CONSTRUCTION AND QUALITY CONTROL OF FLEXIBLE AND RIGID PAVEMENTS

Laboratory Tests on Modified Bitumen

National Rural Infrastructure Development Agency

Ministry of Rural Development

National Institute of Technology

Warangal, Hyderabad

Lecture-11

Laboratory Tests on Modified Bitumen

MODIFIED BITUMEN

- Majority of highways in India are constructed as bituminous pavements

- Early development of distresses such as rutting, cracking, bleeding, shoving, and potholes due to:
  - High traffic density
  - Overloading
  - Variations in daily and seasonal pavement temperatures

- Bituminous pavements constructed using conventional paving bitumen is not able to sustain the present traffic requirements

Modified Bitumen

- Properties of bitumen and bituminous mixes can be enhanced with incorporation of polymers
- Polymer modifies the properties of bitumen, called as modifiers!
- Bitumen premixed with modifiers is called Polymer Modified Bitumen (PMB)
- Use of PMB in wearing or binder courses improves the pavement life
- PMB usage improves pavement performance and is cost-effective (based on life- cycle cost analysis)

MODIFIED BITUMEN

Polymers classifications:

- Thermosets:
  - Polymers that become irreversibly hard on heating or by addition of special chemicals
  - polymers that cross-link irreversibly during the curing process (chemical change), forming chemical bonds
- Thermoplastics:
  - polymers that can be softened and melted by the application of heat
  - Softens and hardens reversibly on heating and cooling without a change in the chemical structure

MODIFIED BITUMEN

Major polymers used to modify bitumen for pavement applications:

- Plastomeric Thermoplastic Polymers
  - Long-chain molecules, sometimes with branches
  - High initial strength and cracks at high strains
  - Do not rebound after deforming force is removed
  - Resists rutting

- Elastomeric Thermoplastic Polymers
  - Long-chain molecules bound to each other through cross-links
  - High failure strain
  - Resists fatigue cracking and rutting

MODIFIED BITUMEN

Major polymers used to modify bitumen for pavement applications:

- Plastomeric Thermoplastic Polymers
  - Polyethylene (PE)
  - Ethylene-Vinyl Acetate (EVA)
  - Ethylene-Methyl Acrylate (EMA)
  - Ethylene-Butyl Acrylate (EBA)
  - Ethylene Ter Polymer (ETP)
- Elastomeric Thermoplastic Polymers
  - Styrene-Butadiene-Styrene (SBS)
  - Styrene-Isoprene-Styrene (SIS)
  - Styrene-Butadiene (SB)
  - Styrene Butadiene Rubber (SBR)

MODIFIED BITUMEN

- IRC:SP:53-2010: “Guidelines on Use of Modified Bitumen in Road Construction”, Second Revision, Indian Roads Congress, New Delhi
- Modified bitumen comprises a base binder (VG bitumen) to which a modifier (natural rubber, crumb rubber, synthetic rubber, synthetic polymer, or blend of these) is added to achieve a high performance binder with improved properties, particularly at extreme temperatures
  - PMB(P): Plastomeric thermoplastic based
  - PMB(E): Elastomeric thermoplastic based
  - NRMB: Natural rubber and SBR latex based, and
  - CRMB: Crumb rubber/treated crumb rubber based
- Further divided into three or two grades (??) based on penetration value or softening point value, as relevant

GRADING OF BITUMEN

- Penetration grading
- Viscosity grading
- Performance grading

PERFORMANCE GRADING

- To identify bituminous binders that provide acceptable performance
- Performance: 15 to 20 years of service life under given traffic and climatic conditions with minimal maintenance

- Performance is quantified in terms of resistance to:

➢Rutting

➢Fatigue cracking

➢Low temperature cracking

PERFORMANCE GRADING

- Need to have specifications to identify bituminous binders that provide acceptable performance against rutting, fatigue cracking, and low temperature cracking

- Characterization of bituminous binders is essential for performance based specifications

- Response of bituminous binders to loading depends on:
  - Stiffness of the binder (extent of aging)
  - Pavement temperature (test temperature)
  - Speed of vehicles (rate of loading)

AGING OF BITUMINOUS BINDERS

- Through loss of volatiles and oxidation

- Bitumen undergoes aging during:
  - Construction
  - Early age of pavement (initial two years)
  - 8 to 10 years of pavement life

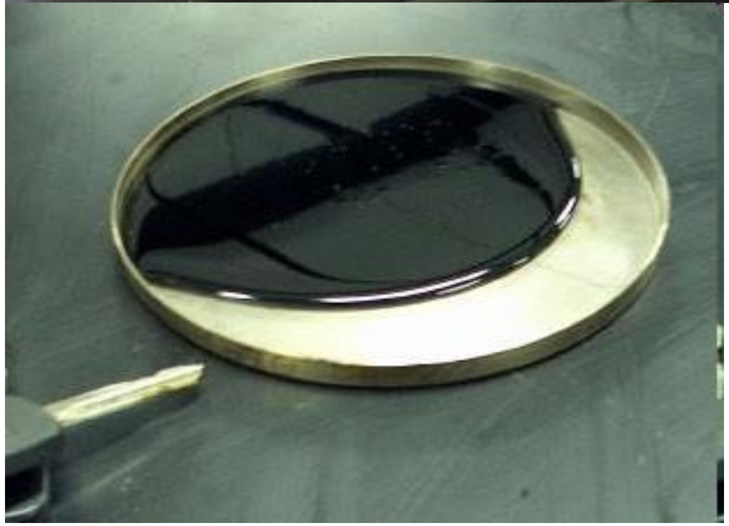
- Aging during construction and initial service: short-term aging (RTFO)
- Aging over pavement life: long-term aging (RTFO+PAV)

RTFO AGING OF BITUMINOUS BINDERS

- Rolling Thin Film Oven (RTFO) is used to simulate short-term aging in the laboratory
- Test temperature: 163°C
- Test duration: 85 minutes

Pressure Aging Vessel (PAV) OF BITUMINOUS BINDERS

- Pressure Aging Vessel (PAV) and Vacuum Degassing Oven (VDO) are used to simulate long-term aging in the laboratory
- Input: RTFO aged bitumen
- Air pressure: 2070 kPa (2.1 MPa)
- Test temperature: 90°C, 100°C, 110°C (depends on climatic conditions)
- Test duration: 20 hours



AGING OF BITUMINOUS BINDERS

- Three different binders based on three aging conditions:
  - Unaged bitumen
  - RTFO aged bitumen
  - PAV aged bitumen
- Rutting occurs at early age of pavement (RTFO)
- Fatigue cracking and low temperature cracking occurs at later age of pavement (RTFO+PAV)

BITUMEN RESPONSE TO TEMPERATURE AND RATE OF LOADING

- In earlier grading systems, bitumen was characterized through penetration and viscosity tests

- Penetration and viscosity tests characterize bitumen only at one temperature and one rate of loading

- Recall limitations of penetration grading and viscosity grading!

