs. It is important therefore to choose the correct grade of material under these conditions.

Where the flooring is softened by heat, foot traffic also will cause indentations, and the material is rarely sufficiently hard—even when polished—to resist scratching.

Effects of Acid Bituminous materials used for acid-resisting construction can be relied upon to be efficient, provided the nature of the acid, working temperatures and other relevant data is duly considered.

Effects of Fats and Oils In so far as resistance to fats and oils is concerned, products based on pitch are likely to be superior to those based on bitumen. None of the material will withstand wholly the effects of oils, and even polishes containing oils may be injurious.

Relation to other Material

Substructure the more rigid products such as asphalt mastic and pitch mastic are liable to cracking if there is differential movement in the substructure, such as occurs in wood boarded roofs. They should therefore always be laid on an isolating membrane such as sheathing felt. On the other hand, an adequate key should always be provided on vertical surfaces, where there would otherwise be a tendency for the bituminous material to flow. It should be remembered that adhesion to a wet background is always liable to be weak.

Paint—Bituminous materials should not be painted with any paint having a strong binder, since to do so may cause the bituminous material to craze. They should not be painted with oil or other paints which are light in colour, since the pitch or bitumen will always bleed though. Light coloured bituminous paints are, however, satisfactory as a decorative finish to bituminous ground.

18.8 TESTING

Bituminous cements are tested for consistency, heat, solubility and composition, ductility, specific gravity and adhesion.

Consistency Test

Furol viscosity test, Engler viscosity test, penetration test, or softening point test may be performed for the purpose.

Viscometer Consistency Test is conducted in Fural viscometer shown in Fig.18.1. It consists of a cylindrical vessel with a standard orifice at the bottom. The vessel is filled with the bitumen sample and time taken, in seconds, for 50 ml of bitumen sample to flow out through the standard orifice denotes its viscosity.

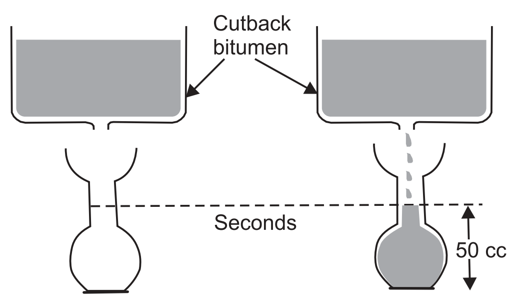

Fig. 18.1 Furol Viscometer

Engler Specific Test In this method the time taken for a 50 cc of the tar sample is divided by the time taken, in seconds, by an equal quantity of water. The quotient gives the specific viscosity of the sample.

Penetration Test determines the hardness of the bituminous materials by measuring the depth in millimeter to which a standard needle penetrates vertically under specified conditions of load, time and temperature. The needle consists of a 1.00 to 1.02 mm diameter rod tapered between 8°40′ to 9°40′. A truncated cone is formed at the pointed end, with the diameter of the smaller base: 0.14 to 0.16 mm. The test is normally conducted at a temperature of 25°C by loading the needle for 5 seconds with a weight of 100 g, and allowing it to penetrate into the sample placed in a small cup below. The apparatus used are standard penetrometer (Fig.18.2), sample cup, water bath, thermometer, benzene solution, bitumen sample, etc.

Procedure The bitumen sample is softened to a pouring consistency and is then poured into the cup to a depth at least 15 mm in excess of the expected penetration. The sample is placed in a temperature controlled water bath and maintained for one hour at 25°C. The sample container is taken out of bath and is placed on penetrometer table under needle. The needle

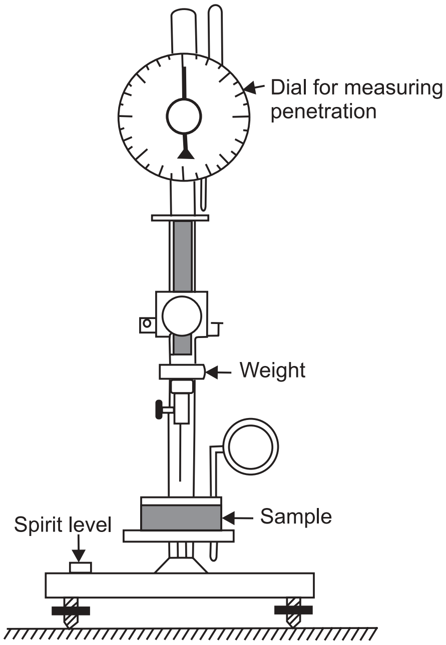

Fig. 18.2 Penetrometer

is kept touching the surface of the bitumen with the dial set zero and the initial reading is recorded.

The needle is then released for 5 seconds. It will penetrate into the bitumen. The needle, is locked and the final reading is recorded. The needle is taken out from bitumen, washed with benzene solution and the process is repeated. Penetration value will be the average of the three results.

Significance The penetration test measures the consistency of bitumen binders so that they can be classified into standard grades but on its own has no relation to binder quality. However, bitumens are known to reduce in penetration with age and to develop cracking tendencies. Penetration values below 20 have been associated with bad cracking of road surfacings, while cracking rarely occurs when penetration exceeds 30. Pentration tests carried out at different temperatures, can also determine the temperature susceptibility of a bitumen. Where resistance to flow is important, *e.g.*, when bitumen is used to fill cracks in concrete road slabs, a small change in temperature is desirable.

Softening Point Test This test is done to determine temperature susceptibility of the bitumen. The ring and ball softening point test is extensively used to evaluate the consistency of bituminous binders. The test consists of placing a 9.5 mm diameter steel ball on a binder sample placed in a steel ring (Fig. 18.3) and its temperature is raised until a value is reached when the test sample is sufficiently soft to allow the ball enveloped in binder, to fall through a height of 25 mm. The water temperature at which this occurs is read to nearest 0.5°C and is called the softening point of the bituminous binder.

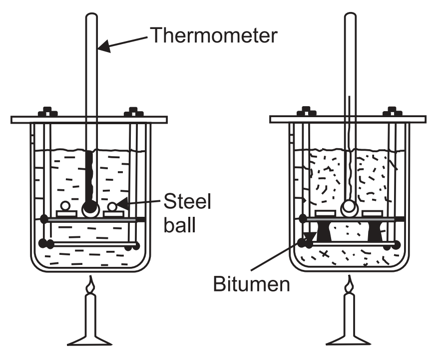

Fig. 18.3 Softening point test (Ring & Ball Apparatus)

Procedure The sample binder is heated approximately between 75°–100°C above softening point and it is ensured that the sample is completely fluid, free from water and air bubbles. If necessary it is filtered. The brass rings are also heated to a temperature approximately equal to that of molten binder and are placed on a metal plate coated with mercury or a mixture of glycerin and dextrine. The brass rings are filled with molten binder slightly above the level of ring. After cooling for about 30 minutes in air, the excess bitumen is removed with a warm sharp knife. The apparatus is assembled with the rings, thermometer and ball guides in position, and the water bath is filled to a height of 50 mm above the upper surface of the rings with freshly boiled distilled water at a temperature of 5°C for 15 minutes. A ball, previously cooled to 5°C is placed in each ball guide. The bath is then heated and the liquid is stirred so that the temperature rises at a rate of 5° ± 0.5°C per minute. The temperature, for each ring and ball is recorded at the instant the binder surrounding the ball touches the bottom plate of the support, if any, or bottom of the bath. The process is repeated. The mean of the two determinations gives the softening point. The hardest grade of bitumen available in India is 30/40, which has a softening point of 50-60°C. The softest paving bitumen is 180/200 grade, having a softening point of 30-45°C.

Significance Bitumen does not suddenly change from solid to liquid state, but as the temperature increases it gradually becomes softer until it flows readily. All semi-solid state bitumen grades need sufficient fluidity before they are used for application with the aggregate mix. For this purpose bitumen is sometimes cutback with a solvent like kerosene. The common procedure, however, is to liquefy the bitumen by heating. The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test. Softening point is found to be related with viscosity. The ring and ball test results with tars having softening point approximately 20°C lower than equiviscous temperatures. Bitumen with higher softening point is also sometimes used to specify hard bitumens and pitches. The range of softening point is from 30°–60°C for bitumen from Assam petroleum.

