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GUIDELINES ON USE OF MODIFIED BITUMEN IN ROAD CONSTRUCTION

(SECOND REVISION)

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1 INTRODUCTION

1.1 During the Second Meeting of Flexible Pavement Committee (H-2) held on 05 September, 2009 the Convenor Shri A.V. Sinha expressed the urgency of revision of IRC:SP:53-2002 and a Sub-group under the Chairmanship of Shri S.C. Sharma consisting of Dr. Sunil Bose, Dr. B.R. Tyagi and Shri S.K. Nirmal was formed to revise the document. The H-2 Committee in its fifth meeting held on 24 April, 2010 approved the revised document presented by the Sub-group. The Personnel of Flexible Pavement Committee (H2) as on 24 April, 2010 are as follows :

Sinha, A.V.	...	Convenor
Bose, Dr. Sunil	...	Co-Convenor
Nirmal, S.K.	...	Member-Secretary

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Secretary General, IRC	(Indoria, R.P.)

The revised draft document was subsequently approved with some suggestions by the Highways Specifications and Standards Committee in its meeting held on 01 May, 2010. The draft document was approved by the Executive Committee in its meeting held on 10 May, 2010. The Council in its meeting held at Munnar, (Kerala) on 22 May, 2010 approved the document with some comments. The document after incorporating comments of Council Members was approved by the Convenor of Highways Specifications & Standards Committee for printing.

1.2 Flexible pavements with bituminous surfacing are widely used in India. The high traffic intensity in terms of commercial vehicles, overloading of trucks and significant variations in daily and seasonal temperature of the pavement have been responsible for early development of distress like rutting, cracking, bleeding, shoving and potholing of bituminous surfacing. A factor, which causes concern in India, is very high and very low pavement temperature conditions in some parts of the country. Under these conditions the bituminous surfacing tends to become soft in summer and brittle in winter.

1.3 Studies have revealed that properties of bitumen and bituminous mixes can be improved/modified with the incorporation of certain additives or blend of additives. These additives are called "Modifiers" and the bitumen premixed with these modifiers is known as "Modified Bitumen". Use of modified bitumen in the top layers of the pavement is expected to significantly enhance the life of the surfacing and extend the time of the next renewal. Full-scale performance studies on overlay carried out by the various research institutions, Indian Institutes of Technology under the aegis of Ministry of Road Transport and Highways; Central Road Research Institute; Highways Research Station, Chennai; Rubber Board, Kerala; Gujarat Engineering Research Institute; and various state Public Works Departments revealed that the use of Modified Bitumen in construction/maintenance of bituminous roads significantly improve the pavement performance and is cost effective, when life-cycle cost is taken into consideration.

1.4 IS 15462:2004 classify the polymer and rubber modified bitumen into the following four types:

a) PMB(P) Plastomeric thermoplastic based

b) PMB(E) Elastomeric thermoplastic based

c) NRMB Natural rubber and SBR latex based, and

d) CRMB Crumb rubber/ treated crumb rubber based.

These are further divided into three grades based on the penetration value/softening point value, as relevant.

The above types of modified bitumen binders are recommended for use in road works.

In this document, the above four types of modified bitumen have been referred to by generic names-modified bitumen without specifying the type of modifier. The specification requirement in respect of some of the properties have been upgraded in view of the fact that with the growing use of new equipment and technology, it is now possible to manufacture products to higher specification. Besides, considerable experience has been gained over the years regarding their manufacture, use and performance.

The specification requirements of modified bitumen for various climatic conditions are given in **Table 2.** The user can specify any type of modified bitumen as per IS classification subject to the condition that the chosen product meets the specification requirements given in Table 2.

1.5 A simple test for defining elastic properties of a modified binder by measuring its torsional recovery has been specified.

2 SCOPE

These guidelines deal with the specifications and use of Modified Bitumen binders in road construction & maintenance works, their advantages, application, manufacturing of modified bitumen, transportation, storage, testing, quality control and quality assurance requirements.

3 ADVANTAGES OF MODIFIED BITUMEN

3.1 Properties of modified bitumen depend upon type and quantity of modifier used and process adopted for their manufacture. The advantages of modified bitumen can include one or more of the following for road works:

- Lower susceptibility to temperature variations
- Higher resistance to deformation at high pavement temperature
- Delay of cracking and reflective cracking
- Better age resistance properties
- Better adhesion between aggregates and binder
- Higher fatigue life of mixes
- Overall improved performance

3.2 The choice of modified bitumen may be made on the basis of traffic, climate, and overall life cycle cost analysis, where data is available.

4 GENERAL REQUIREMENTS OF MODIFIERS

4.1 Modified Bitumen is obtained with the incorporation of selected thermoplastic polymers (Plastomeric or Elastomeric), crumb rubber or natural rubber in bitumen. When used as bitumen modifier, selected polymers/rubbers or a blend of these should have the following properties:

i) Compatible with bitumen
ii) Resist degradation at mixing temperature
iii) Capable of being processed by conventional mixing and laying machinery
iv) Produce coating viscosity at application temperature
v) Maintain premium properties during storage, application and in service
vi) Capable of providing homogeneous blend with bitumen.

4.2 A number of proprietary products are available in market, with which bitumen can be modified. These modifiers shall comply with the above requirements besides conformity to specifications. Products shall be evaluated for their suitability in an approved laboratory.

