HP BITUMEN HANDBOOK

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"Our duty makes us do things well,

but your belief in HP makes us do them beautifully"

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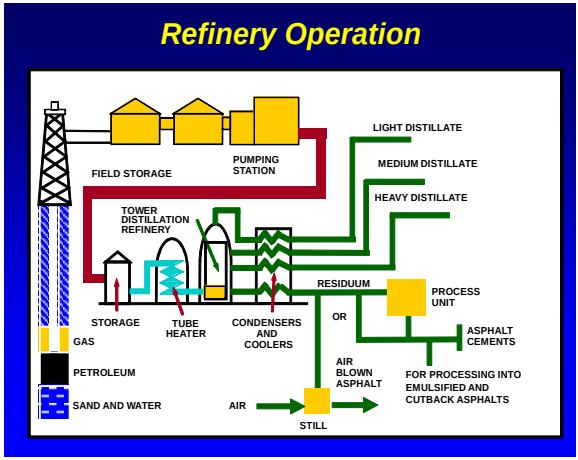
1. INTRODUCTION



Bitumen is manufactured from crude oil. Bitumen is obtained as the last residue in fractional distillation of crude petroleum. Crude petroleum is a mixture of hydrocarbons of different molecular weights. In the petroleum refineries the individual components like LPG, naphtha, Kerosene, Diesel etc. are separated through the process of fractional distillation. The heaviest material obtained from the fractional distillation process is further treated and blended to make different grades of paving grade bitumen.

The actual bitumen output can be controlled not only by selecting the appropriate crude but also by adopting varying processes in the refinery. The choice of process would depend on the availability of suitable crude, demand of the end products and total commercial viability of the complete refining process.

Definition: Bitumen is defined as “A viscous liquid, or a solid, consisting essentially of hydrocarbons and their derivatives, which is soluble in tri-chloro-ethyelene and is substantially nonvolatile and softens gradually when heated. It is black or brown in colour & posseses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum, and is also found as a natural deposit or as a component of naturally occurring asphalt, in which it is associated with mineral matte.

2. TYPES OF BUTUMEN

Bitumen or bituminous binder available in India is mainly of the following types:

2.1 Penetration Grade

2.1.1Bitumen 80/100: The characteristics of this grade confirm to that of S 90 grade of IS-73-1992. This is the softest of all grades available in India. This is suitable for low volume roads and is still widely used in the country.

2.1.2 Bitumen 60/70: This grade is harder than 80/100 and can withstand higher traffic loads. The characteristics of this grade confirm to that of S 65 grade of IS-73-1992. It is presently used mainly in construction of National Highways & State Highways.

2.1.3 Bitumen 30/40: This is the hardest of all the grades and can withstand very heavy traffic loads. The characteristics of this grade confirm to that of S 35 grade of IS-73-1992. Bitumen 30/40 is used in specialized applications like airport runways and also in very heavy traffic volume roads in coastal cities in the country.

2.2 Industrial grade bitumen.

Industrial grade bitumen is also known as **blown** bitumen. This is obtained by blowing air into hot bitumen at high temperatures (normally beyond 180 ^{0}C). Blowing hot air into bitumen at high temperatures results in structural changes in bitumen. Esters are formed in this process and these esters link up two different molecules and higher molecular weight material increases drastically. **In the process the asphaltene content is increased which in turn results in higher softening points and very low penetration number.** Industrial grade bitumen is used in industrial applications and in water proofing, tarfelting etc.

2.3 Cutback

Cutback is a free flowing liquid at normal temperatures and is obtained by **fluxing bitumen with suitable solvents.** The **viscosity of bitumen is reduced** substantially by adding kerosene or any other solvent. **Cutback has been used in tack coat applications**.

2.4 Bitumen Emulsion

Bitumen emulsion is a free flowing liquid at ambient temperatures. Bitumen emulsion is a stable dispersion of fine globules of bitumen in continuous water phase. Dispersion is obtained by processing bitumen and water under controlled conditions through a colloidal mill together with selected additives. The use of proper quality emulsifiers is essential to ensure that the emulsion has stability over time and also that it breaks and sets when applied on aggregates/road surface. It is chocolate brown free flowing liquid at room temperature. Bitumen Emulsions can be of two types cationic & anionic. Anionic bitumen emulsions are generally not used in road construction as generally siliceous aggregate is used in road construction. Anionic bitumen emulsions do not give good performance with siliceous whereas cationic bitumen emulsions give good performance with these aggregates. **Therefore, cationic bitumen emulsions are far more popular than anionic bitumen emulsions.**

2.5 Modified Bitumen

Modified Bitumen are bitumen with additives. These additives help in further enhancing the properties of bituminous pavements. Pavements constructed with Modified Bitumen last longer which automatically translates into reduced overlays. Pavements constructed with Modified Bitumens can be economical if the overall lifecycle cost of the pavement is taken into consideration.

