SPECIFICATIONS
FOR
DENSE GRADED BITUMINOUS MIXES

INDIAN ROADS CONGRESS

2009

1778

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Published by

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector 6, R.K. Puram,
New Delhi-110 022

2009

Price Rs. 300/-
(Packing and Postage charges extra)

IRC : 111-2009

First Published : June, 2009
Reprinted : December, 2009

Printed at I G Printers Pvt. Ltd. New Delhi-110020
(500 copies)

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SPECIFICATIONS FOR DENSE GRADED BITUMINOUS MIXES

1 INTRODUCTION

The Indian Roads Congress published three specifications for dense graded bituminous mixes under titles 'Bituminous Concrete (IRC:29)', 'Dense Bituminous Macadam (IRC:94)' and 'Semi-Dense Bituminous Concrete (IRC: 95)'. The Flexible Pavement Committee (FPC) in its meeting held on 22nd April, 2006 decided to revise the specifications to keep pace with the changes in the technology and improvements in the construction procedures as well as quality control expectations. It was also decided to combine all the documents related to dense graded bituminous mixes into a comprehensive document and authorized Shri R.K.Pandey to finalize the draft with technical input from Prof. P.S.Kandhal. The finalized draft was sent to all FPC members for comments. The FPC in its meeting on 9th September, 2006 discussed all comments in detail. The revised draft was published in the February, 2007 issue of the "Indian Highways" to solicit more comments from users at large. These additional comments were reviewed by the FPC in its meeting on 5th May, 2007. The FPC authorized Prof. P.S. Kandhal to incorporate all comments and finalize the draft.

Draft finalized by Prof. P S Kandhal was discussed by the Flexible Pavement Committee in its meeting held on 27th July, 2008 wherein Committee authorized Convenor, Flexible Pavement Committee to modify the draft in the light of the discussions held and submit to the Highways Specifications and Standards (HSS) Committee. HSS Committee considered the draft in its fifth meeting held on 23rd November 2008. Draft modified by the Convenor, HSS Committee was approved by the Executive Committee in its meeting held on 30th November, 2008, at New Delhi and by the Council in its meeting held on 13th December, 2008 at Kolkata subject to the incorporation of modifications keeping in view the comments of members and approval by the Convenor, HSS Committee. The names of the Personnel of Flexible Pavement Committee (H-2) are given below:

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Nirmal, S.K.	--	Member-Secretary

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2 SCOPE

2.1 This specification deals with the basic outline for the design, construction and controls needed while laying dense graded bituminous mixes in base course, binder course and wearing course.

2.2 Dense graded bituminous mixes shall consist of mineral aggregate and appropriate bituminous binder, mixed in a hot mix plant and laid with a mechanized paver. Dense graded bituminous mixes, such as, binder and wearing courses are usually laid on a previously prepared bituminous layer. Binder course is the intermediate layer between bituminous base course and bituminous wearing course. Three different specifications for dense graded bituminous mixes are available for use for highways. Purpose, layer thickness and number of layers allowed for these specifications are given in Table 1.

Table 1 Types of Dense Graded Bituminous Mixes, their Use, Number of Layers and Layer Thickness

Specification	Purpose	Number of Layers	Thickness of each Layer
Dense Bituminous Macadam **(DBM)**	Base/Binder Course/Overlay for Strengthening	Single or Multiple	50 mm - 100 mm
Semi-Dense Bituminous Concrete **(SDBC)**	Wearing Course	Single	25 mm - 40 mm
Bituminous Concrete **(BC)**	Wearing Course	Single	25 mm/40 mm/ 50 mm

3 MATERIALS

3.1 Bitumen

3.1.1 The bitumen for dense graded bituminous mixes shall comply with Indian Standard Specification for viscosity-graded paving bitumen, IS: 73 or modified bitumen complying with the IS: 15462. Guidelines for selection of grade of viscosity-graded paving bitumen and modified bitumen are given in Tables 2 to 4.

Table 2 Viscosity Graded (VG) Bitumens and their General Applications

Viscosity Grade (VG)	General Applications
VG-40 (40-60 penetration)	Use in highly stressed areas such as those in intersections, near toll booths, and truck parking lots in lieu of old 30/40 penetration grade
VG-30 (50-70 penetration)	Use for paving in most of India in lieu of old 60/70 penetration grade
VG-20 (60-80 penetration)	Use for paving in cold climatic, high altitude regions of North India
VG-10 (80-100 penetration)	Use in spraying applications and for paving in very cold climate in lieu of old 80/100 penetration grade

3.1.2 The type and grade of bitumen to be used shall be specified in the Contract

3.1.3 Both the highest daily mean air temperature and the lowest daily mean air temperatures mentioned in Tables 3 and 4 can be obtained for the weather station nearest to the project site from the Indian Meteorological Organization (IMO). The IMO has data on daily mean high temperature for all 365 days in a year for all weather stations based on historical records of the last 30-40 or more years. This daily mean high temperature on a specific day is the same as daily "normal" high temperature for that day as usually reported in some newspapers. The highest of the 365 daily mean high air temperatures (which usually occurs on some day in May or June) is used in Tables 3 and 4. Likewise, the lowest daily mean air temperature (which usually occurs on some day in January) can also be obtained from the IMO.