5 TYPE OF BITUMEN MODIFIERS

5.1 Over the years, different types of materials have been investigated as modifiers for bitumen modifications. The commonly used modifiers are given in **Table 1**. The modifier should be compatible with bitumen to achieve the required properties.

5.2 Proprietary products may contain a blend of different polymer additives to achieve improvement in properties of bitumen for road works.

Table 1 Classification of Rubber and Polymer Based Bitumen Modifiers

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

6 APPLICATIONS OF MODIFIED BITUMEN

6.1 Since a bituminous mix prepared with modified bitumen has a higher stiffness modulus, enhanced fatigue life, better resistance to creep and higher indirect tensile strength, it is suitable as a wearing course, a binder course and overlay material on surfaces which are cracked and subjected to heavy traffic. Modified binders are also used for application like Stress Absorbing Membrane (SAM) for sealing of cracks, Stress Absorbing Membrane Interlayer (SAMI) for delaying reflection cracking, Porous Asphalt and Stone Matrix Asphalt (SMA).

6.2 Modified bitumen performs better than conventional bitumen in situations, where the aggregates are prone to stripping. Due to their better creep resistance properties, they can also be used at busy intersections, bridge decks and roundabouts for increased life of the surfacing.

7 MANUFACTURING

7.1 The manufacturer shall establish, document and maintain a quality system to ensure that the products supplied conform to the specifications. The quality system shall consist of procedures, regular inspections and tests and/ or assessment and the use of results to control the quality of the finished product. All the equipment used in the manufacturing process shall be regularly inspected, calibrated and maintained to ensure that normal wear and tear or failure does not cause inconsistency in the manufacturing process.

7.2 Bitumen used for modification will fully comply with IS 73 Indian Standard Specification for paving bitumen. The acceptance criteria for modifiers such as polymer, natural rubber, crumb rubber and additives shall be documented for ensuring their conformity with the specifications.

The processes used to manufacture modified bitumen are generally proprietary and different processes are used by various suppliers.

If a modifier in powder form is used, the blending plant should be fitted with a homogenizer like high shear mill or any other device capable of producing a homogeneous blend. The addition of modifier in latex form requires special blending equipment to eliminate the entrapment of moisture which can result in excessive foaming during the blending process.

The modifier into the bitumen should be cured/ digested at an appropriate temperature in a curing tank fitted with heating arrangement, agitator and circulation facility for an optimum time period to attain the desirable properties of the modified bitumen. Full fledged testing facility is essentially required at the blending plant. The storage tanks should have minimal surface area to minimize oxidation and equipped with mixing and circulation equipment to ensure the homogeneity of the product during storage. While modified binders are generally manufactured for immediate delivery, any extended storage must be documented and monitored to ensure that product conforms to the specification characteristics.

7.3 All supply lines throughout the plant, including loading equipment, shall be designed and procedures established so as to avoid contamination during change of product or cleaning of supply lines. Where lines need to be flushed, it should be done with hot bitumen or finished product.

7.4 The manufacturer shall establish procedures to ensure that conformance to the specified characteristics are maintained. Where testing is required on each batch, a batch is considered to be the quantity of binder produced and stored in one tank once the production run into that tank has been completed. The batch can be considered to remain the same as long as no new production has been added.

8 SPECIFICATION REQUIREMENTS FOR MODIFIED BITUMEN

8.1 The requirements of modified bitumen are given in **Table 2**.

8.2 For snow bound area, Fraass breaking point values of modified bitumen will be taken into account. The value of Fraass breaking point shall be less than 7 days minimum atmospheric temperature of the area or as indicated in **Table 2.**

8.3 For checking the elastic recovery of modified binder, Field Engineer shall test for Torsion recovery at 25°C using Torsion recovery method as per **Annexure – 4.** The Torsional recovery value shall not be less than half of the Elastic recovery value at 15°C as indicated in the laboratory testing.

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)	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 δ) 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 δ 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.

9 TRANSPORTATION

9.1 Modified bitumen shall be transported and applied hot. Safety and handling procedures that are applicable for hot bituminous materials also apply to modified bitumen.

9.2 Vehicles used for transportation of modified bitumen must have proper insulation to minimize heat losses, heating arrangements and arrangements for circulation. These vehicles shall be emptied of the previous product to the minimum practical level and be clear of cleaning materials before loading. Vehicles previously used for delivery of cutback bitumen or bitumen emulsion products shall not be used for the delivery of modified bitumen unless thoroughly cleaned, e.g. at least one load of hot bitumen has been put through the tanker to remove traces of other products. Care shall be taken to ensure that tankers which have not been in use for sometime are free from condensation.

9.3 Reheating of bitumen during transportation should be avoided. Incase bitumen viscosity at delivery is not adequate for pumping, bitumen shall be gradually heated to bring it to an appropriate temperature for pumping. The rate of heating shall be such that the increase in temperature of modified bitumen does not exceed 15^{0}C per hour. Where there is only a small loss in temperature, modified bitumen may be transferred directly into storage tanks without reheating.

9.4 Storage tanks for modified bitumen must be properly insulated, have heating and agitating/effective circulation facilities to ensure homogeneity. For circulation the inlet should be close to bottom at one end of storage tank and outlet near the top at another end of the storage tank to ensure effective circulation. Return lines in a recirculation system should re-enter the storage tank below the bitumen surface to prevent hot bitumen cascading through the air.