2.6. Viscosity grade Bitumen:

The new method of grading the product has now rested on the viscosity of the Bitumen (at 60^0C and 135 ^{0}C). The new grades have thus evolved with nomenclature:

Grades	Minimum of Absolute viscosity, Poise@ 60^0C	Approximate penetration grade
VG 10	800	80-100
VG 20	1600	------
VG 30	2400	60-70
VG 40	3200	30-40/40-50

3. INTRODUCTION TO VISCOSITY GRADE

Paving grade bitumen is the bitumen obtained from refineries and conforms to IS 73. Recently, the third revision of Indian Standards for Paving Bitumen Specifications

IS 73:2006 has been released by Bureau of Indian Standards. Three grades of Bitumen confirming to IS 73: 1992 are manufactured in India. In this third revision grading of Bitumen is changed from penetration grade to viscosity grade. To improve the quality of Bitumen, BIS revised IS-73-1992 Specifications based on viscosity grade (viscosity @ 60 deg. C) in July 2006. As per the Specifications, there are four grades VG-10, VG-20, VG-30 & VG-40.

With the current revision several key issues are addressed, like:

- **Performance** at high temperatures by adopting a viscosity-graded bitumen specification (based on viscocity at 60 ºC), in place of the current penetration-graded specification (based on penetration at 25 ºC)
- **Issues** relating to compaction, which the tender asphalt mixtures create as push and shove under the roller wheels, have also addressed by having a requirement of minimum viscosity at 135ºC, it will be helpful in minimizing the tender mix problems in the field.
- **Adoption** of viscosity-graded paving bitumen specifications will also reduce the number of total tests to 7

Without compromising the quality of bitumen and also no new tests are required in implementing this specification.

Viscosity grades Bitumen are categorized according to Viscosity (degree of fluidity) grading. The higher the grade, the stiffer the Bitumen. In Viscosity Grade, Viscosity tests are conducted at 60 deg. C and 135 deg. C, which represents the temperature of road surface during summer and mixing temperature respectively. The penetration at 25 deg. C, which is annual average pavement temperature, has been also retained in Specifications.

4. PROPERTIES OF BITUMEN

4.1. Bitumen –A Visco-Elastic Material

The properties of Bitumen can be defined in terms analogous to the Modulus of Elasticity of solid materials.

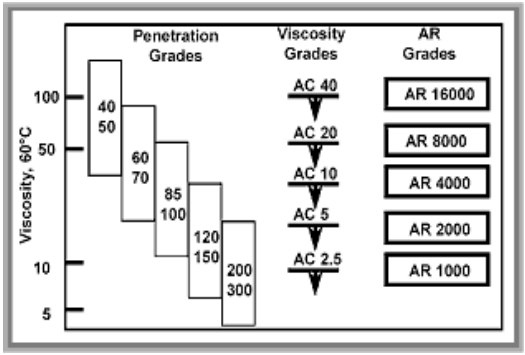
In case of solids, Modulus of Elasticity E is defined by Hooke's law Bitumen is a Visco-elastic material. At high temperatures it behaves like a liquid & hence liquid flow properties like Viscosity are exhibited. However, at low temperatures bitumen behaves like a solid and hence solid properties like stress & strain become relevant. Similarly, for shorter loading time bitumen behaves like a solid whereas for longer loading times bitumen behaves like a liquid.

The properties that bitumen exhibits in the intermediate temperature range and loading time are of great relevance as this range is very long and bitumen is handled in this temperature range most of the times.

Due to the visco-elastic nature of bitumen, there is always a phase lag in stress & strain in case of repetitive loadings. For purely elastic material the phase lag is 0^0 and for purely viscous material the phase lag is 90^0. In case of bitumen since it is neither a liquid nor a solid at most temperatures hence the phase lag is always between 0^0 to 90^0.

The above theory is extremely useful in studying fatigue characteristics, properties of creep & also tensile strength of bitumen.