Viscosity Test

Viscosity defined as inverse of fluidity defines the fluid property of bituminous material. It is measured by determining the time taken by a specified quantity of binder to flow from a cup through specified orifice at a given temperature. Because of the great variation of this time for different binders, it is not practicable to determine the viscosity of all binders under same conditions of temperature, heat and flow. So different viscometers are in use. A typical tar viscometer is shown in Fig. 18.4. The time taken in seconds by 50 ml of binder to flow from a cup through a 10 mm (or 4 mm) orifice under an initial head and at known test temperature is measured. The flow times should lie between 10–140 sec, so that temperatures for tars are chosen to ensure these conditions. With cutback bitumens the 10 mm orifice cup is used at 25°C for materials whose viscosities at that temperature and in that cup exceeds 10 seconds, and at 40°C for materials whose viscosities at 25°C exceeds 75 seconds. The 4 mm cup at a temperature of 25°C is used for cutbacks whose viscosities are less than 10 seconds in the 10 mm cup at 25°C.

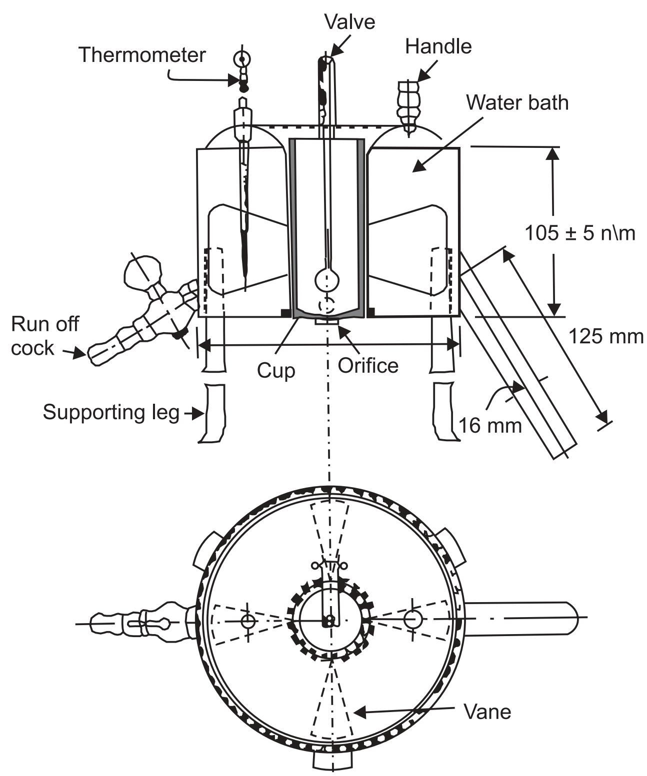

Fig. 18.4 Tar Viscometer

The tar cup is leveled with the help of a bubble level. The cup is immersed in the water bath cup to little above the peg mark. The water is heated to the test temperature specified and is maintained throughout the test. The binder is heated to 20°C above the test temperature and allowed to cool. The tar is poured into the cup (when it is slightly above the test temperature). The receiver is cleaned and soft soap solution (1 per cent soap by weight) up to 20 ml mark is poured. The receiver is placed under the orifice. When the binder reaches the test temperature the valve is opened. The stop watch is started when the receiver records 25 ml and is stopped when the receiver records 75 ml. The time elapsed is recorded in seconds. The observations are repeated 3 times and the mean of three values is taken as the viscosity of the given binder.

Significance Viscosity measurements are useful not only ensuring that material with the desired properties has been obtained, but also as a means of selecting binders for specific uses. If a binder with too low viscosity is premixed with an aggregate, it may flow off the aggregate while en route from the mixing plant. Conversely, if the viscosity is too high, the mixture may be unworkable by the time it reaches the site. If too low viscosity is used for surface dressing purposes, the result may be bleeding or loss of chipping under the traffic. With low viscosity binders, application temperatures can be kept lower and aggregates are more easily coated. The test results are very useful in classifying the grade of tars and cut-backs.

Heat Tests

The complete tests comprise flash and fire point test, loss on heat test, distillation test and water content test.

Flash and Fire Point Test Flash point is the lowest temperature at which the vapour of a substance can be ignited in air by a flame under specified conditions of test. The substance itself does not continue to burn. The sample is filled in an open metal cup suspended in air as shown in Fig. 18.5. It is heated at a uniform rate and an open flame is passed over its surface to determine the temperature at which the volatile vapours are given off and catch fire. The significance of the test is that in practice the bitumen should be heated 10°C below the flash point from safety point of view.

Fire point is the lowest temperature at which the material gets ignited and burns under specified conditions. The name of the test is Pensky-Marten test (Fig. 18.6).

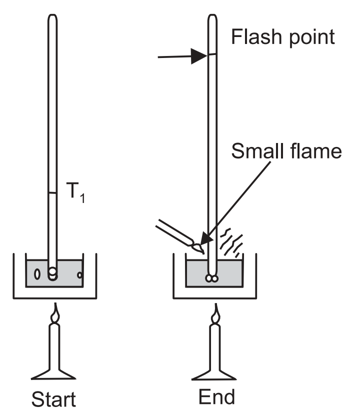

Fig. 18.5 Flash point test

Loss on Heat Test The significance of the test is that the bitumen should contain just sufficient oil to impart consistency necessary for processing and blending. Also the loss of weight in the test is an indication of the hardening that bitumen undergoes when heated.

A bituminous sample of 50 g is headted for 5 hours in a flat-bottom cylindrical container. It should not undergo more than 1 per cent loss in weight.

Distillation Test In this test the quantities of the various volatile oils added to bitumens fluxing or for cutting-back are determined. The residue left behind in the test indicates the actual bitumen quantity.

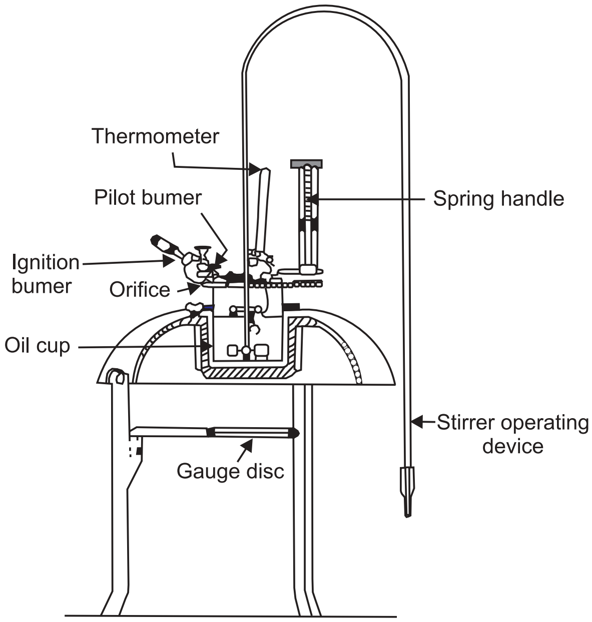

Fig. 18.6 Pensky-Marten test

Water Content Test Foaming occurs when water is in excess of the specified amount. In this test water-free petroleum distillate is added to the sample and heated. Then the distillate is condensed and the quantity of water collected at the bottom is expressed as percentage by weight of the sample. It should not exceed 1 per cent.

Solubility Test

This test indicates the purity of bituminous binders by finding the quantity of bitumen in binder. Insoluble impurities like free carbon, mineral salts, dusts, etc. are found by this test. The sample consists of 2 to 5 g of bitumen in 100 g of carbon-disulphide or carbon tetrachloride.

Sulphonation Index Test

This test is performed to find the presence of paraffin, naphthalene, benzene, etc. which produce greasy effect and fail to hold the aggregate. Moreover, binder does not set in the presence of these impurities.

The tar sample is treated with sulphuric acid and the volume of unsulphonated residue is expressed in millimeter per 100 g to tar. The number denotes the index value of the sample.

Ductility Test

All bituminous materials must have some specified ductility so that when placed in the pavement, they will distort rather than crack. The test consists of stretching the bitumen binder (in the form of a standard briquette shown in Fig. 18.7) at a standard temperature of 27°C and at a standard rate of 5 cm per minute till the thread breaks. The ductility is expressed as the distance stretched in centimeters.