- Dynamic Shear Rheometer (DSR) can be used to capture the response of bitumen to temperature and rate of loading

GRADING OF MODIFIED BITUMEN

- IRC:SP:53-2010: "Guidelines on Use of Modified Bitumen in Road Construction", Second Revision, Indian Roads Congress, New Delhi
- Modified bitumen comprises a base binder (VG bitumen) to which a modifier (natural rubber, crumb rubber, synthetic rubber, synthetic polymer, or blend of these) is added to achieve a high performance binder with improved properties, particularly at extreme temperatures
  - PMB(P): Plastomeric thermoplastic based
  - PMB(E): Elastomeric thermoplastic based
  - NRMB: Natural rubber and SBR latex based, and
  - CRMB: Crumb rubber/treated crumb rubber based
- Further divided into three grades based on penetration value or softening point value, as relevant

GRADING OF MODIFIED BITUMEN

- Classification of rubber and polymer based bitumen modifiers (IRC:SP:53: 2010):

Types of Modifiers	Examples
Plastomeric Thermoplastics	Polyethylene (PE), Ethylene Vinyl Acetate (EVA), Ethylene Butyl Acrylate (EBA), Ethylene-Methyl-Acrylate copolymers (EMA) etc.
Elastomeric Thermoplastics	Styrene Isoprene Styrene (SIS), Styrene-Butadiene-Styrene (SBS) block copolymer, Styrene-Butadiene Rubber , and Ethylene Ter Polymer (ETP) etc.
Synthetic Rubber Latex	Styrene Butadiene Rubber (SBR) latex and any other suitable synthetic rubber
Natural Rubber	Latex or Rubber Powder
Crumb Rubber or Treated Crumb Rubber	Crumb Rubber, Treated Crumb Rubber

GRADING OF MODIFIED BITUMEN

IRC:SP:53-2010 Modified Bitumen

Table 2 Properties of Modified Bitumen

	Highest Mean Air Temperature	< 20°C	20°C to 35°C	Above 35°C
	Lowest Mean Air Temp.	>-10 < -10	>-10 < -10	>-10
Sl. No. (1)	Characteristics (2)	Specified values for the bitumen (3)	(4)	(5)
i)	Penetration at 25°C, 0.1 mm, 100g, 5 s	60 to 120	50 to 80	30 to 50
ii)	Softening point, (R&B), °C, Min.	50	55	60 *
iii)	FRAASS* breaking point, °C, Max.	-20	-16	-12
iv)	Flash Point, COC, °C, Min.	220	220	220
v)	Elastic recovery of half thread in ductilometer at 15°C, percent, min.	50	60	60
vi)	Complex modulus (G*/sin δ) as Min 1.0 kPa at 10 rad/s, at a temperature, °C	58	70	76
vii)	Separation, difference in softening point (R&B), °C, Max.	3	3	3
viii)	Viscosity at 150°C, Poise	1-3	3-6	5-9
ix)	Thin film oven test and tests on residue:			
	a) Loss in mass, percent, Max.	1.0	1.0	1.0
	b) Increase in softening point, °C, Max.	7	6	5
	c) Reduction in penetration of residue, at 25°C, percent, Max.	35	35	35
	d) Elastic recovery of half thread in ductilometer at 25°C, percent, Min.	35	50	50
	Or			
	Complex modulus as (G*/ sin δ as Min 2.2 kPa at 10 rad/s, at temperature °C	58	70	76

* Where max temperature exceeds 40°C, Softening Point should be

**Fraass breaking point requirement will be applicable for areas of su

GRADING OF MODIFIED BITUMEN

	Highest Mean Air Temperature	< 20°C	20°C to 35°C	Above 35°C		
	Lowest Mean Air Temp.	>-10 <-10	>-10 <-10	>-10		
Sl. No. (1)	Characteristics (2)	Specified values for the bitumen (3)	(4)	(5)	Method of Test. IS No. (6)	Ref to Annexure (7)
i)	Penetration at 25°C, 0.1 mm, 100g, 5 s	60 to 120	50 to 80	30 to 50	1203	-
ii)	Softening point, (R&B), °C, Min.	50	55	60 *	1205	-
iii)	FRAASS* breaking point, °C, Max	-20	-16	-12	9381	-
iv)	Flash Point, COC, °C, Min.	220	220	220	1209	-
v)	Elastic recovery of half thread in ductilometer at 15°C, percent, min.	50	60	60		2

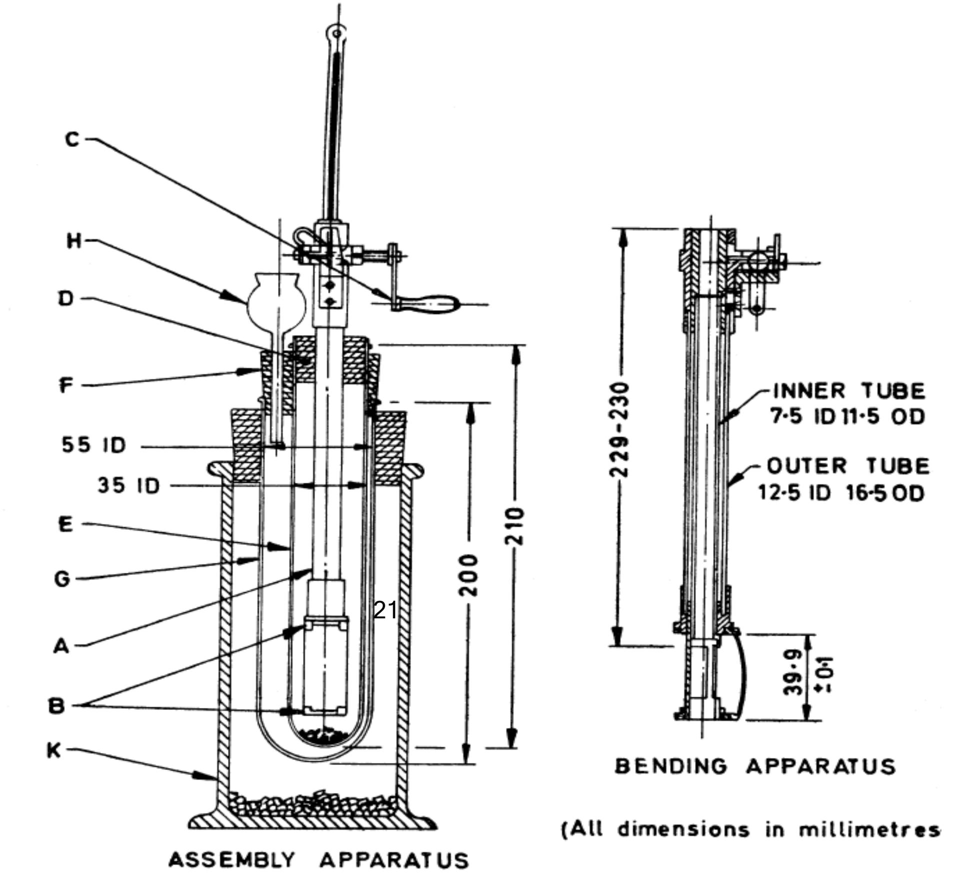
vi)	Complex modulus ($G^*/\sin \delta$) as Min 1.0 kPa at 10 rad/s, at a temperature, °C	58	70	76		1
vii)	Separation, difference in softening point (R&B), °C, Max.	3	3	3		3
viii)	Viscosity at 150°C, Poise	1-3	3-6	5-9	1206 (Part 2)	-
ix)	Thin film oven test and tests on residue:					
	a) Loss in mass, percent, Max.	1.0	1.0	1.0	9382	-
	b) Increase in softening point, °C, Max.	7	6	5	1205	-
	c) Reduction in penetration of residue, at 25°C, percent, Max.	35	35	35	1203	-
	d) Elastic recovery of half thread in ductilometer at 25°C, percent, Min.	35	50	50	-	4
	Or					
	Complex modulus as ($G^*/\sin \delta$ as Min 2.2 kPa at 10 rad/s, at temperature °C	58	70	76	-	1