4.2 Adhesion Properties of Bitumen



Bitumen has excellent adhesive qualities provided the conditions are favourable. However in presence of water the adhesion does create some problems. Most of the aggregates used in road construction possess a weak negative charge on the surface. The bitumen aggregate bond is because of a weak dispersion force. Water is highly polar and hence it gets strongly attached to the aggregate displacing the bituminous coating.

The factors influencing aggregate bitumen adhesion are plenty and some of the factors influencing this property are as below:

4.2.1 External: Rainfall, Humidity, Water pH, Presence of salts, Temperature, Temperature cycle, Traffic, Design, Workmanship, Drainage

4.2.2 Aggregate: Mineralogy, Surface texture, Porosity, Dirt, Durability, Surface area, Absorption, Moisture content, Shape, Weathering

4.2.3 Bitumen: Rheology, Constitution

4.2.4 Mix: Void content, Permeability, Bitumen content, Bitumen film thickness, Filler type, Aggregate grading, Mix type.

The above list is only indicative and not exhaustive.

5. ADVANTAGES OF VISCOSITY GRADE

1. **Based on the fundamental Engineering Properties:** VG system is based on fundamental engineering parameter i.e. actual performance on road and not on the empirical properties.

2. **Takes care of low as well high temperature:** Viscosity is measured at 60º C and 135ºC which takes care of both low and high temperature susceptibility of the Bitumen, which is not possible with Penetration value at 25ºC. Hence, road contractors can have better understanding of Bitumen performance in the field.

3. Any two same Viscosity Grade Bitumen would give similar rutting performance in hot summer unlike Penetration Grade.

4. **Greater Mix in ease design:** Greater ease of handling to customers as Viscosity value at two different temperature is available, which would enable users to measure accurate mixing and compaction temperature. Minimum specified Kinematic Viscosity Value at 135ºC helps to minimize the potential of tender mixes during construction.

5. **Less no. of tests save time and cost:** IS-73-2006 has only 7 tests to evaluate a sample compared to 14 tests in Penetration Grade system. This reduces time and cost of testing without sacrificing the quality.

6. **Longer Durability:** The pavement made from VG Bitumen will have better performance, because Viscosity value at 135ºC gives sufficient idea about mixing and compaction temperature and as a result pavement life is improved.

7. **Takes higher Traffic:** Penetration test was developed in the era of significantly lower pavement loading. In the past, truck weights were less than 30 tons with tyre pressure of 75 PSI. Today truck weight has increased to 35 tons a with tyre pressure of 125 PSI and increased traffic with extreme weather conditions. Therefore, to cope up with these changes shift from PEN Grade to VG Grade is required.

5. ADVANTAGES OF VISCOSITY GRADE

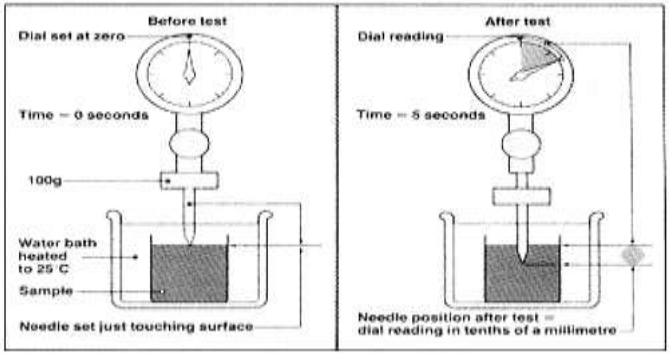
INDIAN BITUMEN SPECIFICATIONS AS PER IS 73:2006							
S.No.	**Characteristic**	**Unit**	**VG 10**	**VG 20**	**VG 30**	**VG 40**	**Test Method**
I)	Absolute viscosity at 60^{O}C, min	Poises	800	1600	2400	3200	IS 1206(Part 2) : 1978
II)	Kinematic viscosity at 135^{O}C, min	cst	250	300	350	400	IS 1206(Part 3) : 1978
III)	Flash Point, Cleveland open cup, min.	^{O}C	220	220	220	220	IS 1209 : 1978
IV)	Matter soluble in trichloroethylene, min.	% wt	99	99	99	99	IS 1216 : 1978
V)	Penetration at 25 ^{O}C, 100 gm, 5 sec.	1/10 mm	80 to 100	60 to 80	50 to 70	40 to 60	IS 1203 : 1978
VI)	Softening Point, min	^{O}C	40	45	47	50	IS 1205 : 1978
VII)	Tests on residue from thin film oven test / RTFOT						
	a) Viscosity ratio at 60 ^{O}C, max		4	4	4	4	IS 1206(Part 2) : 1978
	b) Ductility at 25^{O}C after thin film oven test, min	cm	75	50	40	25	IS 1208 : 1978