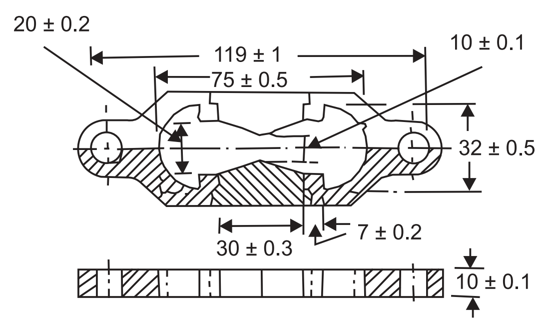

Fig. 18.7 Briquette Mould

Procedure: The binder is heated slowly to a pouring consistency between 75°C to 100°C above the approximate softening point. The mould is placed on a brass plate and coated with a mixture of equal parts of glycerin and dextrine. The fluid bitumen is poured into the mould more than level full and is allowed to cool. The whole assembly is placed for 30 minutes in a water bath maintained at 27°C. The moulds are taken out and the excess bitumen removed by means of a hot sharp knife. The assembly is placed again in bath and kept their for 85 to 95 minutes at 27°C. The sides of the mould are removed and the clips are hooked on to the ductility machine. The pointer is set to read zero. Load is applied and the reading on the scale recorded when the bitumen thread just breaks (Fig. 18.8).

The average distance (of two normal tests) in centimeters through which the pointer has travelled to produce rupture is reported. In a normal test the material between two clips pulls to a thread and rupture occurs where the cross section is minimum. The water cover, both below and above the specimen, must remain at least 10 mm throughout the test.

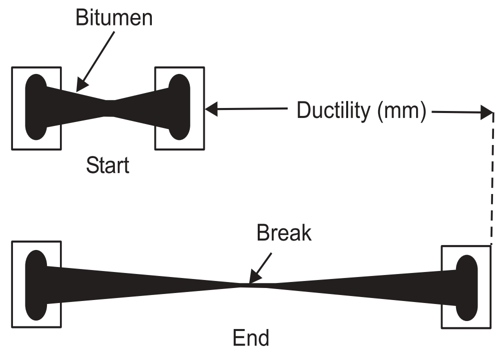

Fig. 18.8 Ductility Test Setup

Significance This test indicates the cohesive property of the bitumen and its ability to form a thin, continuous film around the aggregate. It is also an indication of the binding strength and ability to withstand shocks. In the flexible pavement construction bitumen binders should form thin ductile film around the aggregate. The binder material which does not possess sufficient ductility would crack resulting in damping effect.

The ductility values of bitumen vary from 5 to over 100 cm. Often minimum value of 50 cm is specified for bituminous pavement construction.

Specific Gravity Test

Specific gravity is defined as the ratio of the mass of a given volume of the substance to the mass of an equal volume of water at 27° ± 0.1°C. It can be determined by Pycnometer method or Balance method.

Procedure In the Pycnometer method the specific gravity bottle is cleaned, dried and weighed along with the stopper. It is then filled with fresh distilled water and kept in water container for half an hour at temperature 27° ± 0.1°C. The bottle is removed and cleaned from outside. The bottle containing distilled water is now weighed. The bitumen is heated to a pouring temperature and is poured in the empty bottle. The material is filled up to half and inclusion of air is prevented. To permit an escape of air bubbles, the sample bottle is allowed to stand for half an hour at a suitable temperature, then cooled to 27°C before weighing.

In the Balance method the test specimen is 12 mm cube prepared by pouring the liquefied sample in brass mould. The sample is weighed in air and is then weighed in distilled water, maintained at 27° ± 0.1°C, to the nearest 0.1mg.

The specific gravity of the bitumen material is calculated as follows

Pyncnometer Method

$$\text{Specific gravity} = \frac{(c - a)}{(b - a) - (d - c)}$$

where a = weight of specific gravity bottle
b = weight of the specific gravity bottle filled with distilled water
c = weight of the specific gravity bottle about half filled with material
d = weight of the specific gravity bottle about half filled with the material and the rest distilled water

Balance Method

$$\text{Specifice gravity} = \frac{a}{a - b}$$

where a = weight of the dry specimen
b = weight of the specimen immersed in distilled water

Significance Density of bitumen is a fundamental property frequently used in classifying the binders for use in paving jobs. In most applications, the bitumen is weighed, but finally in use with aggregate system, the bitumen content is converted on volume basis. Thus an accurate specific gravity value is required for conversion of weight to volume.

Adhesion Test

It is also known as *aggregate bitumen affinity* test. From the point of view of behaviour of aggregate towards bituminous binders, aggregate are classified into hydrophilic (which lose bituminous coating in the presence of water) and hydrophobic (which retain its bituminous coating). A number of tests have been developed to test the affinity of aggregate towards bituminous binder. The static immersion test is the simplest. The principle is immersing aggregates coated with binder in water, and estimating the degree of stripping, *i.e.*, the ratio of the uncovered area observed visually to the total area of aggregate expressed as a percentage.

Procedure 200 g of dry and clean aggregate passing 20 mm sieve are heated and retained on 12.5 mm sieve up to 150°C when the binder is bitumen and up to 100°C in case of tar. Then the binder, 5 per cent by weight, is heated up to 10°C more than the aggregate separately. The heated aggregate and binder are mixed thoroughly. The mixture is transferred to a 500 ml beaker and cooled at room temperature for about two hours. The coated aggregate are immersed in distilled water to cover the beaker and then kept in a water bath maintained at 40°C, taking care that level of water in bath is at least half the height of the beaker. The beaker is taken out from the water bath after 24 hours and cooled at room temperature. The percentage of stripping is estimated visually keeping the specimen still under water. The average of the three results (rounded of to nearest whole number) is reported as stripping value of the tested aggregate.

Significance Besides selecting road aggregates of suitable physical strength and exercising normal quality control, it is necessary to foresee the adhesion behaviour of aggregate with bitumen as otherwise road is likely to fail due to disintegration of road components under stresses of traffic. Prior knowledge of the adhesion behaviour of available road metal with bitumen helps the civil engineer to decide on the suitability of available road metal for bituminous construction. The stripping value for aggregate in bituminous constructions should not be more than 25 per cent.

18.9 APPLICATIONS OF BITUMINOUS MATERIALS

Bitumen and tar binders find application for preparing asphaltum concretes, for manufacturing roof waterproofing and steam proofing materials and items, roof-waterproofing pastes, and for making roof coverings and waterproofing and road construction mastics and emulsions.

Bitumen emulsions (bitumen 5%, emulsifier content 0.01 to 5%) are used for making water and steam-proof coatings, priming surfaces in preparation for waterproofing glueing piece and coil materials and making the surfaces of items hydrophobic. Bitumen pastes are prepared from bitumen, water and emulsifiers. The latter are non-orgamic finely dispersed mineral powder, containig active colloidal particles smaller than 0.005 mm, which are added to water to produce pastes. Common emulsifiers are lime, clay and ground tripoli. Bitumen paste is employed to protect water-and steam-proofing coatings, to prime surfaces before they are insulated, to fill roof joints and to prepare cold mastics, in which it plays the part of a binder.

Mastics are used for roofing and waterproofing. Bituminous wall and sheet materials for roofing and waterproofing are widely employed in building practice. These are generally of the following two types: ones prepared by impregnating special card board with petroleum bitumens or tar compounds and subsequently coating it with a compound of higher melting temperature and a granular material (gravel or sand); ones fabricated by calendering thermally and mechanically processed mixtures of binders and additives into sheets of prescribed thichkness

Impregnated roll materials are subclassified by the kind of binder into bitumen, tar, tar-bitumen, petroleum asphalt and bitumen-polymer varieties. By structure, impregnated roll materials are subdivided into coated and non-coated types. Coated impregnated cardborad roll materials include roofing felt, tar paper, tar-bitumen and petroleum asphalt materials.

Roofing felt is a roll material prepared by impregnating roof cardboard with soft bitumen, subsequently coating it on one or both sides with high-melting bitumen and finally facing it with finally-ground mineral powder, mica or coloured mineral granules. Roll roofing fibreglass cloth and felt are manufacrtured by combining fibreglass backing with bitumen, rubber-bitumen or bitumen-polymer films and coating them on one or both sides with a granular material. Fibreglass cloth and felt are laid on hot-or cold-process mastics and used in multi-layer flat roofs, and as a glued-on water-and steam-proofing material.