* Where max temperature exceeds 40°C, Softening Point should be 65°C

**Fraass breaking point requirement will be applicable for areas of subzero temperatures.

GRADING OF MODIFIED BITUMEN FRASS BREAKING POINT TEST

- Frass Breaking Point (IS:9381-1979 [2019]): temperature at which bitumen becomes brittle, indicated by the appearance of cracks when a thin film of bitumen is cooled
- Place 0.40 $\pm$ 0.01 mL on a plaque and heat it till the plaque is uniformly coated
- Allow 1 to 4 h before testing
- Fill gaps between tube E and G with acetone
- Place plaque between clips of bending apparatus
- Add solid CO_2 to acetone at a rate such that temperature falls at 1°C/min.
- Bend plaque once every min. at 1 rev/s
- Record temperature at which one or more cracks appear on bending as breaking point

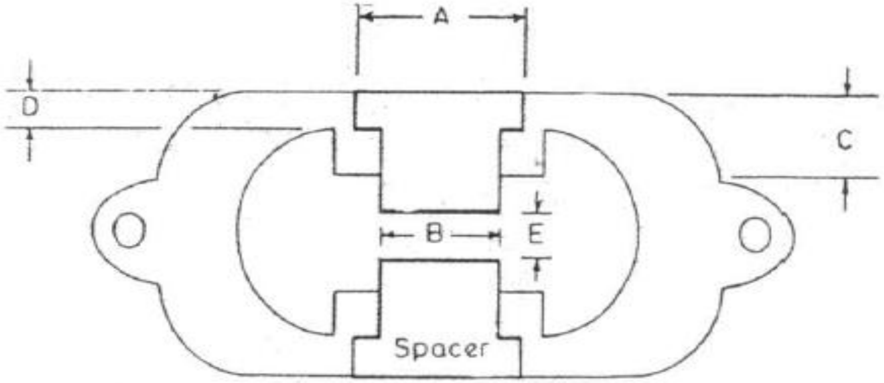


A - CONCENTRIC TUBE
B - STEEL CLIPS OR JAWS
C - ROTATING HANDLE
D - RUBBER BUNG
E - WIDE TEST-TUBE
F - RUBBER BUNG
G - WIDER TEST-TUBE
H - FUNNEL
K - CYLINDER

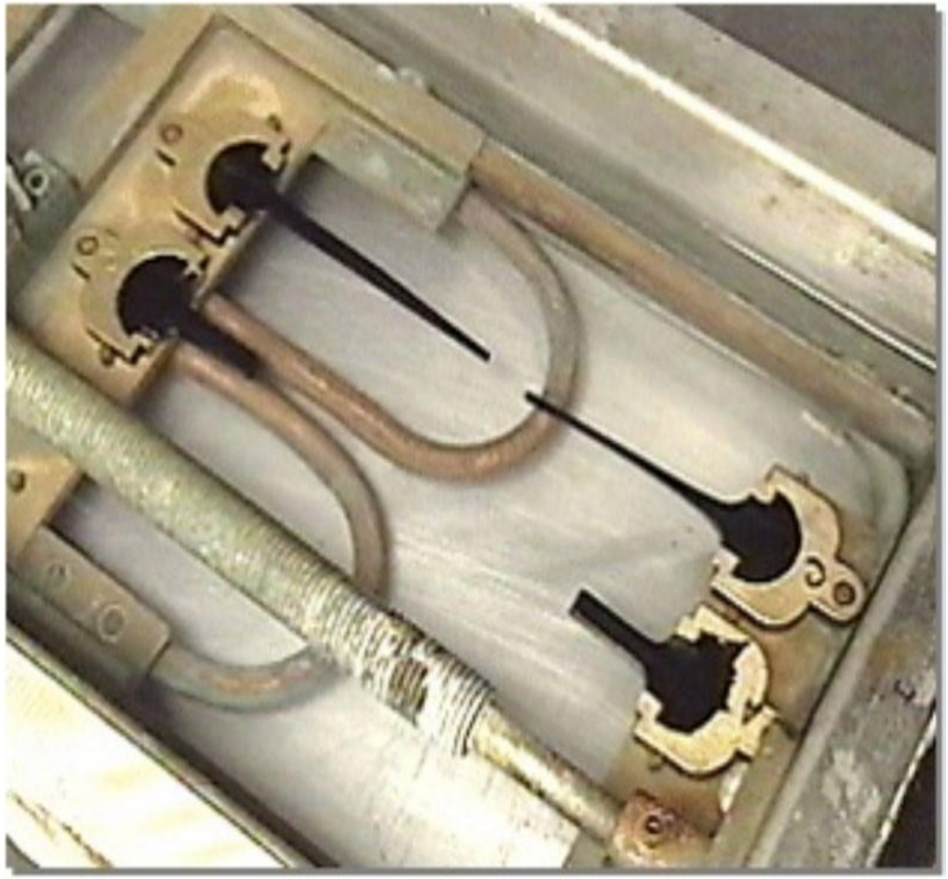
GRADING OF MODIFIED BITUMEN ELASTIC RECOVERY TEST