6. TESTS FOR VG GRADE BITUMEN

There are many bitumen properties which can be tested. All these tests replicate the actual field conditions in different ways. Different types of standard tests conducted on it are briefly described below:

6.1 Viscosity Based System

The actual tests conducted are as follows:

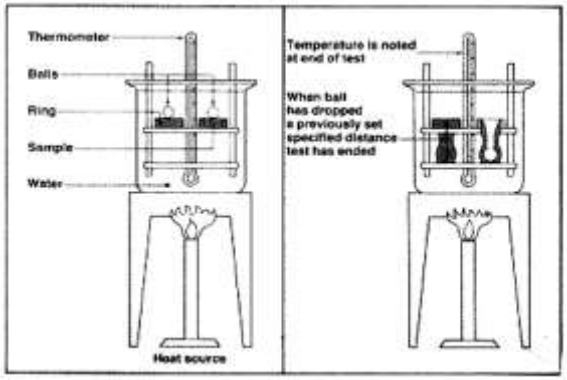


6.1.1 Viscosity Test

Viscosity at 135^{O}C is a fair indicator of the ability of bitumen to coat the aggregates properly. In order to get best coating the viscosity has to be optimum. Too viscous bitumen would result in inadequate and non-uniform coating of the aggregates. Very low viscosity would again result in inadequate coating as the bitumen will tend to bleed. Therefore viscosity at 135^{O}C is a true reflection of the quality of bond that is likely to be formed with the aggregate. Various testing equipments like Capillary Viscometer, Cup Viscometer, Tar Viscometer, etc. can be used for testing the viscosity.

Viscosity at 60^{O}C is a very good indicator of the resistance of bitumen to melting/flowing on the road. It is considered to be replacement test for Softening Point test. Some specifications have replaced softening point test with Viscosity at 60^{O}C. However, at many places both the tests are carried out as both the tests are empirical and have their own limitations.

6.1.2 Softening Point

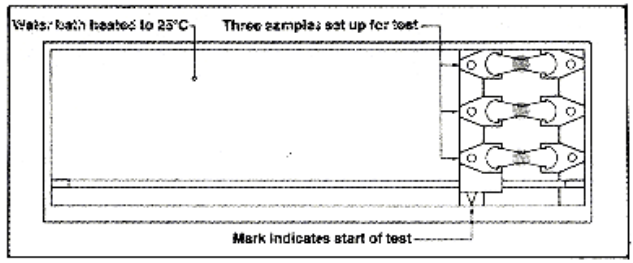


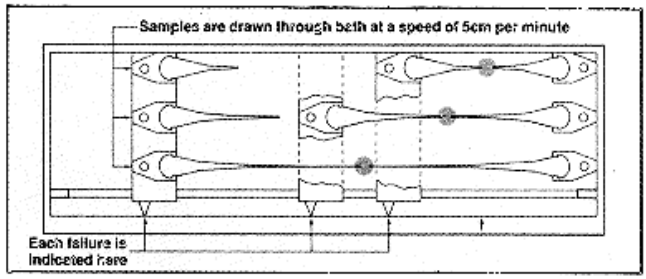
As mentioned earlier bitumen does not have a distinct melting point. It gradually softens when heated. As there is no distinct melting point therefore the softening point test has been developed to arbitrarily indicate the transition temperature. The softening point is also an empirical test and denotes the temperature at which bitumen would behave more like a liquid and less like a solid under standard conditions of heating and loading.

In this test a standard Ring and Ball Apparatus is used. The sample is taken in a standard mould and standard weights (in the form of steel balls) are placed on it. The system is then heated in a water bath at a standard rate. The temperature at which the bitumen coated steel ball touches the bottom of the beaker is called the Softening Point temperature.

Softening Point test is a very important test as it is a fair indicator of melting properties of bitumen. Bitumens with lower softening point tend to melt on the road in summer and start flowing under the impact of temperature and traffic. Subsequently when the bitumen cools down at night the road surface loses its original shape and becomes wavy. This mode of failure of roads due to bitumen is referred to as failure by rutting. Therefore it can be concluded that bitumens with higher softening point melt at higher temperatures and have better rutting resistance.