Table 3 Selection Criteria for Viscosity-Graded (VG) Paving Bitumen Based on Climatic Conditions

Highest Daily Mean Air Temperature, °C

Lowest Daily Mean Air Temperature, °C	Less than 20°C	20 to 30°C	More than 30°C
More than −10°C	VG-10	VG-20	VG-30
-10°C or lower	VG-10	VG-10	VG-20

Table 4 Selection Criteria for Grade of Modified Bitumen

Lowest Daily Mean Air Temperature, °C	Highest Daily Mean Air Temperature, °C: Less than 20°C	20 to 30°C	More than 30°C
	Grade of Modified Bitumen		
More than -10°C	PMB/NRMB 120 CRMB 50	PMB/NRMB 70 CRMB 55	PMB/NRMB 40 CRMB 60
-10°C or lower	PMB/NRMB 120 CRMB 50	PMB/NRMB 120 CRMB 50	PMB/NRMB 70 CRMB 55

PMB = Polymer Modified Bitumen
NRMB = Natural Rubber Modified Bitumen
CRMB = Crumb Rubber Modified Bitumen

Note : When commercial vehicles exceeds 2000 per day per lane and the highest daily mean temperature exceeds 40°C, VG-40 or modified bitumen of equivalent stiffness are recommended for bituminous concrete and top layers of dense bituminous macadam.

3.2 Coarse Aggregate

3.2.1 The coarse aggregate shall consist of crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve. It shall be clean, hard, durable and have cubical shape, free from dust and soft organic and other deleterious substances. The aggregate should preferably be of low porosity. The coarse aggregate shall satisfy the physical requirements specified in Table 5.

3.2.2 Where crushed gravel is proposed as aggregate, not less than 95% and 90% by weight of the crushed material retained on 4.75 mm sieve shall have at least two fractured faces for bituminous concrete and DBM/SDBC respectively.

3.3 Fine Aggregate

3.3.1 Fine aggregate shall consist of crushed or naturally occurring mineral material, or a combination of two, passing 2.36 mm sieve and retained on 0.075 mm sieve. No natural sand will be allowed in the binder and wearing courses and no more than 50 percent natural sand will be allowed in the base courses. The fine aggregate shall be clean, hard, durable, dry and free from dust and soft organic and other deleterious substances. Fine aggregate shall have a sand equivalent value not less than 50 when tested in accordance with the requirement of IS: 2720 Part 37. The plasticity index of the fraction passing the 0.425 mm sieve shall not exceed 4 when tested in accordance with IS: 2720 Part 5

Table 5 Physical Properties of Coarse Aggregate

Property	Test	Requirement	Test method
Cleanliness	Grain size analysis	Max. 5% passing 0.075 mm	IS: 2386 Part I
Particle Shape	Flakiness and Elongation Index (combined)	Max. 35%	IS: 2386 Part I
Strength *	Los Angeles Abrasion Value	BC-Max. 30% Others-Max 35%	IS: 2386 Part IV
	Aggregate Impact Value	BC-Max. 24%	IS: 2386 Part IV
		Others-Max. 27%	
Polishing **	Polished Stone Value	Min. 55	IS: 2386 Part IV
Durability	Soundness (Either Sodium or Magnesium Sulphate) – 5 cycles		
	Sodium Sulphate	Max. 12%	IS: 2386 Part V
	Magnesium Sulphate	Max. 18%	IS: 2386 Part V
Water Absorption	Water Absorption	Max 2%	IS: 2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures	Min. Retained Coating 95%	IS:6241
Water sensitivity	Retained Tensile strength***	Min 80%	ASHTO 283

Notes:

* The aggregate may satisfy either of the two tests

** Only for wearing courses

*** If the minimum retained tensile strength falls below 80%, use of anti-stripping agent is recommended to meet the minimum requirements.

3.4 Filler

3.4.1 Filler shall consist of finally divided mineral matter such as rock dust, or hydrated lime or cement approved by the Engineer. The use of hydrated lime is encouraged because of its very good anti-stripping and antioxidant properties. The filler shall be graded within the limits indicated in Table 6.

Table 6 Grading Requirement of Mineral Filler

IS Sieve (mm)	Cumulative % passing by weight of total aggregate
0.6	100
0.3	95 - 100
0.075	85 - 100

3.4.2 The filler shall be inert material free from organic impurities and have plasticity index not greater than 4. Plasticity index requirement will not apply if filler is hydrated lime or cement. Where the complete bituminous mixture fails to satisfy requirement of Moisture Susceptibility test (AASHTO T283 with freeze & thaw option), 2% by total weight of aggregate of hydrated lime shall be used and percentage of fine aggregate reduced accordingly. See Annex A for the outline of AASHTO T283.