- Elongate the specimen to 10 cm at a rate of 5 ± 0.25 cm/min at 15 °C temperature
- Cut specimen into two halves at mid point
- Percentage recovery is measured after 1 h
- Elastic recovery

  = [(10-X)/10]*100



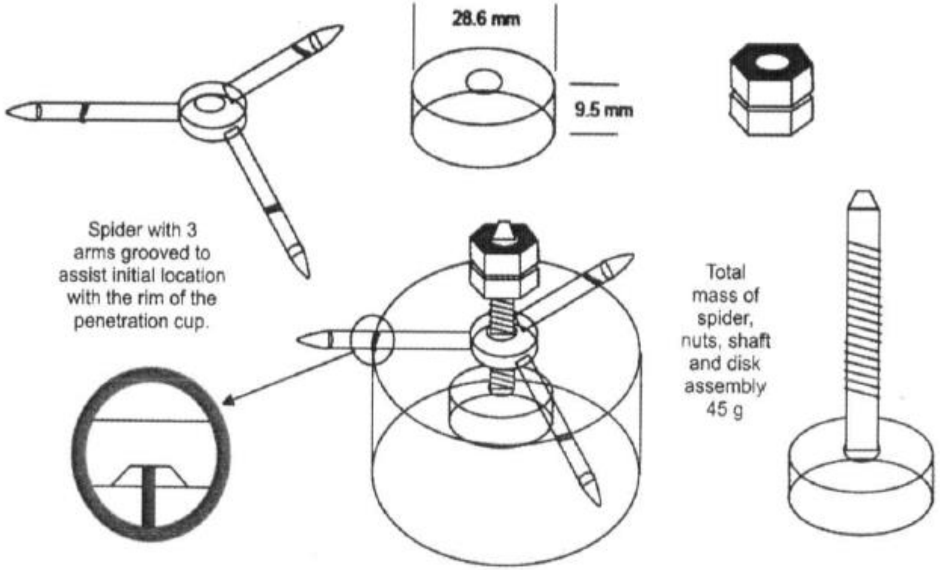
A 36.5 ± 0.1 mm
B 30.0 ± 0.1 mm
C 17.0 ± 0.1 mm
D 10.0 ± 0.1 mm
E 10.0 ± 0.1 mm

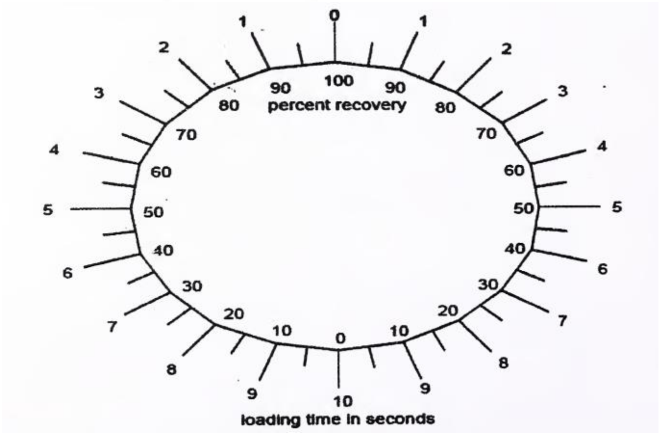


Source: http://www.priasphalt.com/testingandspecifications.aspx?id=730

GRADING OF MODIFIED BITUMEN TORSIONAL RECOVERY TEST

- Rotate aluminum bolt embedded in modified binder to 180° and measure recovery over 30 s period
- 180° twist applied over 10 s period
- Test performed in an air conditioned laboratory at 25 ± 3°C
- Torsional recovery, % = [(recovery angle in degree)*100]/180
- Torsional recovery value shall not be less than half of the elastic recovery value at 15°C



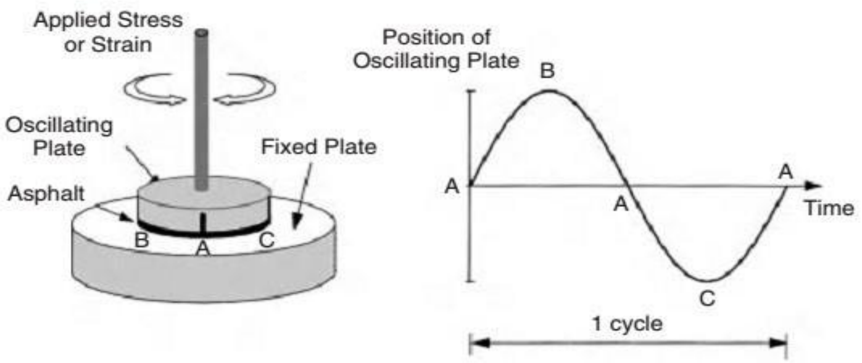


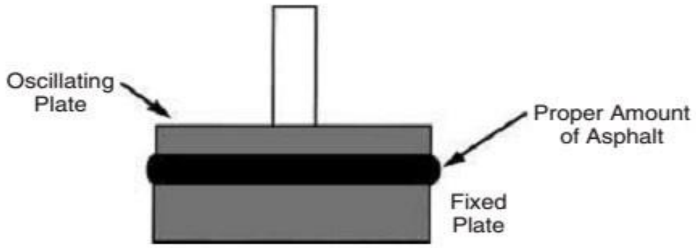
GRADING OF MODIFIED BITUMEN SEPARATION TEST

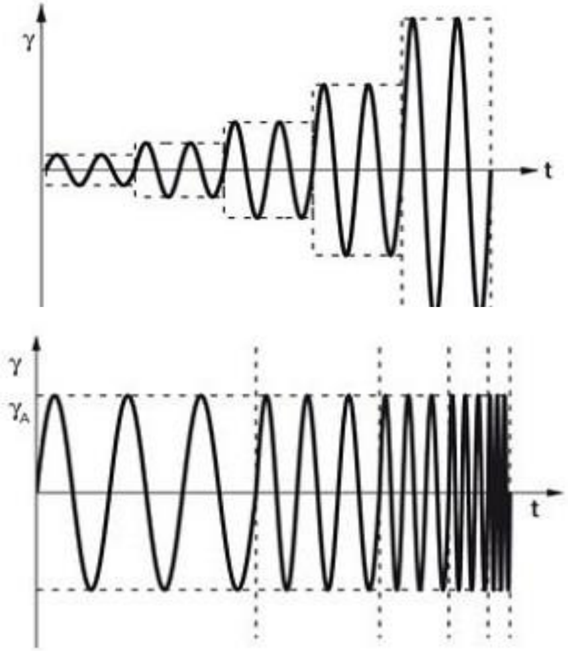
- Evaluated by comparing the ring and ball softening point of the top and bottom portion samples taken from a conditioned, polymer or rubber modified bitumen passing through 600 μm in a sealed aluminum tubes of 25.4 mm diameter placed in a vertical position at 163 ± 5 °C in an oven for a period of 48 hours
- Kept in a freezer at 6.7 ± 5 °C in a vertical position for 4 hours to solidify the sample
- Tube cut into three equal parts and middle portion is discarded
- Heat the upper and lower portions of the tube and determine softening point on the binder
- Separation difference of modified bitumen between top and bottom tubes should not be greater than 3 °C