6.1.3 **Ductility Test**





The Ductility test is again an empirical test which measures the cohesive strength of bitumen. In this test a standard size bitumen sample is maintained at a constant temperature. The sample is pulled at a constant rate at constant temperature. The length at which the sample breaks is called the ductility of the sample. One unique feature of ductility test is that the test temperature at times varies from country to country and also from grade to grade.

Ductility test is an indicator of the cohesive strength of bitumen which in turn is a very loose indicator of the fatigue strength of the material. Material with higher ductility is more likely to withstand repeated cycles of loading and unloading in a better way. However some of the countries have completely discarded this test as the relationship between the fatigue strength and ductility appears to be very hazy. Moreover, testing of Thin Film Oven Test residue for change in penetration, softening point, viscosity, etc. is considered to be a much better indicator of the fatigue resistant properties.

6.1.4 Penetration Index or Penetration Ratio

The penetration of the same sample of bitumen can be measured at different temperatures and a temperature vs penetration graph can be plotted on a log log graph sheet. The graph is a straight line and the slope of this straight line is called the penetration index. Penetration index can also be calculated with the help of the following formula:

Penetration index is a fair indicator of the ability of bitumen to resist repeated variations in the temperature of the pavement. Penetration ratio is a simplified version of the Penetration Indext. It is very similar to penetration index but in this case the sample is tested with 100 gm weight on the needle at 25^{O}C and 200gm weight on the needle at 4^{O}C. While deriving the values of Penetration Index and Penetration Ratio the assumption is that the properties of bitumen vary in a linear manner over the entire range of temperature (in service as well during application. However, this assumption may not be entirely true in case of certain bitumen or modified bitumens.

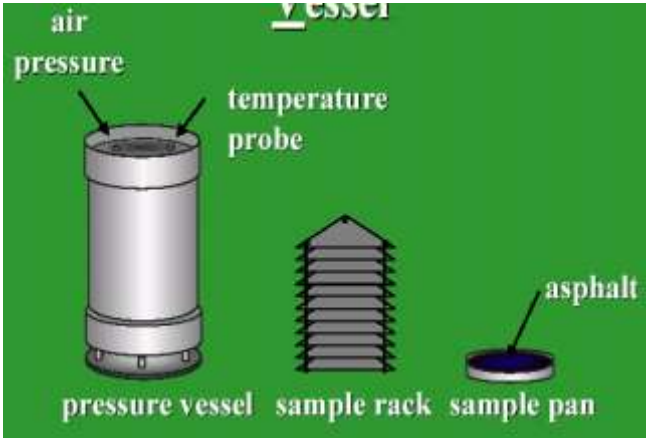
6.1.5 Matter Soluble in Organic Solvents

This test measures the presence of inorganic impurities in bitumen. Solvents like trichloroethylene, carbon disulphide, carbon tetrachloride, toluene, etc. are used for this purpose. In this test bitumen is dissolved in the solvent (trichloroehylene, carbon disulphide, carbon tetrachloride or toluene) and the material insoluble in the solvent is filtered out. It is then repeatedly washed with the solvent to remove all soluble matter. The insoluble matter that is finally left behind is weighed and the percentage calculated. The choice of solvent has been a matter of debate and discussion in the scientific community. Some of these solvents are considered to be toxic and hazardous. The laboratories and test method specification making bodies prefer not to use these toxic solvents and have switched over to less toxic or non-toxic solvents.

6.1.6 Flash Point

The flash point test like the flash point test of any other petroleum product tests the flammability of bitumen.

6.1.7 Rotating Thin Film Oven Test (RTFOT)



Once the bitumen is found to be meeting the viscosity criterion the next step of aging the sample in the laboratory is undertaken. The conventional TFOT test is replaced by Rotating Thin Film Oven Test. In the Rotating Thin Film Oven Test small bottles, like medicine bottles, are coated with bitumen on the inner side and the bottles are fixed in the oven on a shelf in horizontal position. A jet of air is periodically blown into each bottle to speed up the oxidation process. Therefore this test is faster test and can cause aging equivalent to two years (after laying) within 135 minutes.

7. AGING OF BITUMEN

Bitumen, like any organic matter, is affected by factors like presence of oxygen, ultraviolet rays and changes in temperature. These factors are responsible for hardening of bitumen. Hardening results in decrease in penetration increase in softening point and increase in penetration index (PI). For increased life of bituminous pavement it is essential that excessive hardness does not take place. Hardening of bitumen takes under the influence of external factors in the following ways:

7.1 **Oxidative hardening**: When bitumen is exposed to atmosphere for a prolonged period the oxygen starts reacting with the bitumen constituents and higher molecular weight molecules are formed. Larger molecules results in lesser flexibility and hence increased hardness. The degree of hardness is dependent on factors like ambient temperature, exposure time & thickness of bitumen film. It is observed that for 10 ^{0}C increase in temperature above 100 ^{0}C the oxidation rate doubles.