Asphalt reinforced mats are manufactured by coating impregnated fibreglass cloth on bothe sides with bitumen or waterproofing asphlat mastic. By the impregnating material and composition of the covering layer-asphalt reinforced mats are subdivided into common and high heat-resistant grades. Reinforced mats are manufactured 3.0–10.0 m long, up to 1 m wide and 4–6 mm thick. These are used for glued-on waterproofing jobs and for sealing expansion joints.

Some of the other applications of bitumen and asphalt are in the manufacture of piece waterproofing items such as waterproofing asphalt slabs, waterproofing stone and prefabricated concrete items.

Waterproofing asphalt slabs are manufactured by covering preimpregnated fibreglass or metal mesh by a hot-process waterproofing mastic or sand asphalt concrete mastic or by press moulding hot-process waterproofing asphalt mastic or sand asphalt concrete mixture. Slabs are either reinforced or non-reinforced. Non-reinforced slabs are made 80–100 cm long, 50–60 cm wide and 1–2 cm thick, where as reinforced slabs are 100–120 cm long, 75–120 cm wide and 2–4 cm thick. These are used for glued-on waterproofing work and filling of deformation joint. They may be employed during the cold season.

Waterproofing stones are manufactured by imprgnating artifical or natural porous materials (brick, concrete, tuff, opoka, chalk, limestone etc.) with bitumen or coal tar products to a depth of 10–15 mm. They are employed for making waterproof brickwork and lining with the use of cement and asphalt mortars.

Prefabricated waterproofing reinforced concrete items are manufactured by impregnating prefabricated reinforced concrete elements (piles, slabs, sections of pipes, tubings, etc.) with organic binders to a depth of 10–15 mm. These items are used for anticorrosion waterproofing of instalations exposed to simultaneous action of impact loads and mineralized water.

EXERCISES

1. (a) Define bitumen, asphalt and tar and how do they differ?
   (b) What are the various types of bitumen and what are their uses?
   (c) What is meant by flash point and fire point of bitumen?
2. Describe briefly the classification of tar and the specifications of bitumen as a building material.
3. (a) Describe Penskey-Marten's test of bitumen
   (b) What are the properties of bitumen and asphalt?
   (c) What do you understand by the following terms:
   Cut-back bitumen, Straight-run bitumen, Blown bitumen
4. (a) Describe briefly the classification of bitumen
   (b) How bitumen is tested for ductility?
   (c) Give the comparison of tar and asphalt in a tabular form
5. Describe the tests for
   (a) Penetration (b) Flash point and fire point
   (c) Ductility (d) Softening point
6. Write short notes on:
   (a) Rock asphalt (b) Cut-back asphalt
   (c) Bituminous felt (d) Coal tar
   (d) Tar-macadam (f) Coal tar pitch
7. Discuss the significance of following tests:
   (a) Stripping value test (b) Ductility tests
   (c) Ring and ball test (d) Viscosity test
8. Discuss the general properties of bituminous materials.

OBJECTIVE TYPE QUESTIONS

1. Defects such as blisters and cracks in bitumen may be caused by natural agencies such as
   1. water 2. air 3. light
   of the above, the correct agency(ies) is/are
   (a) 1 and 2 (b) 1 alone
   (c) 1 and 3 (d) 1, 2 and 3

papers are washable. Wall paper with sound absorbing properties are also available Metal-coated wall papers are prepared from wall papers coated with a primer of metallic powder and then patterns are printed or embossed in the surface.

8.9 **a) Bitumen:** Bitumen is the binding material, which is prevent in asphalt. This is also called far obtained from partial distillation of crude petroleum

1. It is chemically a hydro-carbon
2. Insoluble in water
3. Soluble in carbon disulphide
4. Black or brown in colour

The following are the forms of bitumen

1. Bitumen emulsion
2. Blow bitumen
3. cut-back bitumen
4. plastic bitumen
5. straight run bitumen

b) Tar: Tar is a dark black liquid with high viscosity. According to its source, tar is classified into following categories

1) Coal Tar
2) Mineral Tar
3) Wood Tar

1) Coal Tar: Usually obtained as a bye-product during the manufacture of coal gas. Coal tar is used for making macadam roads, preserving timber etc.

2) Mineral tar: This variety of tar is obtained by distilling bituminous shales. It contains less volatile matter

3) Wood tar: This type of tar is obtained by distillation of pines and similar other resinous trees. It contains creosote oil hence, it possesses strong preservative property.

Uses:

1. Rooting, damp proofing felts
2. Fill eracks in masonary structures, for stopping leakages etc

8.10 Thermocole:

It is used for thermal insulation and sound insulation.

* * *

17

Paints, Enamels and Varnishes

17.1 INTRODUCTION

Paint is a liquid surface coating. On drying it forms a thin film (60–150 μ) on the painted surface. Paints are classified as oil paints, water paints, cement paints, bituminous paints and special paints such as fire proof paints, luminous paints, chlorinated rubber paints (for protecting objects against acid fumes), etc.

The functions of the paints are: to protect the coated surface against possible stresses—mechanical or chemical; deterioration—physical or environmental; decorate the structure by giving smooth and colourful finish; check penetration of water through R.C.C; check the formation of bacteria and fungus, which are unhygienic and give ugly look to the walls; check the corrosion of the metal structures; check the decay of wood work and to varnish the surface to display it to better advantage.

17.2 COMPOSITION OF OIL PAINT

Base The base, usually a metallic oxide, is the principal constituent of the paint. It makes the paint film opaque and possesses binding properties which reduce the shrinkage cracks in the film on drying. Some of the examples of base are white lead, red lead, zinc white, aluminium powder, iron oxide, etc. Their detailed description is given in Table 17.1. Lead based paints are in general affected by atmosphere and are not recommended for final coats. Zinc white is weather resistant. For inferior works Lithophone (barium sulphate chemically combined with

Table 17.1 Description of Bases

S.No.	*Name*	*Description*
1.	White lead	This is a carbonate of lead and forms the base of lead paints. It is dense, permanent and water-proof. It is not suitable for delicate works as lead becomes discoloured when exposed to sulphur vapours. It is most suitable for wood surfaces; Since it does not afford protection against rusting, it is not suitable for iron surfaces.
2.	Red lead	This is an oxide of lead and forms the base of lead paints. It is most suitable for painting iron surfaces and for providing a priming coat to wood surfaces. It solidifies in a short time with linseed oil and hence, it is used as a drier also.
3.	Zinc white	This is an oxide of zinc and forms the base of all zinc paints. It is smooth, transparent and non-poisonous. It is not discoloured when exposed to sulphur vapours. It is less durable and is difficult to work.
4.	Oxide of iron	This is an oxide of iron and forms the base of all iron paints. The tint of paint varies from yellowish brown to black. It mixes easily with the vehicle. It is effective in preventing rusting of iron surfaces and is cheap and durable. It is generally used for priming coat of iron surfaces.
5.	Titanium white	This material possesses intense opacity. It is non-poisonous and provides a thin transparent film. It is used for receiving the coat of an enamel.
6.	Antimony white	This is almost similar to titanium white.
7.	Aluminium powder	This forms the bulk of aluminium paints. It keeps moisture content of wood surfaces practically the same and also prevents cracking and warping of wood. It is generally used for a priming coat to new wood work.
8.	Lithophone	This is a mixture of zinc sulphide and barytes. It is similar in appearance to oxide of zinc. It is cheap and can easily be applied on the surface. However, when exposed to daylight, it changes colour, hence used for interior works only.

zinc sulphide) is used for inside work. Aluminium powder is used as base for all aluminium paints.

Vehicle Also known as *binder*, vehicle is an oil to which the base is mixed. It holds the constituents of paint in suspension and helps spread it over the surface to be painted, imparts durability, toughness and water proofness to the paint film and resistance to weathering and gloss to the painted surface and forms the body of the paint. The examples are natural drying oils such as linseed oil, nut oil, poppy oil and tung oil (Table 17.2); animal, paint, artificial and synthetic glues in glue paints and air slaking lime and polymer in lime water colours and polymer paints respectively.

The natural drying oils (glycerides of the unsaturated fatty acids) harden in this layers to form strong and elastic surface coats. These are available in oxidized and polymerized varieties. The former being obtained by blowing air through linseed oil heated to about 160°C and by introducing a manganese-lead-cobalt drier the latter is obtained by polymerising linseed oil by heating it to about 275°C and introducing a manganese-lead-cobalt siccative. Linseed oil is the most widely used vehicle. It contains acid which reacts readily with oxygen and hardens by forming a thin film known as *linoxyn*. A priming coat of pure linseed oil induces corrosion which is greatly retarded by the presence of pigments. For this reason priming coat should contain little oil. Raw linseed oil has slow drying rate as such pale boiled linseed oil having better drying properties is used. The best results are obtained by using double boiled linseed oil.