GRADING OF MODIFIED BITUMEN COMPLEX MODULUS TEST

- Complex modulus determined from Dynamic Shear Rheometer (DSR)
- $G^*/\sin\delta$ determined from oscillatory amplitude sweep test at 10 rad/s







GRADING OF MODIFIED BITUMEN COMPLEX MODULUS TEST

- Rutting in bituminous mixtures occurs at high pavement temperatures
- Fatigue cracking in bituminous mixtures occurs at intermediate pavement temperatures
- Low temperature cracking in bituminous mixtures occurs at low pavement temperatures
- Historical air temperature data can be used to estimate pavement temperatures over service life of the pavement
- For PG 64-22, the intermediate temperature = [(64-22)/2]+4°C = 25°C
- Intermediate test temperature should be slightly higher based on field observations

GRADING OF MODIFIED BITUMEN

- Performance grading is reported using two numbers:

PG 64-22

Performance Grade

Average 7-day max. pavement temperature

Min. pavement temperature

High Temperature, °C

Low Temperature, °C	52	58	64	70	76
-16	52-16	58-16	64-16	70-16	76-16
-22	52-22	58-22	64-22	70-22	76-22
-28	52-28	58-28	64-28	70-28	76-28
-34	52-34	58-34	64-34	70-34	76-34
-40	52-40	58-40	64-40	70-40	76-40

= Crude Oil

= High Quality Crude Oil

= Modifier Required

Source: https://www.pavementinteractive.org/wp-content/uploads/2008/10/Pg_grades_with_modifiers.gif

- Binder modification required for temperature difference exceeding 90°C (max.-min.)

GRADING OF MODIFIED BITUMEN

- IS:15462-2004: “Polymer and Rubber Modified Bitumen Specification”, Bureau of Indian Standards, New Delhi

- Revised in 2019 and bifurcated into these two codes:

- IS:15462-2019: “Polymer Modified Bitumen (PMB) - Specification” [First Revision]

- IS:17079-2019: “Rubber Modified Bitumen (RMB) - Specification”

GRADING OF MODIFIED BITUMEN

IS:15462-2019:

- 2004 version was not adequate to reflect field performance of PMB
- If bitumen test temperature is decreased by 6°C, viscosity increases by 2 times
- Requirements of PMB:

Sl No.	Characteristics	Grades and Requirements					Method of Test, Ref to	
		PMB 64-10	PMB 70-10	PMB 76-10	PMB 82-10	PMB 76-22	Annex	IS/ASTM
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(A) Tests to be Carried out on Original Binder								
i)	Softening point (R and B), °C, *Min*	60	65	70	80	75	—	IS 1205
ii)	Elastic recovery of half thread in ductilometer at 15°C, percent, *Min*	70	70	70	85	80	Annex A	—
iii)	Flash point, COC, °C, *Min*	230	230	230	230	230	—	IS 1209
iv)	Viscosity at 150°C, Pa.s, *Max*	1.2	1.2	1.2	1.6	1.5	—	ASTM D 4402
v)	Complex modulus (G*) divided by Sin delta (G*/sin δ) as *Min* 1.0 kPa, 25 mm Plate, 1 mm Gap, at 10 rad/s, at a temperature, °C	64	70	76	82	76	Annex B	—
vi)	Phase Angle (δ), degree, *Max*	75	75	75	75	75	Annex B	—
vii)	Separation, difference in softening point (R&B), °C, *Max*	3	3	3	3	3	Annex C	—
viii)	FRAASS breaking[1] point, °C, *Max*	–10	–10	–10	–10	–22	—	IS 9381
(B) Tests to be Carried out on Rolling Thin Film Oven (RTFO) Residue[2]								
i)	Loss in mass, percent, *Max*	1.0	1.0	1.0	1.0	1.0	—	IS 9382
ii)	Complex modulus (G*) divided by Sin delta (G*/sin δ) as *Min* 2.2 kPa, 25 mm Plate,1 mm Gap, at 10 rad/s at a temperature, °C	64	70	76	82	76	Annex B	—
iii)	MSCR TEST							
	a) Standard Traffic (S) $J_{nr3.2}$, *Max* 4.5 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
	b) Heavy Traffic (H) $J_{nr3.2}$, *Max* 2 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
	c) Very Heavy Traffic (V) $J_{nr3.2}$, *Max* 1 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
	d) Extremely Heavy Traffic (E) $J_{nr3.2}$, *Max* 0.5 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
(C) Tests to be Carried out on Pressure Aging Vessel (PAV) Residue[3]								
i)	Complex modulus (G*) multiplied by Sin delta (G*sin δ) as *Max* 6 000 kPa, 8 mm Plate, 2 mm Gap, at 10 rad/s at a temperature, °C	31	34	37	40	31	Annex C	—

GRADING OF MODIFIED BITUMEN

Performance Grading bitumen tests:

1)Rotational Viscometer (RV)

2)Rolling Thin Film Oven Test (RTFOT)

3)Pressure Aging Vessel (PAV)

4)Dynamic Shear Rheometer (DSR)

5)Bending Beam Rheometer (BBR)

6)Direct Tension Tester (DTT)

FRAAS breaking point is used in IS:15462 (2019) instead of BBR and DTT

ASTM D 6373-15: “Standard Specification for PG Asphalt Binder”