7.2 **Hardening due to loss of volatiles:** Over a period of time the volatile components in bitumen evaporate. The rate of evaporation is dependent on temperature only. The volatiles in bitumen are relatively very low and hence hardening due to loss of volatiles is relatively small.

7.3 **Physical hardening:** At ambient temperatures bitumen molecules slowly reorient themselves. This result in physical hardening. This process is an extremely slow process and hence actual hardening due to the above factor is very low.

7.4 **Exudative hardening:** Educative hardening takes place due to the movement of oily components out of bitumen over a period of time. The rate of hardening due to this process is dependent on the type of bitumen and also on the porosity of the aggregate.

7.5 **Hardening of bitumen during storage**: Hardening of bitumen during storage can be easily minimised by taking a few simple precautions. Bitumen is stored in above ground tanks at high temperatures and high temperature and presence of oxygen are the two primary factors responsible for hardening of bitumen. Hence it is very important that bitumen be

handled at the lowest possible temperature, consistent with efficient use. Also the storage tanks should have low surface to volume ratio so as to minimize the exposed surface area.. Lower exposed surface area would mean lower oxidation rate.

While designing the tanks it should be ensured that the recirculation pipelines always enter the tank below the bitumen surface. This will reduce splashing during recirculation. When the recirculation line enters the tank above the product surface all the three factors which promote oxidation viz. high temperature, access to oxygen and high exposed surface to volume ratio, are present. Therefore bitumen quality deteriorates very fast.

If handled properly the hardening in tanks can be insignificant as the product is stored for shorter durations. If bitumen is to be stored for long durations (4 to 5 days) then the temperature should be reduced to 20 ^{0}C to 25 ^{0}C above softening point.

In case where bitumen is to be reheated to increase the temperature adequate precautions have to be exercised. Bitumen should not be heated continuously in the beginning. Continuous heating can result in very high localized temperatures in area close to the heating source.

7.6 **Hardening of bitumen during mixing & transportation of mix:** During with a thin film of bitumen the size of which may vary from 5 microns to bituminous macadam is approximately 10, 000 sqm. Therefore again the conditions are very favorable for oxidation and hardening. It is generally observed that bitumen hardens by one grade during mixing and laying. The above factor is taken into consideration while selecting the right grade of bitumen.

7.7 **Hardening of bitumen on road:** Some hardening of bitumen can take place on the road also due to oxidation. The level of oxidation is purely dependent on the access to oxygen. If the pavement is well graded and well compacted the hardening is nominal as the void content will be low.

Pressure Aging Vessel (PAV)

The RTFOT produces bitumen which is as aged as bitumen in a two year old road. However the bitumen on the road continues to age and tests need to be developed this aging also. The Pressure Aging Vessel (PAV) is used to age the sample further. The Pressure Aging Vessel consists of a stack of small trays. Bitumen sample is filled into these stacks and is further aged under high pressure. RTFOT + PAV aged sample is considered to be equivalent to bitumen in a 7 year old road.

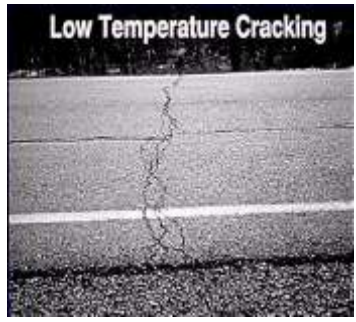
8.1 Rutting Properties (Complex Modulus)

The complex modulus of the bitumen sample is an indicator of the ability of bitumen to resist deformation at high temperature and prevent subsequent rutting. The test is carried out separately on unaged sample on RTFOT aged sample. The testing is done on a Dynamic Shear Rheometer. In this the bitumen sample is placed between two plates and the upper plate is oscillated. The torque required for oscillation is directly converted into complex modulus digitally. The testing is done at the maximum pavement temperature and not at a standard temperature as in case of Penetration / Viscosity tests.

8.2 Fatigue Properties

The fatigue properties are also measured in the Dynamic Shear Rheometer. The sample is tested at temperature equal to average of maximum and minimum temperature of the grade + $4^{O}C$. This testing is done on a sample which is RTFOT + PAV aged.