Table 17.2 Description of Vehicles

S.No.	*Name*	*Description*
1.	Linseed oil	This is most common vehicle extracted from flax seeds. Linseed oil prepared from fine full-grown ripe seeds is clear, transparent, pale, sweet to the taste and practically odourless. It is used in the following grades:
	(a) Raw linseed oil	Raw linseed oil is thin and pale. It requires more time for drying and is used for interior works of delicate nature.
	(b) Boiled linseed oil	This oil is thicker and dark coloured than that of the raw oil. It dries quickly and is prepared by adding some quantity of drier such as litharge or red lead to the raw oil. It is used for exterior surfaces only.
	(c) Pale boiled linseed oil	This is similar to boiled linseed oil except that it does not posses a dark colour. It is more suitable for painting plastered surfaces.
	(d) Double boiled linseed Oil	This oil dries very quickly and is suitable for external works. It, however, requires a thinning agent like turpentine.
	(e) Stand oil	Formerly this oil was prepared by exposing raw linseed oil to sun till it thickened like honey. However, at present, heat treatment is used for this purpose. This oil dries slowly and provides a durable, clear and shining finish.
2.	Tung oil	This oil is far superior to linseed oil and is used for preparing paints of superior quality.
3.	Poppy oil	This oil is prepared from poppy seeds. It dries slowly and its colours are long lasting. It is used for making paints of delicate colours.
4.	Nut oil	This oil is extracted from ordinary walnuts. It is nearly colourless and dries rapidly. It does not provide a durable finish and is used for ordinary work.

Pigments are used to hide the surface imperfections and to impart the desired colour. They protect the paint film by reflecting the destructive ultra violet light, which acts as a catalytic agent for the destructive oxidation of the film. They also improve the impermeability of the paint film and enhance its resistance to weathering, affect the flow characteristics making it possible to paint vertical and uneven surfaces smoothly. Pigments are finely ground mineral, organic substances or metal powders; their size in organic coatings ranges from 0.1 to 5.0 microns in diameter. Their general properties are covering power, colouring capacity, fineness, fire resistance, chemical stability and weather resistance. The fine particles of the pigments have a reinforcing effect on the paint film.

The common pigments are classified as natural and artificial. The former used for preparing limestone and glue paints, putties and coloured building mortars, include ground natural white chalk, mastics, grey graphite, dry yellow ochre (a clay containing over15 per cent of iron oxide), etc. Artificial mineral pigments, obtained by chemical processing of raw mineral materials, include titanium dioxide, zinc white, lead white ($2\ PbCO_3.Pb\ (OH)_2$), lithophone ($BaSO_4 + ZnS$), chrome oxide, red lead, gas black soot, etc. metal powders such as aluminium powder, metallic powders, gold dust, etc. synthetic substances of organic origin, possessing high dyeing capacity. Some of the examples of pigments used to produce the desired colours are lamp black and ivory black (Black), Prussian blue, indigo (Blue), chrome yellow, yellow orchre (yellow), burnt umber, burnt siena (Brown), vermilion, red lead (Red) and copper sulphate (Green).

Solvents are the oils used to thin the paints, increase the spread, and are also known as *thinners*. They make the paint of workable consistency and evaporate during drying of the film. The common thinning agents used are petroleum, spirit, naptha and turpentine oil—a mixture of the various terpens, obtained from the steam distillation of the resinous exudations of the pine tree, leaving resin as a by-product. Turpentine is used extensively because of high solvent power, excellent flattening properties and ideal rate of evaporation.

Driers also known as plasticizers, are chemicals added to paint for specific purposes, *e.g.*, as catalyst (accelerate the drying of the vehicle) for the oxidation, Polymerisation and condensation of the vehicle in paint. The quantity of drier is limited to 8 per cent, excess of it affects the elasticity of paint leading to flaking failure. Some of the examples of driers are letharge (oxidized lead, PbO), lead acetate, red lead (Pb_3O_4), manganese dioxide and cobalt, zinc and lead chromate. Red lead is the best for primary coat over steel and metal work; it produces an extremely hard and tough film, almost impervious to air and moisture, adheres firmly to the metal and is extremely effective in protecting steel from corrosion. The cost of zinc and lead chromates is high.

Adultrants bring down the overall cost, reduce the weight and increase the durability. Adultrants also help to reduce cracking of dry paint and sometimes help to keep the pigment in suspension. Barium sulphate, calcium carbonate, magnesium silicate and silica are but a few examples. The best adultrant is barium sulphate. Silica is used only in the undercoats so as to take the advantage of its roughness in development of bond with the next coat.

17.3 CHARACTERISTICS OF AN IDEAL PAINT

The requirements are uniform spread as a thin film, high coverage, good workability and durability, sufficient elasticity to remain unaffected by expansion or contraction of the surface to be painted or by weathering action of atmosphere. The paints should also be: impervious to air and water, cheap and economical to form a hard surface.

17.4 PREPARATION OF PAINT

The base is ground in a vehicle to the consistency of paste in a stone pestle known as *muller*. Linseed oil, is intermittently added to the paste in small quantities and the mixture is stirred with a wooden puddle. In case of coloured paints, the pigment is mixed with linseed oil separately and the paste is formed as explained above. Driers are also ground separately in linseed oil. The three pastes so prepared are mixed and a little linseed oil is added further to soften the paste. The mixture is continuously stirred till a consistency of cream is obtained. The mixture is thereafter strained through fine canvas or a sieve. The paint is now ready for use. The paint so prepared can be used by adding oil or a thinner to make it of workable consistency before application.

For commercial manufacturing of paints a four-storey building is used to have gravitational flow of materials. Pigments, oil, thinner, plasticizer, drier, etc. are stored on the fourth floor and are fed by means of chutes in proper proportions, to the grinding mill placed on the third floor and are ground. The thoroughly ground materials are then sent to storage tanks on the second floor. The charge in the tanks is kept in motion by agitation mechanism so that settling of materials does not take place. An additional quantity of vehicle is added here to get the desired composition. The batch is then tested for quality control. The paint material is then strained and sent to first floor, where it is packed in containers. Finally the packed material in containers is sent to the ground floor. A flow diagram of paint manufacture is shown in Fig. 17.1.