Where modified bitumen is placed in a storage tank previously used for straight bitumen or a different grade of modified bitumen, the tank shall be emptied to the minimum practicable level in order to minimize any dilution effect on the modifier content of the delivered modified bitumen.

9.5 Storage Temperature and Time

9.5.1 The binder shall be stored at minimum pumping temperature and not at the application temperature. The binder shall only be heated to the application temperature just prior to use to limit degradation of modifier. The binder should not be allowed to solidify in the storage tank.

Obtain a method statement from the supplier as the correct handling and storage temperature for the modified bitumen.

9.5.2 The following Table gives guidance regarding storage temperature and time:

Modified Binder	Binder Temperature °C at point of mixing	Holding Time at Mixing Temperature (max)	Temperature for Medium-Time Storage Period (°C)	Medium-Time Storage Period
Blended from Specified modifiers	170-185	4 days	130-140	14 days

When modified bitumen is required to be stored at a temperature less than 100°C or at ambient, then reheating should be done gradually and the hot oil inlet temperature or surface temperature of the heating elements must not exceed 200°C. During reheating, the product must be agitated and recirculated to ensure homogeneity.

10 DESIGN OF MIXES

10.1 The mix design for dense graded bituminous mixes using modified bitumen shall be done in the same manner as used for conventional bitumen by Marshall Method of Mix Design (MS 2). The requirements of mixes with modified bitumen are indicated in **Table 3.**

Table 3 Requirements of Mix Prepared with Modified Bitumen

Sl. No.	Properties	Requirement			Method of Test
		Hot Climate	Cold Climate	High Rainfall	
1)	Marshall Stability (75 blows) at 60°C, kg, Minimum	12kN	10kN	12kN	MS :2
2)	Marshall Flow at 60°C, mm	2.5-4.0	3.5-5.0	3.0-4.5	MS: 2
3)	Marshall Quotient, kg/mm	250-500			Stability – Flow
4)	Voids in compacted mix, %	3.0-5.0			
5)	Modified Binder content by weight of Mix - Minimum **	BC - Grading 1 * – 5.4% Grading 2 * – 5.6% SDBC - Grading 1 – 4.7% Grading 2 – 5.2% DBM - Grading 1 – 4.3% Grading 2 – 4.7%			
6)	Requirement of retained stability after 24 hours in water at 60°C, %, Minimum	90	95	100	MS:2
7)	Coating with aggregate, %	95	95	100	AASHTO T 182

* Grading 1 & 2 corresponds to IRC:111.

** Corresponds to specific gravity of the Aggregate being 2.7. In case aggregate have specific gravity more than 2.7, bitumen content can be reduced proportionately. Further, for regions where highest daily mean air temperature is 30°C or lower and lowest daily mean air temperature is – 10°C or lower, the bitumen content may be increased by as much as 0.5 percent.

11 CONSTRUCTION OPERATION

The hot mix construction using modified bitumen should be carried out when the atmospheric temperature is above 15°C. The properties of dense graded bituminous mixes prepared with modified bitumen shall be in compliance with the requirements given in **Table 3.**

11.1 IRC or MORTH Specifications and Guidelines shall be applicable for construction of roads with modified bitumen. There should be at least 2 vibratory rollers, alternately, one Vibratory roller and one Pneumatic tyre roller placed as close to the paver as possible, this will reduce cooling of the mix and shall ensure proper compaction within the stipulated time. The quantity of water used should be enough to ensure wetting of the roller wheels but excess water should not be used at any cost.

11.2 The temperature of mixing and rolling shall be higher than conventional bituminous mixes. The broad range of temperature at different stages is given in **Table 4.** The exact temperatures depend upon the type and amount of modifier used and shall be adopted as per advice of supplier.

Table 4 Broad Range of Temperature Requirements for Modified Binders

Stage of Work	Indicated Temperature (°C)
Binder at mixing	165-185
Aggregates temperature	165-185
Mix at mixing plant	150–170
Mix at laying site	130-160
Rolling at laying site	115-155

11.3 The specifications for various items of road works using modified bitumen are same as those for conventional grade bitumen except those for any special conditions, which the manufacturer of modified bitumen will indicate in technical literature of product.

11.4 The other control during mixing, laying, shall be same as specified in IRC:111, for dense asphalt concrete, semi-dense bituminous concrete and dense bituminous macadam respectively or as indicated in technical literature of product.

12 QUALITY ASSURANCE IN STORAGE AND HANDLING OF MODIFIED BITUMEN AND MIXES AT SITE

12.1 The main objective of the quality assurance process is to ensure that product supplied meets the required specification and that the quality of the binder be maintained until it is applied. From the time the product is dispatched from the blending plant it is exposed to the risk of degradation unless the binder is handled in the correct way. To ensure that the properties of the applied modified binder have not changed significantly from that of the original product dispatched from the blending plant, the following quality control measures are recommended:

i) The supplier must conduct the necessary tests on the product to ensure that it meets the specification requirements before dispatching the product.

ii) Samples should be taken from the tanker while discharging the product on-site and retained for further testing in the case of a dispute. . The sample size should not the less than 1 kg.

iii) The retention samples for each batch should be kept in the custody of the engineer till the completion of the project or as specified in the contract.