TABLE 1 Performance Graded Asphalt Binder Specification

Performance Grade	PG 46	PG 52	PG 58	PG 64	PG 70	PG 76	PG 82
	−34 −40 −46	−10 −16 − 22 −28 −34 −40 −46	−16 −22 −28 −34 −40	−10 −16 −22 −28 −34− 40	−10 −16 −22− 28 −34 −40	−10 −16 −22 −28 −34	−10 −16 −22 −28 −34
Average 7-day maximum Pavement Design Temperature, °C	<46	<52	<58	<64	<70	<76	<82
Minimum Pavement Design Temperature,° C[A]	> −34 > −40 > −46	> −10 > −16 > −22 > −28 > −34 > −40 > −46	> −16 > −22 > −28 > −34 > −40	> −10 > −16 > −22 > −28 > −34 > −40	> −10 > −16 > −22 > −28 > −34 > −40	> −10 > −16 > −22 > −28 > −34	> −10 > −16 > −22 > −28 > −34
Original Binder							
Flash Point Temp., D92; min °C	230						
Viscosity, D4402:[B] max. 3 Pa·s, Test Temp., °C	135						
Dynamic Shear, D7175:[C] G*/sinδ, min. 1.00 kPa 25 mm Plate, 1 mm Gap Test Temp. at 10 rad/s, °C	46	52	58	64	70	76	82
Rolling Thin Film Oven (Test Method D2872)							
Mass Change, max. percent	1.00						
Dynamic Shear, D7175: G*/sinδ, min. 2.20 kPa 25 mm Plate, 1 mm Gap Test Temp. at 10 rad/s,°C	46	52	58	64	70	76	82
Pressure Aging Vessel Residue (Practice D6521)							
PAV Aging Temperature, °C[D]	90	90	100	100	100 (110)	100 (110)	100 (110)
Dynamic Shear, D7175: G*·sinδ, max 5000 kPa 8 mm Plate, 2 mm Gap Test Temp. at 10 rad/s, °C	10 7 4	25 22 19 16 13 10 7	25 22 19 16 13	31 28 25 22 19 16	34 31 28 25 22 19	37 34 31 28 25	40 37 34 31 28
Creep Stiffness, D6648:[E] S, max 300 MPa, m-value; min. 0.300 Test Temp at 60 s, °C	−24 −30 −36	0 − 6 −12 −18 −24 −30 −36	− 6 −12 −18 −24 −30	0 − 6 −12 −18 −24 −30	0 − 6 −12 −18 −24 −30	0 −6 −12 −18 −24	0 − 6 −12 −18 −24
Direct Tension, D6723:[E] Failure Strain, min. 1.0 % Test Temp. at 1.0 mm/min., °C	−24 −30 −36	0 − 6 −12 −18 −24 −30 −36	− 6 −12 −18 −24 −30	0 − 6 −12 −18 −24 −30	0 −6 −12 −18 −24 −30	0 − 6 −12 −18 −24	0 − 6 −12 −18 −24

[A]Pavement temperatures are estimated from air temperatures using an algorithm contained in the LTPP Bind software program, or are provided by the specifying agency.

[B]The referee method shall be D4402 using a #21 spindle at 20RPM, however alternate methods may be used for routine testing and quality assurance. If the binder is too stiff to test with the No. 21 Spindle, the No. 27 spindle shall be used. The spindle size and shear rate shall be reported. This requirement may be waived at the discretion of the specifying agency if the supplier warrants that the asphalt binder can be adequately pumped and mixed at temperatures that meet all applicable safety standards.

[C]For quality control of unmodified asphalt cement production, measurement of the viscosity of the original asphalt cement may be substituted for dynamic shear measurements of G*/sinδ at test temperatures where the asphalt is a Newtonian fluid. Any suitable standard means of viscosity measurement may be used, including capillary viscometry (Test Methods D2170 or D2171) or rotational viscometry.

[D]The PAV aging temperature is based on simulated climatic conditions and is one of three temperatures 90°C, 100°C or 110°C. Normally the PAV aging temperature is 100°C for PG 58–xx and above. However, in desert climates, the PAV aging temperature for PG 70–xx and above may be specified as 110°C

[E]If the creep stiffness is below 300 MPa, the direct tension test is not required. If the creep stiffness is between 300 and 600 MPa the direct tension failure strain requirement can be used in lieu of the creep stiffness requirement. The m-value requirement must be satisfied in both cases. If the creep stiffness and m-value data are unobtainable because the binder is too soft at the test temperature, the asphalt binder will be deemed to pass at that grade temperature if it meets the creep stiffness and m-value requirements at the test temperature minus 6°C.

GRADING OF MODIFIED BITUMEN

Sl No.	Characteristics	Grades and Requirements					Method of Test, Ref to	
		PMB 64-10	PMB 70-10	PMB 76-10	PMB 82-10	PMB 76-22	Annex	IS/ASTM
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(A) Tests to be Carried out on Original Binder								
i)	Softening point (R and B), °C, *Min*	60	65	70	80	75	—	IS 1205
ii)	Elastic recovery of half thread in ductilometer at 15°C, percent, *Min*	70	70	70	85	80	Annex A	—
iii)	Flash point, COC, °C, *Min*	230	230	230	230	230	—	IS 1209
iv)	Viscosity at 150°C, Pa.s, *Max*	1.2	1.2	1.2	1.6	1.5	—	ASTM D 4402
v)	Complex modulus (G*) divided by Sin delta (G*/sin δ) as *Min* 1.0 kPa, 25 mm Plate, 1 mm Gap, at 10 rad/s, at a temperature, °C	64	70	76	82	76	Annex B	—
vi)	Phase Angle (δ), degree, *Max*	75	75	75	75	75	Annex B	—
vii)	Separation, difference in softening point (R&B), °C, *Max*	3	3	3	3	3	Annex C	—
viii)	FRAASS breaking[1)] point, °C, *Max*	–10	–10	–10	–10	–22	—	IS 9381

GRADING OF MODIFIED BITUMEN

(B) Tests to be Carried out on Rolling Thin Film Oven (RTFO) Residue[2)]								
i)	Loss in mass, percent, *Max*	1.0	1.0	1.0	1.0	1.0	—	IS 9382
ii)	Complex modulus (G*) divided by Sin delta (G*/sin δ) as *Min* 2.2 kPa, 25 mm Plate,1 mm Gap, at 10 rad/s at a temperature, °C	64	70	76	82	76	Annex B	—
iii)	MSCR TEST							
	a) Standard Traffic (S) $J_{nr3.2}$, *Max* 4.5 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
	b) Heavy Traffic (H) $J_{nr3.2}$, *Max* 2 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
	c) Very Heavy Traffic (V) $J_{nr3.2}$, *Max* 1 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
	d) Extremely Heavy Traffic (E) $J_{nr3.2}$, *Max* 0.5 kPa^{-1} J_{nrdiff}, *Max* 75 percent Test Temperature, °C	64	70	76	82	76	Annex D	—
(C) Tests to be Carried out on Pressure Aging Vessel (PAV) Residue[3)]								
i)	Complex modulus (G*) multiplied by Sin delta (G*sin δ) as *Max* 6 000 kPa, 8 mm Plate, 2 mm Gap, at 10 rad/s at a temperature, °C	31	34	37	40	31	Annex C	—

GRADING OF MODIFIED BITUMEN

IS:15462-2019: Selection criteria for PMB:

Service Condition	Pavement Temp Range (*Max* and *Min*), °C				
	64 to (-10)	70 to (-10)	76 to (-10)	82 to (-10)	76 to (-22)
Standard S $J_{nr3200} < 4.5\ kPa^{-1}$	PMB 64-10	PMB 70-10	PMB 76-10	PMB 82-10	PMB 76-22
Heavy H $J_{nr3200} < 2\ kPa^{-1}$	PMB 64-10	PMB 70-10	PMB 76-10	PMB 82-10	PMB 76-22
Very Heavy V $J_{nr3200} < 1\ kPa^{-1}$	PMB 64-10	PMB 70-10	PMB 76-10	PMB 82-10	PMB 76-22
Extremely Heavy E $J_{nr3200} < 0.5\ kPa^{-1}$	PMB 64-10	PMB 70-10	PMB 76-10	PMB 82-10	PMB 76-22

1) **Standard Service Condition** — Traffic levels fewer than 10 million Equivalent Single Axle Loads (ESALs) and more than the standard traffic speed (>70 km/h).
2) **Heavy Service Condition** — Traffic levels 10-30 million ESALs or slow-moving traffic (20 to 70 km/h).
3) **Very Heavy Service Condition** — Traffic levels of greater than 30 million ESALs or very slow moving/ standing traffic («20 km/h)
4) **Extremely Heavy Service Condition** — Traffic levels of greater than 30 million ESALs and very slow moving/ standing traffic («20 km/h)

GRADING OF MODIFIED BITUMEN

IS:15462-2019: Calculation of Pavement Temperatures:

a) Since only air temperatures are available from weather data, the following equation may be used to estimate the Average Maximum Pavement Temperature (at a depth of 20 mm) from high air temperature and latitude of the project location based on State Highway Research Program (SHRP) research:

$$T_{20mm} = (T_{air} - 0.00618\,L^2 + 0.2289\,L + 42.2)\,(0.9545) - 17.78$$

where,

T_{20mm} — average Maximum Pavement Temperature at 20 mm below the road surface;

T_{air} — high air temperature; and

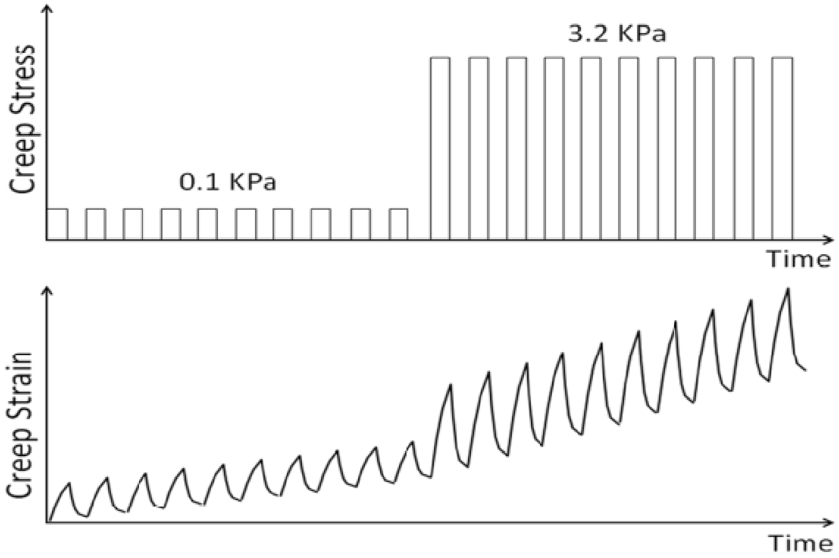
L — latitude in degrees of the project location.

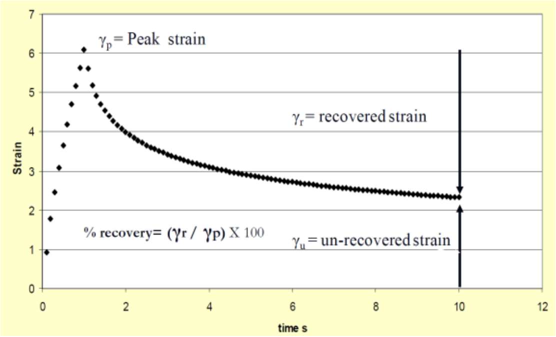
Example — Churu (Rajasthan) has high air temperature of 50°C and its latitude is 28.3 degrees N. The Average Maximum Pavement Temperature computed from the above equation works out to be 71.7°C. Therefore, a PMB 76 should be used in Churu.

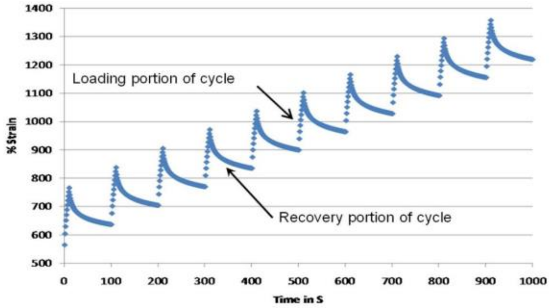
b) For low pavement temperatures, the lowest air temperature may be used as Minimum Pavement Temperature.

GRADING OF MODIFIED BITUMEN

Multiple Stress Creep and Recovery:







Source: https://www.fhwa.dot.gov/pavement/materials/pubs/hif11038/hif11038.pdf

GRADING OF MODIFIED BITUMEN

Multiple Stress Creep and Recovery:

- Test temperature: PG upper temperature
- 25 mm plate, 1 mm gap
- Loading for 1s and recovery for 9 s
- Ten creep and recovery cycle each at 0.1 kPa and 3.2 kPa creep stress
- Record stress and strain at 0.1 s intervals for creep cycle and 0.45 s intervals for recovery cycle
- Record data points at 1 s and 10 s for each cycle
- ε_0 is initial strain at beginning of creep portion of each cycle
- ε_c is strain at the end of the creep portion (after 1 s) of each cycle
- ε_1 is adjusted strain at the end of creep portion (after 1 s) of each cycle
- ε_r is strain at the end of recovery portion (after 10 s) of each cycle
- ε_{10} is adjusted strain at the end of recovery portion (after 10 s) of each cycle

$$\varepsilon_1 = \varepsilon_c - \varepsilon_0$$

$$\varepsilon_{10} = \varepsilon_r - \varepsilon_0$$

$$\varepsilon_{r(100,\,N)} = (\varepsilon_1 - \varepsilon_{10}) \times 100 / \varepsilon_1$$

$$\varepsilon_{r(3200,\,N)} = (\varepsilon_1 - \varepsilon_{10}) \times 100 / \varepsilon_1$$

$$R_{100} = \text{SUM}\,[\varepsilon_{r(100,\,N)}] / 10 \quad \text{for } N = 1 \text{ to } 10$$

$$R_{3200} = \text{SUM}\,[\varepsilon_{r(3200,\,N)}]/10 \quad \text{for } N = 1 \text{ to } 10$$

$$R_{diff} = [(R_{100} - R_{3200}) \times 100] / (R_{100})$$

$$J_{nr(100,\,N)} = \varepsilon_{10} / 100$$

$$J_{nr(3200,\,N)} = \varepsilon_{10} / 100$$

$$J_{nr100} = \text{SUM}\,[J_{nr(100,\,N)}] / 10 \quad \text{for } N = 1 \text{ to } 10$$

$$J_{nr3200} = \text{SUM}\,[J_{nr(3200,\,N)}] / 10 \quad \text{for } N = 1 \text{ to } 10$$

$$J_{nr-diff} = [(J_{nr3200} - J_{nr100})100] / (J_{nr100})$$

GRADING OF MODIFIED BITUMEN

Multiple Stress Creep and Recovery:

- Test temperature: PG upper temperature
- 25 mm plate, 1 mm gap
- Loading for 1s and recovery for 9 s
- Ten creep and recovery cycle each at 0.1 kPa and 3.2 kPa creep stress
- Record stress and strain at 0.1 s intervals for creep cycle and 0.45 s intervals for recovery cycle
- Record data points at 1 s and 10 s for each cycle

- ε_0 is initial strain at beginning of creep portion of each cycle
- ε_c is strain at the end of the creep portion (after 1 s) of each cycle
- ε_1 is adjusted strain at the end of creep portion (after 1 s) of each cycle
- ε_r is strain at the end of recovery portion (after 10 s) of each cycle
- ε_{10} is adjusted strain at the end of recovery portion (after 10 s) of each cycle

$$\varepsilon_1 = \varepsilon_c - \varepsilon_0$$

$$\varepsilon_{10} = \varepsilon_r - \varepsilon_0$$

$$\varepsilon_{r(100,\,N)} = (\varepsilon_1 - \varepsilon_{10}) \times 100 / \varepsilon_1$$

$$\varepsilon_{r(3200,\,N)} = (\varepsilon_1 - \varepsilon_{10}) \times 100 / \varepsilon_1$$

$$R_{100} = \text{SUM}\,[\varepsilon_{r(100,\,N)}] / 10 \quad \text{for } N = 1 \text{ to } 10$$

$$R_{3200} = \text{SUM}\,[\varepsilon_{r(3200,\,N)}]/10 \quad \text{for } N = 1 \text{ to } 10$$

$$R_{diff} = [(R_{100} - R_{3200}) \times 100] / (R_{100})$$

From ASTM D 7405 - 15

$$J_{nr}(0.1, N) = \frac{\varepsilon_{10}}{0.1}$$

$$J_{nr}(3.2\,,\quad N) = \frac{\varepsilon_{10}}{3.2}$$

$$J_{nr100} = \text{SUM}\,[J_{nr(100,\,N)}] / 10 \quad \text{for } N = 1 \text{ to } 10$$

$$J_{nr3200} = \text{SUM}\,[J_{nr(3200,\,N)}] / 10 \quad \text{for } N = 1 \text{ to } 10$$

$$J_{nr-diff} = [(J_{nr3200} - J_{nr100})100] / (J_{nr100})$$

GRADING OF MODIFIED BITUMEN

IS:17079-2019:

- PMB and RMB differ in composition, method of preparation and product performance (thus, bifurcated)
- IS:15462 (2004) had 3 grades of CRMB: CRMB 50, CRMB 55, CRMB 60; NRMB had three grades: NRMB 40, NRMB 70, NRMB 120
- Last decade (ref. 2019), no production or demand for CRMB 50 and NRMB 120
- Thus, only two grades of CRMB and NRMB are included in IS: 17079 (2019) [CRMB 55, CRMB 60; NRMB 40, NRMB 70]
- Moisture in crumb rubber < 0.75% by weight
- Specific gravity of crumb rubber: 1.15 ± 0.05
- Crumb rubber particle size < 0.6 mm
- Ferrous metal particles < 0.01% by weight
- Should not contain visible non-ferrous particles

GRADING OF MODIFIED BITUMEN

IS:17079-2019: Requirements of NRMB:

Sl No.	Characteristics	Requirements		Method of Test, Ref to	
		NRMB 70	NRMB 40	IS No.	Annex
(1)	(2)	(3)	(4)	(5)	(6)
i)	Penetration at 25°C, 0.1 mm, 100 g, 5 s, *Min*	50	30	1203	–
ii)	Softening point (R and B), °C, *Min*	55	60	1205	–
iii)	Flash point, COC,°C, *Min*	220	220	1209	–
iv)	Elastic recovery of half thread in ductilometer at 15°C, percent, *Min*	40	30	–	A
v)	Separation, difference in softening point, R and B, °C, *Max*	4	4	–	B
vi)	Viscosity at 150°C, Poise	2-6	3-9	1206 (Part 2)	–
vii)	Thin film oven test and tests on residue				
	a) Loss in mass, percent, *Max*	1.0	1.0	9382	–
	b) Change in Softening Point, °C, *Max*	6	5	1205	–
	c) Reduction in penetration of residue at 25°C, percent, *Max*	40	40	1203	–
	d) Elastic recovery of half thread in ductilometer at 25°C, percent, *Min*	25	20	–	A

GRADING OF MODIFIED BITUMEN

<u>IS:17079-2019:</u> Requirements of CRMB:

Sl No.	Characteristics	Requirements		Method of Test, Ref to	
		CRMB 55	CRMB 60	IS No.	Annex
(1)	(2)	(3)	(4)	(5)	(6)
i)	Penetration at 25°C, 0.1 mm, 100 g, 5 s	60-30	50-20	1203	–
ii)	Softening point (R and B), °C, *Min*	55	60	1205	–
iii)	Flash point, COC,° C, *Min*	220	220	1209	–
iv)	Elastic recovery of half thread in ductilometer at 15°C, percent, *Min*	60	60	–	A
v)	Complex modulus as (G*/Sin) as *Min* 1.0 kPa at 10 rad/s at a temperature, °C	64	70	15462	–
vi)	Separation, difference in softening point, R&B, °C, *Max*	4	4		B
vii)	Viscosity at 150°C, Poise	4-8	6-12	1206 (Part 2)	–
viii)	Thin film oven test and tests on residue				
	a) Loss in mass, percent, *Max*	1.0	1.0	9382	–
	b) Change in Softening Point, °C , *Max*	5	5	1205	–
	c) Reduction in penetration of residue at 25°C, percent, *Max*	35	35	1203	–
	d) Elastic recovery of half thread in ductilometer at 25°C, percent, *Min*	35	35	–	A
	e) Complex modulus as (G*/Sin) as *Min* 2.2 kPa at 10 rad/s at a temperature, °C	64	70	15462	–