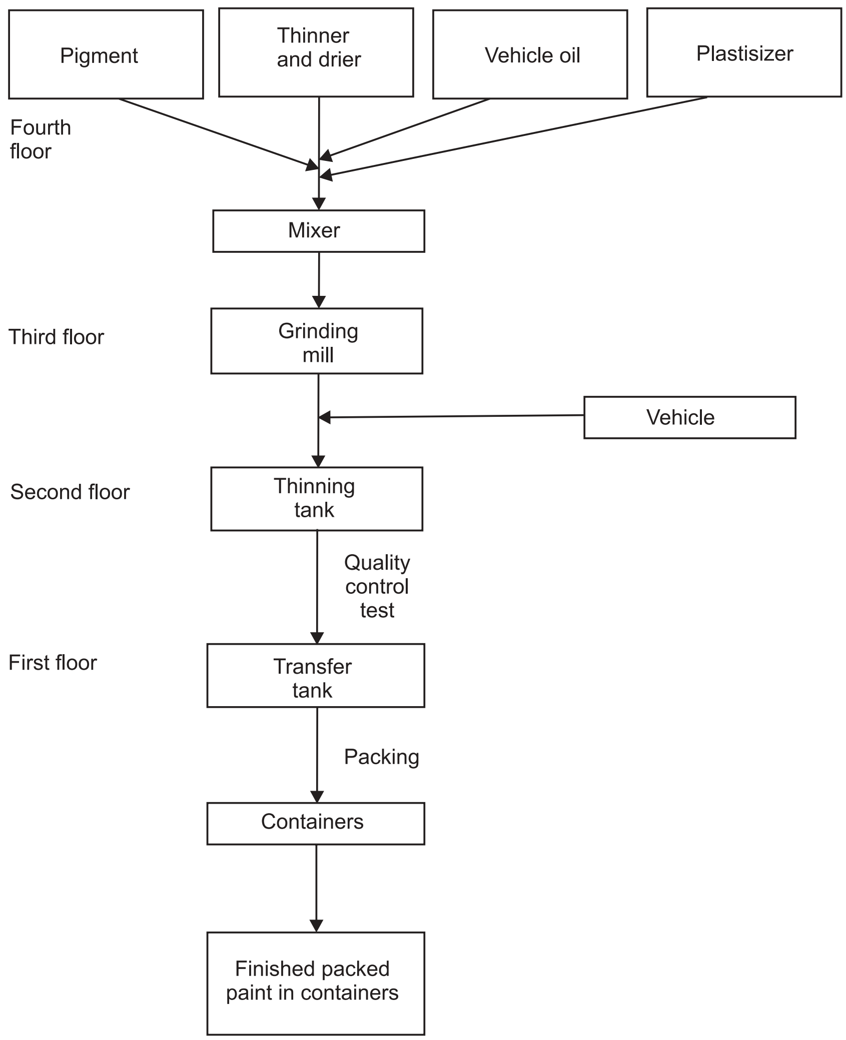

Fig. 17.1 Flow Diagram of Paint Manufacture

The factors affecting the quality of paint so prepared are quality of ingredients, grinding, intimate mixing and proportioning, straining, packing, etc. Ready mixed paints are also available in the market with different trade names, *e.g.*, Asian, Ducco, Shalimar, Berger Nerolac, etc.

17.5 COVERING POWER OF PAINTS

The covering power is the capacity, of a given quantity of the paint of the suitable consistency for application, to cover the extent of area.

The covering power, also known as *spreading capacity* of paints and varnish depends upon the type of paint and its constituents, type of surface to be painted, and number of coats to be applied. The area covered by different paints is given in Table 17.3.

Table 17.3 Covering Capacities of Paints

S.No.	*Type of paint or varnish*	*Type of surface*	*Area covered in sq.m/litre*
1.	Lead priming coat	Wood work	10
		Metal work	11
2.	Under coat	Flat surface	11
3.	Gloss paint	Flat surface	11
4.	Enamel	Flat surface	11
5.	Varnish (first coat)	Flat surface	12
6.	Varnish (second coat)	Flat surface	15

17.6 PIGMENT VOLUME CONCENTRATION (P.V.C.)

It is the concentration by volume of the pigments expressed as a percentage of the total volume of non-volatile constituents of the paint.

Volume of pigment in paint

$$\text{P.V.C.} = \frac{\text{Volume of pigment in paint}}{\text{Total volume of nonvolatile constituents of the paint}}$$

$$= \frac{\text{Volume of pigment in paint}}{\text{Volume of (pigment + nonvolatile vehicle constituents) in paint}}$$

The PVC value is essential in determining the amount of a particular pigment that can be added to the polymer of the coating. The pigment has to have sufficient wetting to create a protective coating. Wetting means there must be sufficient polymer or binder, to completely wet or surround all the pigment particles. Also, there must be enough polymer to completely fill the voids between the pigment particles. The point at which there is just sufficient polymer to wet the pigment particles is known as critical pigment volume concentration (CPVC). Below the CPVC there is sufficient polymer for pigment wetting and above the CPVC it is not. At CPVC many physical and optical properties of paint change abruptly.

Importance The pigment volume concentration largely controls such factors as gloss, washability, adhesion, undertone, hiding power, permeability and durability. With increase of PVC the gloss reduces until paint becomes flat; blistering also reduces. Above CPVC, permeability increases since above CPVC there are voids in the coating filled by air and the coating becomes discontinuous. If there is not enough polymer to wet the pigment then the pigment becomes a defect and the properties of paint decrease. With a decrease in the relative quantity of binder, the film formed looses cohesion and durability and the washability of paint film decreases. Some of the properties that can be evaluated above and below the CPVC are blistering, gloss, rusting, permeability, enamel hold out, scrub resistance, tensile strength, and contrast ratio. A range of PVC for different types of paints is given in Table 17.4.

Extenders, when added to a paint, amounts to increase in P.V.C. and thus decrease the gloss, washability, durability, and adhesion. So, if a pigment is costly and its covering power is high, a portion of the pigment may be economically replaced by extenders without sacrificing efficiency in covering power of pigment. Opacity of a white paint is created by the difference in the refractive indices of the pigment and vehicle. It is also influenced by the size of the dispersed pigment particles and by P.V.C.

Table 17.4 Different finisher of paints and P.V.C.

S.No.	*Type of paint*	*P.V.C.*
1.	Flat	50–75
2.	Semi-gloss	35–45
3.	Gloss	25–35

17.7 PAINTING PLASTERED SURFACES

Painting a New Surface

The operations are as follows:

Surface Preparation Paint cannot take care of construction defects. Before applying the paint it is ensured that the surface is free from dust, dirt, loose matter, grease etc. and is rubbed with an emery paper, to provide a mechanical key between surface and paint for satisfactory adhesion.

Sequence of Painting The primer (first coat) is applied with brush or spray on the prepared surface. It should be thinned with water or thinner in the recommended manner and proportion before application. After drying it is rubbed with emery paper.

Dents and cracks, if any, are filled with putty using a knife applicator. Putty should not be applied thick. If the required thickness is large, it should be applied in two coats. After the putty has dried, the whole surface is rubbed down well in order to smoothen the putty and provide a mechanical key to the finished coats.

Two or three finish coats are applied. Each coat is allowed to dry before the application of next coat.

Painting Old Surfaces

The procedure depends on the state of the existing coating. If any of the defects discussed below is very much pronounced it is completely removed and the surface is painted as a new surface.

Chalking Clean the surface, rub with an emery paper so that the chalk is removed. Apply one or two finish coats.

Efflorescence, Blistering, Cracking and Flaking Scrap off the old paint from affected areas. Touch up with primer and apply one or two finish coats on effected areas. Rub the entire surface and apply the finish coats.

Glossy surface Remove all gloss by rubbing with emery paper and then apply the finish coats.

Fungus growth Remove the fungus. Apply fungicidal solution liberally and observe for further growth. If no further growth of fungus is observed apply the desired paint.

17.8 PAINTING WOOD SURFACES

Painting of wood work should be done with great care. Normally 3–4 coats are sufficient for wood work.

New Wood Work

Surface Preparation The wood should be well seasoned, dried, cleaned and the surface made smooth with an emery paper. Nails, if any, should be driven down the surface by at least 3 mm.

Knotting Knots in the wood create lot of problems. These excrete resin which causes defects such as cracking, peeling and brown discolouration. Knotting is done so that resin cannot exude from the knots. Any of the following methods may be used suitably.

Ordinary Knotting This is also known as *size knotting*. The knot is treated with a coat of hot red lead ground with a strong glue size in water. Then a coat of red lead ground in boiled linseed oil is applied.

Lime Knotting The knot is covered with hot lime for 24 hours after which it is scrapped off. Thereafter, the process described in ordinary knotting is followed.

Patent Knotting Two coats of varnish or shelac are applied.

Priming Coat The main function of priming coat or primer is to form the base for subsequent ones. After knotting priming coat is applied over the entire surface to fill all the pores. A second priming coat is applied after first has dried. In general the ingredients are same as those of the subsequent coats but with a difference in proportion. A typical composition of primer may be

Ingredient	*Primer*	
	Exterior work	*Interior work*
Red lead	0.03 kg	0.12 kg
White lead	4.5 kg	3.6 kg
Boiled linseed oil		0.57 litres
Raw linseed oil	2.27litres	0.57 litres
Litharge	0.06 kg	0.45 kg

Stopping After the priming coat putty is applied to fill the pores of the surface. Then it is rubbed smooth. Colouring pigment is also added to it to match the shade of the finished coat. On drying, the selected paint is applied with brushes to bring smoothness and uniformity in colour. After painting the surface in one direction, the brush is worked in the perpendicular direction to eliminate brush marks. This is known as *crossing*. All the successive coats are applied after drying and slight rubbing of previous coats for proper bond.

Old Wood Work

The old paint is removed with a sharp glass piece, sand paper, paint remover or with a blow lamp. Any smoky or greasy substance should be washed with lime and subsequently rubbed with pumice stone. The surface is then washed with soap and water and dried completely. Then two coats of paints are applied in a way similar to that described in painting new surfaces.