iv) The supplier should supply a laboratory certificate for each batch stating the binder properties. This should include the indicative tests like softening point, penetration, viscosity, elastic recovery and phase separation. The tests for complex modulus shall be provided for the batch specified by the engineer.

v) Samples should be taken from the site storage tank on a daily basis and tested prior to application and tested for penetration, softening point, viscosity, storage stability and torsional recovery.

vi) Product not applied can be returned to storage and retested for compliance prior to further use. All samples must be clearly labeled with all relevant details for ease of identification and traceability.

vii) It is recommended that correlation testing be done between the laboratories or supplier and user before commencement of the binder supply to identify any variations in test results.

viii) Prior to the commencement of a contract, the full spectrum of tests should be conducted on the first batch of the product to demonstrate the supplier's ability to comply with the specification. Thereafter, the respective tests are to be conducted at an agreed frequency unless there is a change in the source of raw material (base bitumen or polymer grade). The supplier must also provide a set of curves showing the changes in the softening point and viscosity properties with time for the modified bitumen.

12.2 Site Quality Control Plan

The following quality control tests are to be carried out:

i) The contractor's production programme and the binder quantities required on a daily basis including procedures for ordering product including minimum lead times should be notified in advance.

ii) On-site binder storage requirements to meet the demand, including heating and pumping requirements must be indicated.

iii) Environment management plan for the storage, spillage and waste disposal of binders and flushings is to be notified and meticulously followed.

iv) Modified bitumen supplied in bulk, drums or bags shall be agitated/re-circulated in hot condition using suitable device before use to ensure homogeneity of the product.

v) Manufacturer of proprietary products shall be responsible to provide full details to user for special precautions needed for their products at site or may depute their technical personnel, if required.

vi) Multiple heating of modified bitumen shall be avoided to retain its premium properties.

13 SAMPLING AND CRITERIA

13. Sampling and criteria for conformity shall conform to the requirement of IS 15462:2004.

Annex-1

(Table - 2)

METHOD FOR DETERMINATION OF COMPLEX MODULUS

Scope

This method covers the determination of complex modulus (G*), Phase angle (Sin δ) and G*/Sin δ of modified bituminous binders. This standard is appropriate for unaged material and material aged in thin film oven or rolling thin film oven. A particulates material in binder is limited to particles with longest dimensions less than 300 micrometer.

Significance and Use

The test temperature for this test is related to the temperature experienced by the pavement in the geographical area for which the use of binder is intended. The shear modulus is an indicator of stiffness or resistance of binder to deformation under load at specified temperature. The complex (G*) modulus and phase angle (Sin δ) define the resistance to deformation of the binder in the visco-elastic region. The complex modulus and phase angle are used to evaluate performance aspect of modified bitumen, where elastic recovery is insignificant.

Summary of Test Method

This standard contains the procedure used to measure the complex modulus (G*), phase angle (sin δ) and shear modulus (G*/ Sin δ) of binders using a Dynamic Shear Rheometer (DSR) and parallel plate test geometry. The standard is suitable for use when the complex modulus (G*) varies between 100 Pa and 10 Mpa. The range of test temperature lies in between 35°C and 85°C depending upon grade, type and conditioning of the test sample. Test specimen of 1mm thick, 25 mm diameter or 2 mm thick and 8 mm diameter as prepared between parallel metal plates. During the testing, one of the parallel plates is oscillated with respect to the other at pre-selected frequency and rotational deformation amplitudes. The required amplitudes depend upon the values of complex shear modulus of binders being tested. The required amplitudes depend upon the values of complex shear modulus of binders being tested. The test specimen is maintained at the test temperature within ± 0.1°C by heating and cooling of upper and lower plates. The recommended frequency of testing is 10 rad/s. The complex modulus (G*) and phase angle (Sin δ) are calculated as apart of the operation of the rheometer using software available with the equipment.

Test Equipment

The test equipment comprises following items:

a) ***Dynamic Shear Rheometer Test System*** – A dynamic shear rheometer consisting of parallel metal plates, an environmental chamber, a loading device and a control and data acquisition system.

b) ***Test Plates*** – Metal test plates with polished surface, one 8 ± 0.5 mm in diameter and one 25 ± 0.05 mm in diameter. The base plate in some rheometer is a flat plate.

c) ***Environmental Chamber*** – A chamber for controlling the test specimen temperature by heating or cooling. The medium for heating and cooling the specimen in the environmental chamber is either a gas or liquid that will not affect binder properties. The temperature in the chamber may be controlled by the circulation of fluid or conditioned gas. When the air is used as medium a suitable drier must be included to prevent condensation of moisture on the plates and fixture.

d) ***Temperature Controller*** – A temperature controller capable of maintaining specimen temperature within ± 0.1°C for the test temperature ranging from 35 to 85°C is needed. A resistance thermal detector mounted inside the environmental chamber, in intimate with fixed plate with a range of 35 to 85°C readable to the nearest 0.1°C. The detector shall be used to control the temperature in the chamber and provide continuous read out of the temperature during the mounting, conditioning and testing of the specimens.

e) ***Loading Device*** – The loading device shall be capable to apply a sinusoidal oscillatory load to the specimen at the frequency of 10 rad/s. The loading device shall be capable of providing either a stress-controlled load. If the load is strain controlled the loading shall apply a cyclic torque sufficient to cause an angular rotational strain accurate to with in 100 micron radian of the strain specified. If the load is stress controlled, the loading device shall apply a cyclic torque accurate to within 10mN.m of the torque specified. Total system compliance to 100 N.m torque shall be <2m. rad/N.m.