8.3 Low Temperature Properties



The low temperature properties are measured using the Bending Beam Rheometer. The testing is done on RTFOT + PAV aged sample. As achieving extremely low temperatures in the laboratory can be a difficult task, the testing is done at minimum temperature + 10^{O}C. The sample in the form of a beam is taken in the Bending Beam Rheometer and is tested for deflection. The deflection values are directly translated with the help of a transducer into the Creep Stiffness value. In case of Modified Bitumen this test is replaced by the Direct Tensile Test

8.4 Bond failure by Displacement:

This type of bond failure takes place when water is introduced in bituminous mix. Water displaces the bitumen particles due to its strong polar nature and hence the bond failure takes place.

8.5 Bond failure by detachment:

This type of bond failure is slightly different from displacement failure. This type of failure takes place due to improper handling of the aggregate at the time of mixing. Due to the hydrophilic nature of most of the aggregates they are coated with a thin invisible layer of water. The aggregate needs to be heated to break this water layer. If the aggregate is not properly heated or dust content in the aggregate is high, bitumen will not be able to coat the aggregate properly. Bitumen will form a thin coat over the water layer without proper bonding and will detach very easily.

8.6 Film rupture:

Film rupture takes place when the aggregates are not properly coated with bitumen. At the sharp edges where the bitumen layer is thin water will penetrate the film and reach the aggregate and displace bitumen completely. This process can be very fast and is the single largest reason for road damage.

8.7 Blistering & pitting:

During summers due to the pavement temperature is high and hence bitumen viscosity is reduced. If this is preceded or succeeded by rainfall bitumen particles migrate to the water droplets and form a thin film over them and form blisters. Whenever the temperature goes up again the water evaporates leaving a pit with exposed aggregate surfaces.

8.8 Hydraulic scouring:

During monsoon water penetrates the voids in the pavement. Due to compression & tension cycle induced by the vehicular movement water and bitumen particles continuously rub against each other resulting in hydraulic scouring.

8.9 Pore pressure:

In poorly compacted mixes the void content is high and in monsoon the voids near the surface can get completely filled up with water. Since the material is poorly compacted movement of traffic compacts the surface making the surface impermeable and pore water pressure is exerted. With subsequent traffic movement water penetrates deep into the surface and erodes the bitumen aggregate bond.

9. MODIFIED BITUMEN

9.1 Advantages of Modified Bitumen:

a. Lower susceptibility to temperature variations.
b. Higher resistance to deformation/wear and tear.
c. Better adhesion between aggregates and binder.
d. Increase in fatigue life.
e. Resistance in reflective cracking.
f. Better age resistance properties.

9.2 Types of Modified Bitumen:

A variety of additives are used for modification of Bitumen. The degree of modification depends on type of Modifier, its dose and nature of Bitumen. The most commonly used Modifiers are:

9.2.1 Synthetic Polymers

9.2.1.1 Synthetic Polymers - Plastomeric Thermoplastics

1. Low Density Polyethylene(LDPE)
2. Ethylene Vinyl Acetate (EVA)
3. Ethylene Butyl Acetate (EBA)
4. Ethylene Ter Polymer (ETP)

9.2.1.2 Synthetic Polymers - Elastomeric Thermoplastics

1. Styrene Isoprene Styrene (SIS)
2. Styrene Butadiene Styrene Block Copolymer

9.2.2 Natural Rubber

1. Latex Powder
2. Rubber Powder

9.2.3 Crumb Rubber

1. Crumb Rubber without additives
2. Crumb Rubber with additives

9.3 Cost Benefit Analysis:

Since other components of the cost of construction remains same except for the binder, the overall increase in the cost of construction is approx. 15-25%. However, the field trials have proved that frequency of overlaying can be minimized and the maintenance cost can be reduced to about 22-30% excluding the cost of interest, safety and comfort to the road user.