Paints for Wood Work

A mixed pigment paint provides better protection; white lead combined with zinc oxide and a moderate amount of filler such as barytes or silica gives good results. Tinted paints have proved to be satisfactory for maintaining colour and durability. Generally enamel paints are used to give high gloss surface. When the wood is of superior quality and if the grains are to be highlighted the only choice is the varnish forming a transparent or translucent film.

17.9 PAINTING METAL SURFACES

New Iron Work

The surface should be free from scales, rust and grease. Scales and rust are cleaned by hard wire brush. Grease is removed by using petroleum or by hot alkaline solution of Na_2CO_3 or NaOH, benzene, and lime water. A priming coat of red lead with barytes and raw linseed oil is then applied over the prepared surface. After drying of the priming coat, one or more undercoats with desired paint are applied. The second coat is given only after the first coat has dried. The finishing coat is applied carefully to produce a smooth fine surface.

Old Iron Work

The surface is prepared by scraping properly all the scales and rust with emery paper. The greasy substances are removed with lime water. The old paint may be burned with a blow lamp or by suitable solvents. After this the surface is brushed with hot linseed oil and painted as for new iron work.

Paints for Structural Steel Work

The major problem to overcome in painting iron and steel is corrosion due to electrolysis caused by the presence of air and moisture. Red lead is considered to be the best priming coat; it produces a tough elastic film, impervious to air and moisture. Pure linseed oil priming coat is detrimental in that it stimulates corrosion. The linseed oil film is rendered more impervious by the use of spar varnish. Graphite paint used for black colour, is very durable and is not affected by sulphur films, ammonia or chlorine gases. Silica-graphite paints are best; they do not crack and blister in course of time. Aluminium paint is also gaining popularity because of its shining and contrast properties and heat and chemical resistance. Bituminous paints may be very well adopted to paint inside of pipes, iron under waters, piles, ships and boats; they are unsatisfactory when exposed to sunlight. Lead or zinc paint should never be applied directly over the iron surface as it encourages galvanic action destroying the paint.

17.10 DEFECTS

A painted building with full colour effects gives complete satisfaction. But the appearance of defects, becomes a ready source of complaint. Unfortunately painting defects are by no means uncommon. They may arise from a variety of causes but the principal reasons behind them are incorrect choice of paint in relation to backing materials, application of paint to a damp surface or one to which moisture may have access and; poor workmanship.

Effects of Background

The factors affecting durability are dampness, cleanliness, movements, chemical reactions, etc.

Dampness The traditional construction in brick, cement, etc. involve the use of wet procedures. If paint is applied on an insufficiently dry background the moisture is trapped and in the process of subsequent drying the adhesion of the paint breaks down. Emulsion paints are somewhat better in this respect.

Cleanliness Paint will not adhere to the surface if it is not cleaned of dirt or dust.

Movements The painting processes can be delayed for proper results for movements caused by shrinkage and special paints should be used for thermal movements.

Chemical Reactions between backing material and paint film may push the paint off the backing material and lead to softening or discolourise the paint. This effect generally occurs only if moisture is present and is noticeable in oil paints over materials containing cement or lime. The breakdown of bond is because of the crystallization of salts below the paint film and the discolouration is usually due to action of free lime on the pigments.

Effect of Weather

The paint film is subjected to chemical attack of atmosphere, sunlight and heat, all deteriorating it. Special chemical resistant paints should be applied in industrial areas. Alkali resistant paints weather well in coastal areas. Blue and green colours tend to fade when exposed to bright light. In addition the fierce heat of sun may breakdown the paint film because of the disintegration of the material itself and also because of the thermal movement. The most common defects noticed after painting are as as follow:

Blistering and Peeling are swelling of the paint film and can be defined as localized loss of adhesion between one or more coatings or between primer and parent surface. When swelling is because of oil or grease on the surface it is known as *blistering* and in case of moisture it is called *peeling*. It occurs in nonporous coatings such as oil based paints and enamels. A special heat-resisting type of paint should be used for hot surfaces such as radiators.

Causes It is brought about by moist air, oily or greasy surface, or imprisoned gases between the painted surface and the paint film, which expand under the influence of heat.

Cure Emulsion paints provide a porous coating and allow the moisture to pass through.

Checking is a mild form of cracking. If hair cracks produced enclose small area it is known as *crazing*. In case the enclosed area is large the defects is called *crocodiling*.

Causes It is caused when the paint film lacks in tensile strength and occurs when paint is applied during very cold weather or because of insufficient drying of undercoat.

Cure When cracks are very small and do not enlarge with time, the top coating is flattened with emery paper and a fresh coat of paint is applied.

Cracking The cracks extend throughout the entire paint system extending right down to the original surface.

Causes

1. Cracks in the plaster or masonry do not let the paint to remain intact.
2. Paint applied on glossy surface.
3. Premature application of top coat before the previous coat has completely dried.
4. Painting improperly seasoned wood.

Cure The causes of cracking should be attended to.

Flaking is detachment of paint film from the surface.

Cause The moisture penetrates through the cracks on the coatings and the bond between surface and paint film is lost.

Cure

1. Use of plastic emulsion paints.
2. Surface should be rubbed with emery paper before applying a fresh coat.
3. All dirt or dust on surface should be removed prior to painting.

Chalking Paint film becomes powder due to insufficient oil in primer.

Alligatoring One layer of paint films sliding over the other one, when a hard paint is applied over a soft one or vice versa.

Wrinkling or crawling appears when the paint film is quite thick or the oil in the paint is more than required. The lower portion of the paint does not dry due to greater thickness of the paint film which shrinks due to drying in course of time.

Running and Sagging Paints applied over smooth and glossy surface do not stick and flow back or towards the unpainted area. This is known as *running* and *sagging*. The surface to-be painted should, therefore, be rubbed with an emery paper before painting.

Mildew Mildew thrives in warm, moist and dark places. Zinc oxide and phenol mercury oleate are very useful to check its growth.

Bloom is identified as dull patches on the finished, polished or painted surface due to defect in the quality of paint or poor ventilation.

Flashing is characterized by the appearance of certain glossy patches on the painted surface. The reasons attributed to this defect are weathering actions, use of cheap paint, and poor workmanship.

Grinning is due to the imperfect opacity of the paint film even after the final coat. The background and its defects can be clearly visible in such a case.

17.11 ENAMEL

Enamels consists of bases like zinc oxide, etc. ground in varnish. If desired colouring pigments may be added. They dry quickly and furnish a hard glossy surface. Enamel can be used for internal as well as external works and are generally recommended for application on wood work. Theses are acid resistant, not affected by alkalis, gases and, are waterproof.

Process of application The surface of the wood is rubbed with a sand paper and cleaned. A primer coat consisting of titanium white in pale linseed oil is followed by two to three coats of enamel paint.

17.12 DISTEMPER

Distemper is made with base as white chalk and thinner as water. Some colouring pigments and glue are added. They are available in powder and paste forms and are substantially cheaper than paints. They are most suitable for plastered surfaces as well as white washed surfaces of interior walls. Oil bound washable distemper, washable oil free distemper, and nonwashable distemper or emulsion paints are some of the types of distemper. In the oil bound distemper, the drying oil is rendered mixable with water. While using they are thinned by adding water. On drying, the oil content in distemper hardens and yields a comparatively durable coating.

Characteristics

1. The coatings are thick and more brittle compared to paints.
2. They are workable, easy in application but less durable.
3. The film being porous can be applied on even newly plastered surface.

Distempering

Distempers are applied in the following manner:

Preparation of Surface The surface is thoroughly rubbed and cleaned. In case of a new plastered surface, the surface is kept exposed, to weather, for drying before the application of distemper. If an existing (old) distempered surface is to be redone, surface is cleaned with profuse watering. The efflorescence and patches, if any, should be wiped out by a clean cloth. Cracks, etc. if any should be filled with putty.

Priming Coat A priming coat as recommended by the manufacturer is applied on the prepared surface.

Final Coat Two or three coats of distemper are applied. Each coat should be applied only after the previous coat has dried.

17.13 WATER WASH AND COLOUR WASH

Fresh lime slaked with water is mixed thoroughly with water in a tub and then screened through a fine, clean cloth. Thereafter glue, dissolved in water, is added to it. The surface is cleaned and the white wash is applied with jute brushes. A white wash when mixed with colouring pigment such as yellow earth is called *colour wash*.

Characteristics

1. Lime is toxic for germs, for which white wash is good from hygiene considerations.
2. A bright surface is provided at a very low cost.