f) ***Control and Data Acquisition System*** – The control and data acquisition system shall provide a record of temperature, frequency, deflection angle and torque. The system shall be capable to record and calculate the shear stress, shear strain, complex shear modulus and phase angle of binder at specified test temperature.

g) ***Specimen Mould*** – A silicone rubber mould for preparation of test specimen.

h) ***Specimen Trimmer*** – A specimen rubber mould for preparation of test specimen.

i) ***Calibrated Temperature Detector*** – A calibrated thermocouple, thermistor, or Resistance Temperature Detector (RTD) with a thickness or diameter < 2.0 mm is suitable for measuring the temperature of a dummy specimen sample of binder. Thermocouples and thermistors are not reliable to ± 0.1°C unless calibrated to a standard traceable to the National Institute of Standard and Technology (NIST) and must be calibrated with associated meters or circuitry. Platinum RTDs are typically not suitable because they are too large to fit in the gaps between the plates in the DSR.

Preparation of Test Specimen

A disk of binder with diameter equal to the oscillating plate (often called a spindle) of the DSR is needed for testing. There are two ways to prepare the sample for testing (1) Bitumen binder can be poured directly onto the spindle in sufficient quantity to provide the appropriate thickness of material, or (2) a mould can be used to form the disk of material to be tested. Then the disk can be place between the spindle and fixed plate of DSR. In the first method, operator should have sufficient experience to apply exact quantity of binder. In the second method, binder is heated until fluid to pour. The heated binder is poured in to a rubber mould and allowed to cool. The mould consisting of binder may be placed in a refrigerator until it attains solid consistency. Then the sample is removed from the mould and placed between the fixed plate and oscillating spindle of the DSR. The excess binder beyond the edge of the spindle should be trimmed. Regardless of the method used for preparation of the specimen, the final step in preparing the specimen is to slightly readjust the gap between the spindle and the lower plate so that a slight bulge is evident near the edge of the spindle. The step is normally occurring immediately prior to the testing. The thickness of the bitumen binder disk sandwiched between the spindle and fixed plate must be carefully controlled. The proper specimen thickness is achieved by adjusting the gap between the spindle and fixed plate. This gap must be set before mounting the binder sample, but while spindle and base plate are mounted in the rheometer at the test temperature, the gap is adjusted by means of a micrometer wheel. The micrometer wheel is graduated usually in units of micron. Turning the wheel allows precise positioning the spindle and base plate related to each other. On some rheometer, the micrometer wheel moves the spindle down. On other, it moves the base plate up. Thickness of the gap depends on the test temperature. High test temperature of 46°C or greater require a small gap of 1 mm. High temperature measurement requires a large spindle (25 mm) and low temperature a small spindle (8 mm). With the specimen mounted, the operator shall set the gap at the desired value of 1,000 or 2,000 micron. After the specimen is trimmed flush with upper plate, the extra 50-micron is dialed so that gap is exactly at the desired value and specimen bulges slightly.

Test Procedure

Bring the specimen to the test temperature ± 0.1°C. After the sample is correctly in place and test temperature appear stable then allow the specimen for 10 minutes minimum at the set temperature of the specimen to equilibrate. The actual temperature equilibration time is equipment dependent and should be checked using a dummy specimen with very accurate temperature sensing capabilities.

When operating in a strain control mode, testing consists of using the rheometer software to select appropriate strain value as under:

Material	KPa	Target Strain, %	Strain Range, %
Original binder	1.0 (G*/Sin δ)	12	9-15
TFOT residue	2.2 (G*/Sin δ)	10	8-12

When operating in a stress controlled mode, select an appropriate stress level using software as under:

Material	KPa	Target Stress, %	Stress Range, %
Original binder	1.0 (G*/Sin δ)	0.12	0.09-0.15
TFOT residue	2.2 (G*/Sin δ)	0.22	0.18-0.26

Testing consists of using rheometer software to set the DSR to apply a constant oscillating stress and recording the resulting strain and time lag. The specification requires oscillation speed to 10 rad/s, which is approximately 1.59 hz. A computer is used with DSR to control test parameter and record test results. The operator need not worry about setting the value of applied stress. Instead, the operator should set the approximate value of shear strain. Shear strain values vary from 1-12 percent and depend on the stiffness of the binder being used. Relatively soft materials tested at high temperature are tested at strain values of approximately 10-12 percent. Hard materials are tested at strain value of about 1 percent. In the initial stage of the test, rheometer measures the stress required to achieve the set shear strain and then maintain this stress very precisely during the test. The shear strain can vary small amounts from the set value to achieve the constant stress. Variation in shear strain is normally controlled by rheometer software. In the beginning of the test, the sample is first conditioned by loading the specimen for 10 cycles and then 10 additional cycles are applied to obtain test data. The rheometer software automatically computes and reports values of complex modulus (G*) and phase angle (Sin δ).