ABRADED ROAD (UNMODIFIED)

CRACKED ROAD (UNMODIFIED)

POTHOLE (UNMODIFIED)

MODIFIED (CRMB) SECTION

11. BITUMEN REQUIREMENTS FOR VARIOUS ROAD APPLICATIONS

			Quantity of Bitumen (Kg per 10sqm)
11.1	Prime coat over granular base:		
	a)	Low porosity (WMM or WBM)	6 to 9
	b)	Medium porosity (Cement stablized)	9 to 12
	c)	High porosity (Gravel base)	12 to 15
11.2	Tack coat:		
	a)	Normal bituminous surface	2.0 to 2.5
	b)	Dry hungry bituminous surface	2.5 to 3.0
	c)	Granular surface treated with primer	2.5 to 3.0
	d)	Non-bituminous surface	
		(i) Granular base (not primed)	3.5 to 4.0
		(ii) Cement concrete pavement	3.0 to 3.5
11.3	Bituminous penetration macadam:		
	a)	Compacted thickness 50 mm	50
	b)	Compacted thickness 75 mm	68
11.4	Bituminous macadam:		
	Total bitumen content - 3 to 3.5 % by weight of total mix.		
11.5	Built up spray grout:		15
11.6	Dense bituminous macadam:		
	Total bitumen content - 4 % by weight of total mix.		
11.7	Surface dressing:		
	a)	Single coat or first coat of 2 coats	18
	b)	Second coat	10
11.8	Open grade premix carpet:		
	a)	13.2 mm stone chipping	9.5
	b)	11.2 mm stone chipping	5.1

11. BITUMEN REQUIREMENTS FOR VARIOUS ROAD APPLICATIONS

		Quantity of Bitumen (Kg per 10sqm)
11.9	Mix seal surfacing:	
	a) Type A mix seal surfacing	22.0
	b) Type B mix seal surfacing	19.0
11.10	Semi-dense bituminous concrete:	
	Total bitumen content -	not less than 4.0 % of total weight of mix.
11.11	Bituminous concrete:	
	Total bitumen content -	minimum 4.5 % of total weight of mix.
11.12	Seal coat:	
	a) Type A - Liquid seal coat comprising of application of a layer of bituminous binder followed by a cover of stone chippings.	9.8
	b) Type B - Premixed seal coat comprising of a thin application of fine aggregates premixed with bituminous binder.	6.8
11.13	Bitumen mastic:	14 to 17
11.14	Slurry Seal:	
	Total bitumen emulsion content -	180-250 litres per tonne of dry aggregate.

RECOMMENDED HANDLING TEMPERATURES

Grade	Minimum Pumping temp. ºC	Mixing/Coating temp. º C	Laying tempº C	Spraying tempº C	Mixing safe Handling tempº C
VG 10	105	150-163	130-160	175	175
VG 30	115	150-165	130-160	-	175
VG 40	125	160-175	140-160	-	175

APPENDIX-I : THE FEVER CHART

DISTRESS	PROBABLE CAUSE	TREATMENT
Edge Failure	Insufficient thickness of mat, excessive loads, lack of shoulder support, base saturation-usually due to high shoulders, trapping run-off.	Check drainage and clean ditches. Check shoulders for permeability and if shoulder high, blade it down to surface grade and compact. Fill cracks and seal coat outer edge.
Weathered or dry surface	Insufficient bitumen, or overheating of bitumen, age of pavement, or absorptive aggregates.	Fog seal of slow setting Bitumen Emulsion, if there are pitted areas needing filling use a slurry seal or conventional seal coat.
Pot holes	Any of the several types of distress cited here will lead to pot-holing, also water infiltration, unstable base, insufficient Bitumen or open or segregated mix.	Square up hole, making sides almost vertical, replace lost base material, spray cavity lightly with Bitumen, fill with premix material to compacted height that will allow for additional traffic compaction.
Alligator cracking	Base saturation, lack of base support or insufficient thickness of mat.	Check and correct drainage faults, apply thin coat of liquid Bitumen with cover of mineral aggregates.
Bleeding and Instability	An excess of Bitumen, changing in character from Binder to Lubricant, or presence in mat of large amount of silt or clay with rounded gravel, lacking interlocking. Often moisture accumulating beneath surface, destroys the bond and traffic pushes the pavement to form waves or ridges.	Scarify, remix and relay, adding sand where there is an excess of Bitumen, where the cause is weak base and/or poor drainage, underlying fault must be corrected.
Ravelling	A lean or over-heated mix	Apply fog seal, regular seal with cover mineral or slurry seal as required.
Base Saturation	Standing water in side drains, leaking ditches or culverts, or other condition which traps moisture beneath the surface. Too high a percentage of fines or presence of plastic fines in the base.	Clean ditches and install new or additional drainage as indicated.
Longitudinal & transverse cracking	Contraction or subgrade movement.	Crack filling and sealing.
Distortion and depression	Inadequate compaction of subgrade or base.	Spot leveling and skin patching.