Uses They are generally recommended for low and medium class houses; ceilings are white washed and walls are generally colour washed.

17.14 VARNISH

Varnish is a nearly homogeneous solution of resin in oil, alcohol or turpentine. The type of solvent depends upon the type of resin used and is given in Table 17.5. The oil dries with time and the other solvents evaporate leaving behind a solid transparent resin film over the surface. For rapid drying, driers such as letharage, lead accetate, etc. are used.

Table 17.5 Materials for making Varnishes

S. No.	*Resin*	*Solvent*
1.	Amber, copal, gum anime	Boiled linseed oil
2.	Common resin, gum dammer, mastic	Turpentine
3.	Lac, shellac, sandarch	Methylated spirit
4.	Raw copal, cheaper types of resins	Wood naptha

Note: **The commonly used resins are copal, lac or shellac and rosin. Copal is a hard substance and is available from the earth at places where pine trees existed in past. It is available in variety of forms. Lac or shellac is obtained by exudation of some types of insects in India. Rosin is obtained from pine trees.**

Varnishes provide a protected coating and gloss to the surface and intensify the wood grains.

The objects of varnishing a surface are to:

1. Brighten the appearance of the grain in wood.
2. Render brilliancy to the painted surface.
3. Protect painted surface from atmospheric actions.

Characteristics of an ideal varnish:

1. It should render the surface glossy.
2. It should dry rapidly and present a finished surface which is uniform in nature and pleasing in appearance.
3. The colour of varnish should not fade away when the surface is exposed to atmospheric actions.
4. The protecting film developed by varnish should be tough, hard and durable.
5. It should not shrink or show cracks after drying.

Varnishing

Varnish is applied as under:

Preparation of Surface The wood work is made smooth by rubbing it with sand paper and the surface is cleaned.

Knotting is the process of covering the knots in the wood work, using any of the following methods.

Size knotting A coat of red lead ground in water mixed with glue size is applied. After it dries another coat of red lead ground in oil and thinned by boiled turpentine oil is applied.

Patent knotting Two coats of varnish prepared by dissolving shellac in methylated sprit or wine, are used.

Stopping The surface of the wood work is then rubbed again and cleaned. Before rubbing, the surface is applied with size of hot, weak glue.

Varnish coat Varnish is then applied in two coats. The second coat is applied after the first has dried.

Types of Varnishes

Varnishes are classified as oil, spar, flat, spirit and asphalt varnishes.

Oil Varnish uses linseed oil and takes about 24 hours to dry. Hard resins such as amber and copal are dissolved in linseed oil. If the varnish is found unworkable, a small amount of turpentine oil may be added. It is suitable both for interior and external works.

Spar Varnish derives its name from its use on spars and other parts of ships. It gives sticky effect in warm weather and is not used indoors.

Flat Varnish materials such as wax, metallic soap or finally divided silica when added to varnish produce a dull appearance on drying and are known as flat varnish.

Spirit Varnish is resins of soft variety such as lac or shellac dissolved in spirit. The examples are French polish, lacquer and shellac varnish. It dries very quickly. These are not durable and are easily affected by weathering action.

Asphalt Varnish is made by dissolving melted hard asphalt in linseed oil with a thinner such as turpentine or petroleum spirit. It is used over shop fabricated steel works.

Water Varnish is shellac dissolved in hot water to which enough quantity of either ammonia, borax, soda or potash is added. These are used for varnishing maps and pictures.

17.15 FRENCH POLISH

It is a type of spirit varnish, prepared by dissolving resin in methylated spirit at room temperature for use on hardwood substances to hide the grain defects. The surface is made smooth by rubbing. A filler mixed with desired colour is prepared to the consistency of a paste applied to the cracks, pores, etc. The surface is rubbed after drying and dusted off. Two coats of polish are then applied. The filler material is prepared by mixing 2 kg of whiting in 1.5 litres of methylated spirit or by mixing Plaster of Paris, red ochre and linseed oil.

17.16 WAX POLISH

It consists of bees wax dissolved in turpentine and is used for highlighting the grain over wooden surfaces. The polish is rubbed over the surface with rag until a bright appearance is obtained. Generally two coats are applied. It may also be used over marble with 1 part of was dissolved in 4 parts of hot turpentine or by mixing wax, linseed oil, turpentine oil and varnish in the ratio 2 : 1.5 : 1 : 05, by weight.

17.17 MISCELLANEOUS PAINTS

Aluminium Paints consist of aluminium powder (as base) held in suspension by varnish. They are highly heat reflective and resistant to acid fumes. Aluminium paints are used for painting metal roofs, silos, machinery, poles, towers and storage tanks. It provide a very attractive appearance to the surface and the painted surface is visible even in darkness. Aluminium paints have high dispersive property—over 200m^2/litre.

Anticorrosive Paints Linseed oil is used as vehicle with dry red lead, sublimed blue lead, zinc oxide and iron oxide and zinc chromate as pigments. They are used for preservation of structural steel work against acid fumes and adverse weather conditions. The anticorrosive paints impede or obstruct the corrosion by reducing the direct access of air and water to the metal. These paints should have quick drying and hardening properties.

Asbestos Paints The main constituent is fibrous asbestos. These are used for stopping leakage in metal roofs, painting of spouts, gutters, etc. and sometimes on the outer surface of basement wall to prevent dampness. Absestos paint is also called *fire proof paint*.

Bitumenous Paints are made of asphalt bitumen dissolved in mineral spirit or nephtha. They are black in colour, but suitable colouring pigments may be added for desired colour. They are alkali resistant and are used to paint exterior brick work, concrete and plastered surfaces and to reduce the moisture permeability. Bitumenous paints are also used over iron works under water. When exposed to sunlight they deteriorate very fast.

Bronze Paints Generally a pigment such as aluminium or copper powder is used with a vehicle like nitrocellulose lacquer. They are highly reflective and is applied over radiators.

Cellulose Paints are made by celluloid sheets, amyl-acetate substitute or nitrocotton dissolved in petroleum. Also known as *lacquers*, they are colloidal dispersion of cellulose derivative, resin and plasticisers in solvent and dilutents. Castor oil is also added to improve adhesion, toughness and smoothness of the paint film. A cellulose paint hardens by evaporation of the thinning agent, whereas an ordinary paint hardness by oxidation. Being very costly their use is restricted to painting cars, ships and airplanes. The trade names are spray paint, Ducco etc. Cellulose paints are not affected by adverse weather conditions.

Casein Paints Casein, a protein substance extracted from milk, curd, is mixed with a base like whiting and lithophone. They are available in powder or paste form. They are used over new plaster surface, walls and ceilings. A drying varnish is added when these are used over exterior surfaces of buildings. Casein paints can be tinted in any colour.

Cement Based Paints (IS 5410) White or coloured Portland cement with (OPC minimum 65 per cent) forms the base. They are thinned with water during application. Proper curing is necessary for strength and durability. Cement paints are durable, strong and display better water-proofing qualities and are used on exterior surfaces of buildings. Mixed with boiled linseed oil they are also used over corrugated iron sheets. To get good results, an aqueous solution of sodium silicate and zinc sulphate is applied as primary coat on the surface to be painted.

Rubber Based Paints Rubber treated with chlorine gas is dissolved in solvent and desired pigment is added. These paints are resistant to acid, alkalis and dampness. Rubber based paints are used over concrete and cement plastered surfaces.

Plastic Emulsion Paints (IS: 5411 parts I & II) are essentially a dispersion of rubber-like resin polyesterene, and polyvinyl acetate in water and are prepared by grinding suitable pigments (titanium dioxide) in an emulsion of water (vehicle) and film forming drier, *e.g.*, Co and Mn. Sometimes oil is used as vehicle. In the former case the emulsifying agents are sodium or ammonium soaps whereas in the latter case metallic soaps of magnesium or zinc are used. Stabilizers such as proteins (dextrin, starch, casein) are added to impart chemical resistance to the emulsion. Moreover, protein provides body thereby improving brushing. Antifoaming agents such as pine oil and kerosene are added to check any excessive foam formation by the agitation of emulsion paint during its manufacture. These paints should become surface dry within 15 minutes and hard dry within 4 hours and are alkali resistant. Plastic emulsion paints are useful in porous and/ or wet surface. The emulsion coats are less odorous, non-inflammable, quick drying and easier to apply than other paints.