Interpretation of Results and Data Presentation

The complex modulus (G*) and phase angle (Sin δ) decrease with increasing shear strain. A linear region may be defined as small region where the modulus is relatively independent of shear strain. This region will vary with magnitude of complex modulus. The linear region is defined as range in strains where the complex modulus is 95 percent or more of the zero strain value. The shear stress varies nearly from 0 at the centre of the plates to a maximum at the extremities of the plate perimeter. The shear stress is calculated from the applied or measured torque, measured or applied strain and the geometry of the test specimen. For the present specification only, values of G* and Sin δ are required. A complete report includes following parameters:

a) G* to the nearest three significant figures,

b) Sin δ to the nearest 0.1 degrees,

c) Test plate size to nearest 0.1 mm and gap to nearest 1 μm,

d) Test temperature to the nearest 0.1°C,

e) Test frequency to the nearest 0.1 rad/s, and

f) Strain amplitude to the nearest 0.01 percent.

The test temperature as per requirement of specification for complex modulus value of 1kPa (G*/Sin δ) for original binder and 2.2 kPa (G*/Sin δ) for residue of thin film over test shall be calculated from the plot of (G*/Sin δ) and temperature for compliance of specification.

Annex-2
(Table 2)

METHOD FOR ELASTIC RECOVERY TEST

The elastic recovery of modified bitumen is evaluated by comparing recovery of thread after conditioning specimen for 1 hour at specified temperature and the specimen is elongated upto 10 cm deformation in a ductility machine. This is mainly intended to assess degree of bitumen modification and quality of modified bitumen. The cross-section of thread shall be as shown in **Fig. 1.** This is a simple test intended to optimize dose of polymeric and/or rubber additive in bitumen and help in assessing quality of PMB/RMB in laboratory.

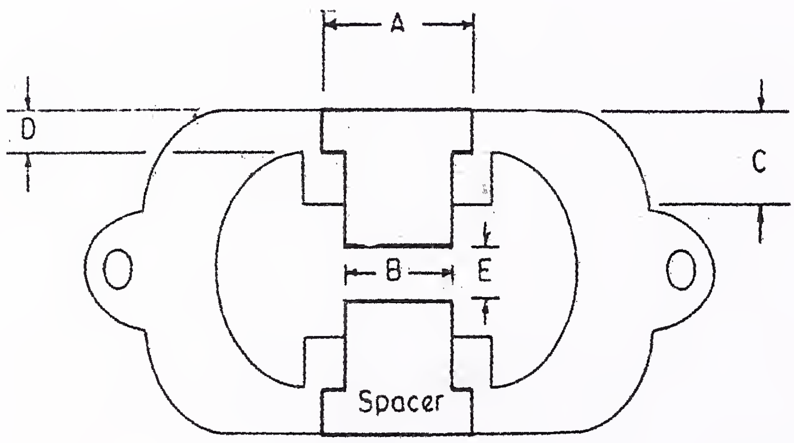
Apparatus

Ductility Machine: Conforming to specification given in IS:1208-1978 and mould is shown in **Fig. 1.**

Thermometer: An ASTM 63^{0}C thermometer or any other standard thermometer of equivalent range.

Scissors: Any type of conventional scissors capable of cutting modified bitumen at the test temperature.

Scale: Any transparent scale of measuring ductility upto 25 cm with ± 1 mm accuracy.



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

Fig. 1 Design of Mould for Elastic Recovery Test

Procedure

Prepare three test specimens for one sample and condition as prescribed in Test Method IS-1208 at specified temperature. Elongate the test specimen at the specified rate to a deformation 10 cm at a rate of 5 ± 0.25 cm/minute at specified temperature. Immediately cut the test specimen into two halves at the midpoint using the scissors. Keep the test specimen in the water bath in an undisturbed condition for 1 hour at specified temperature.

After the 1 hour time period, move the elongated half of the test specimen back into position near the fixed half of the test specimen so that the two pieces of modified bitumen just touch. Record the length of the recombined specimen as X.

Report

Calculate the per cent/elastic recovery by the following procedure:

$$\text{Elastic Recovery (\%)} = \frac{10-X}{10} \times 100$$

Annex-3
(Table 2)

METHOD FOR SEPARATION TEST

Scope

The separation of modifier and bitumen during hot storage is often seen and this can be 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 in a sealed tubes of modified bitumen in a vertical position at 163 ± 5^{0}C in an oven for a period of 48 hours.

Apparatus

Aluminum Tubes: 25.4 mm in diameter and 136.7 mm long blind aluminum tubes.

Oven: Capable of maintaining 163 ± 5^{0}C

Freezer: Capable of maintaining 6.7 ± 5^{0}C

Rack: Capable of supporting the aluminum tubes in a vertical position in the oven and freezer.

Spatula and Hammer: The spatula must be rigid and sharp to allow cutting of the tube containing the sample when at a low temperature.

Procedure

Place the empty tube, with sealed end down in the rack. Heat the sample carefully until sufficiently fluid to pour. Care should be taken to prevent localized over-heating. Pass the molten sample through IS sieve 600 micron mess size. After through stirring, pour 50.0 g into the vertically held tube. Fold the excess tube over two times, and crimp and seal. Place the rack containing the sealed tubes in a oven maintained at a temperature of 163 ± 5^{0}C. Allow the tubes to stand undisturbed in the oven for a period of 48 ± 4 hour. At the end of the period, remove the rack from the oven and place immediately in the freezer at 6.7 ± 5^{0}C, taking care to keep the tubes in a vertical position at all times. Leave the tubes in the freezer for a minimum of 4 hours to solidify the sample completely. Upon removing the tube from the freezer, place it on a flat surface. Cut the tube into three equal length portions with the knife. Discard the central portion of sample, and place the top and bottom portions of the tube into separate beakers. Place the beaker into a 163 ± 5°C oven until the bitumen is sufficiently fluid to remove the pieces of aluminum tube. After thoroughly stirring, pour the top and bottom samples into appropriately marked rings for the ring and ball softening point test. Prepare the rings and ball apparatus according to Test Method IS 1205. The top and bottom samples from the same tube should be tested at the same time.

Report

Report the difference, in °C, between the softening points of the respective top and bottom samples as average of three specimens.

Annex-4
(*Clause* **8.3**)

TORSION RECOVERY OF MODIFIED BINDERS

1. Scope

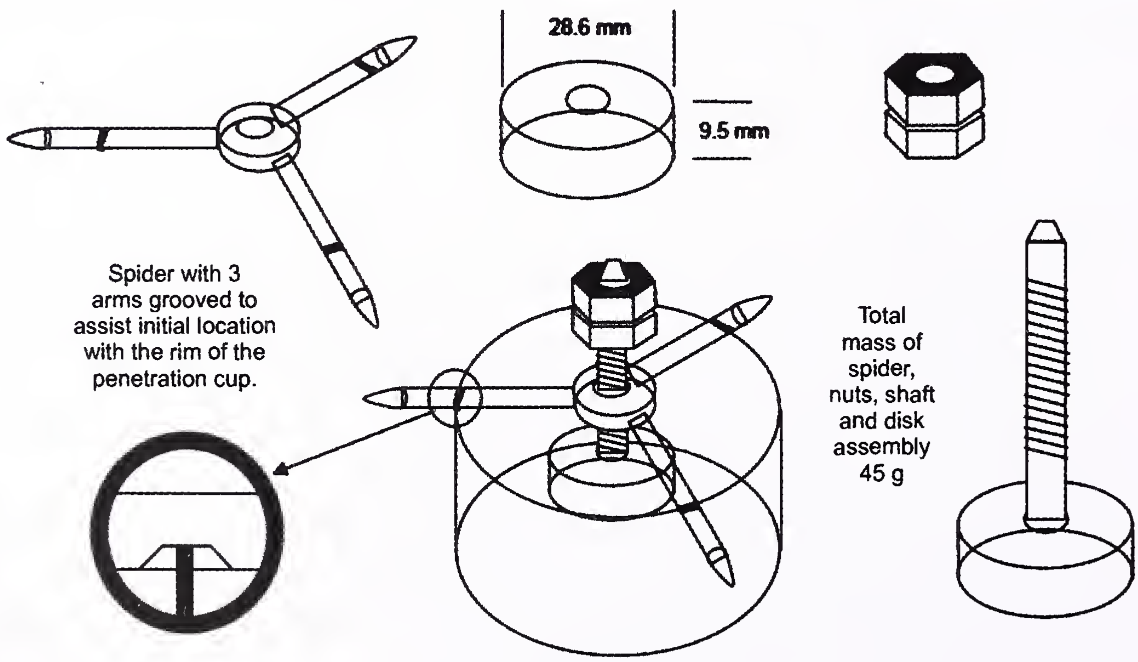
This test method sets out the procedure for the determination of torsional recovery of polymer modified binders using a sample bolt and cup assembly.

2. Definition

A simple means of determining the elastic properties of a polymer-modified binder is to measure its Torsional recovery.

3. Apparatus

3.1 A cylindrical headed aluminium bolt assembly, as illustrated in Figure 2 with a total mass of 45 ± 5 g. The bolt has a cylindrical head with a diameter of 28.6 mm and a thickness of 9.52 mm. The threaded shank of the bolt is 44.5 mm long. A metal "spider", with three radial pins and two nuts, can be used to centre the assembly. A pointer is required for angle measurements in the absence of the spider. See Fig 1 for details of this assembly and the optional components.



Not Drawn to Scale Tolerance on mass 1g, dimensions 0.1 mm

Fig. 2 Cylindrical Headed Aluminium Bolt Assembly

3.2 A sample tin, cylindrical, flat bottomed and 55 mm in diameter.

3.3 An angle-measuring device and sample clamp assembly, or an alternative means of clamping the sample/bolt assembly and determining the initial and recovered angle. The recommended device provides a scale, of 80 mm radius and graduated in degrees around at least half its circumference and a clamp capable of holding the sample cup within 3 mm of its centre and without deforming the cup by more than 3 mm in any direction.

3.4 A water bath capable of operating at 25°C ± 0.5°C, fitted with an appropriate thermometer.

3.5 A drying oven, thermostatically controlled and capable of maintaining a temperature of 60°C to 200°C, with a set point accuracy of ± 5°C.

3.6 A stop watch

3.7 A spanner to suit the bolt assembly

4. Method

The torsional recovery apparatus operates by manually rotating an aluminium bolt, previously embedded in a cup of modified binder, through an angle of 180 degrees and measuring the extent of recovery of the original applied rotation. The initial 180-degree twist is applied with a spanner over a 10 second period. The recovery after 30 seconds is reported.

4.1 Prepare the sample as described in Method MB-2. Assemble the bolt; spider and nuts to position the surface of the bolt head 8 ± 2 mm below the top of the sample cup. Preheat the assembly and cup to 180°C and pour the modified binder into the tin assembly, until it begins to form meniscus on the top surface of the bolt.

4.2 Testing

Allow the assembly to cool for one hour by leaving it to stand at room temperature (25° ± 3°C). Adjust the assembly height to keep the top surface of the bolt flush with the sample surface. Place the assembly into the 25°C water bath and allow it to stabilize for one hour (see Note 6.1) Adjust the spider to a position 7 ± 2 mm above the rim and return the assembly to the bath. Place the sample assembly on the base-plate and fit the pointer to the 180-degree position without disturbing the sample. Using the spanner, turn the bolt moving the pointer from the 180-degree position to the zero position using a steady motion for 10 seconds. Release the bolt when the pointer reaches the zero position and commence timing (See Note 6.3). Record the recovered angle after 30 seconds as 'A'.

5. Calculation

The torsional recovery is given by the following equation:

$$\text{Torsional recovery, \%} = \frac{A \times 100}{180}$$

Where A = Recovered angle in degrees. When the scale presented in Figure 3 is used, the torsional recovery is read directly.

6. Notes

6.1 The test should be conducted in an air-conditioned laboratory at 25 ± 3°C. Alternatively, the test can be conducted within the water bath.

6.2 The rate at which the torque is applied to the sample is critical for reproducible results. The objective is to apply 180 degrees of rotation in 10 seconds. **Fig. 3** presents a practical scale marked from zero (0 degree) to 10 (180 degrees) to help with this task.

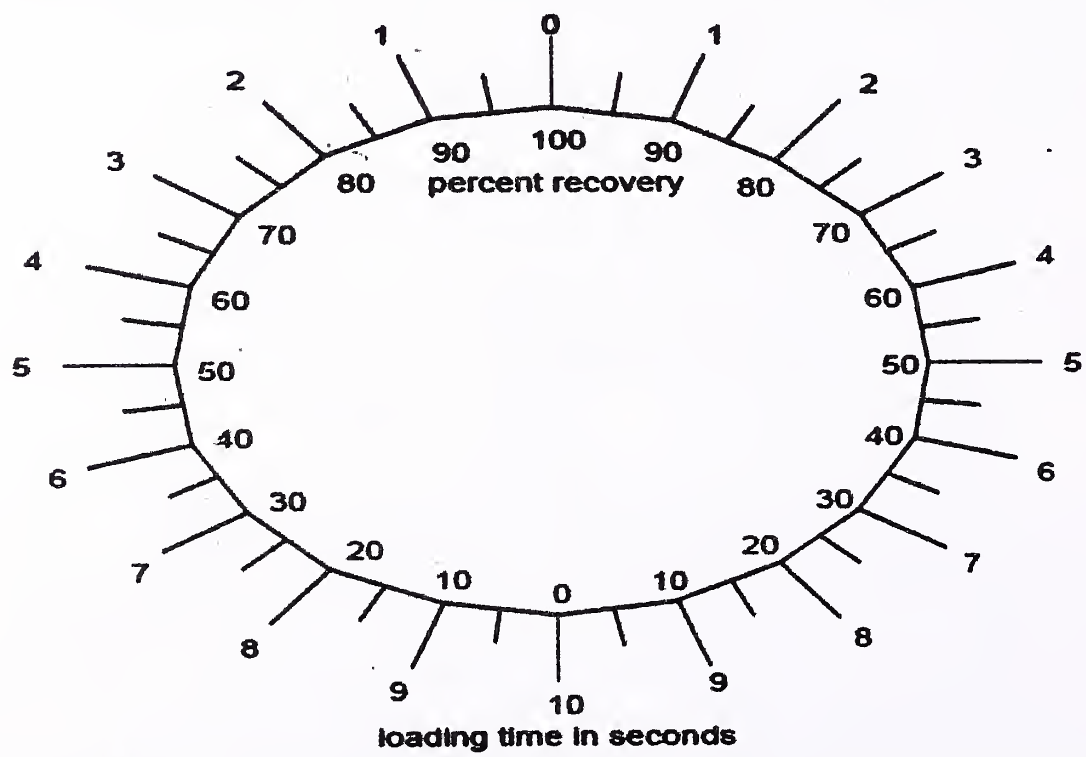


Fig. 3 Practical Scale Marked from 0 to 10 Seconds (0 to 100 percent Recovery)

6.3 The spider assembly should not come into contact with the rim of the cup at any time during the recovery phase.

6.4 The following precautions should be taken when handling all bitumens:

a) Eye protection, such as safety glasses and/or face shields, shall be worn when handling hot bitumen.

b) Heat resistant gloves, with close fitting cuffs and other suitable protective clothing shall be worn when handling hot bitumen.

c) There shall be no smoking while handling hot bitumen.

d) While the material is still cold, loosen the lid of the sample container (invert the can and warm the lid, if necessary), or punch a hole in the lid.

7. Acceptability of Results

The following criteria could be used for judging acceptability of results.

Property	**Units of Precision**	**Repeatability (r)**	**Reproducibility (R)**
Torsional Recovery	Units of measurement (*)	0.09√m (100-m)	0.30√m (100-m)

Where 'm' is the mean test result (*) While actual result for these properties are calculated in percent, the generic term "units of measurement" is preferred to avoid any confusion between the absolute value (percent) or percentage of the actual value.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)