3.5 Aggregate Grading and Bitumen Content

3.5.1 The combined grading of the coarse aggregate, fine aggregate and filler, when tested in accordance with IS 2386 Part 1, wet sieving method, shall conform to limits given in Table 7.

3.5.2 The combined aggregate grading shall not vary from the lower limit on one sieve to the higher limit on the adjacent sieve to avoid gap grading

Table 7 Aggregate Grading and Bitumen Content

Specification	DBM		SDBC		BC	
Grading	1	2	1	2	1	2
Nominal maximum aggregate size*	37.5 mm	26.5 mm	13.2 mm	9.5 mm	19 mm	13.2 mm
Layer thickness	75-100 mm	50-75 mm	40 mm	25 mm	50 mm	25/40 mm
IS Sieve size (mm)	Cumulative Percent by weight of total aggregate passing					
45	100					
37.5	95–100	100				
26.5	63–93	90–100			100	
19	–	71–95	100		90–100	100
13.2	55–75	56–80	90–100	100	59–79	90–100
9.5	–	–	70–90	90–100	52–72	70–88
4.75	38–54	38–54	35–51	35–51	35–55	53–71
2.36	28–42	28–42	24–39	24–39	28–44	42–58
1.18	–	–	15–30	15–30	20–34	34–48
0.6	–	–			15–27	26–38
0.3	7–21	7–21	9–19	9–19	10–20	18–28
0.15	–	–			5–13	12–20
0.075	2–8	2–8	3–8	3–8	2–8	4–10
Bitumen content (Min)**	4%	4.5%	4.5%	5%	5.2%	5.4%

* Nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate material is retained.

** 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.

3.5.3 Bitumen content indicated in Table 7 is the minimum only. The exact bitumen content required shall be determined following the Marshall Mix Design procedure contained in the Asphalt Institute Manual MS-2 (Sixth Edition).

3.5.4 The fines to bitumen (F/B) ratio by weight of total mix shall range from 0.6 to 1.2 for all mixes in Table 7

4 DESIGN OF MIX

4.1 Mix Requirements

4.1.1 Besides conforming to the requirement of grading and quality for individual ingredients the mix shall meet the requirement set out in Tables 8 depending upon the type of binder.

Table 8 Requirement of the Dense Graded Bituminous Mix Using Viscosity-Graded (VG) Paving/ Modified Bitumen

Properties	Viscosity Grade Paving Bitumen	Modified Bitumen		Test Method
		Hot Climate	Cold Climate	
Compaction level (Number of blows)	75 blows on each face of the specimen			
Minimum stability (kN at 60°C)	9.0	12	10	AASHTO T245
Marshall flow (mm)	2–4	2.5–4	3.5–5	AASHTO T245
Marshall Quotient (stability/flow)	2–5	2.5–5		
% Air Voids	3–5			MS-2 and ASTM D2041
% Voids filled with bitumen (VFB)	65–75			MS–2
Tensile Strength Ratio	80% (Minimum)			AASHTO T283
Coating of Aggregate Particles with bitumen		95% (Minimum)		IS: 6241
% Voids in Mineral aggregate VMA				
Nominal Maximum Particle size (mm)	Min. % VMA related to designed % air voids***			
	3	4	5	
9.5	14	15	16	
13.2	13	14	15	
19.0	12	13	14	
26.5	11	12	13	
37.5	10	11	12	

***For intermediate value of designed percentage air voids interpolate the VMA.

4.2 Binder Content

4.2.1 The binder content shall be selected to obtain 4 percent air voids in the mix design and shall meet all requirements given in Table 8. The Marshall Method for designing the mix shall be adopted as described in the sixth edition of the Asphalt Institute Manual MS-2.

4.2.2 Where maximum size of the aggregate is more than 26.5 mm, modified Marshall method using 150 mm (6 inches) diameter specimen described in the Asphalt Institute Manual MS-2 (Sixth Edition) and ASTM D5581 shall be used. This test method requires modified equipment and procedure. When the modified Marshall test is used, the specified minimum stability values and the specified flow values given in Table 8 shall be multiplied by 2.25 and 1.5, respectively

4.3 Job Mix Formula

4.3.1 The laboratory mix design gives the proportion of the mineral aggregate combination in terms of individual sieve sizes, for actual operational purpose in the field, blending of the two or more sizes of aggregates (each size having within its range of individual sieve size) would be necessary. This blending ratio is obtained on a weight basis giving percent weight of the coarse aggregate, fine aggregate and filler needed to give the ultimate gradation. This mineral aggregate combination together with the corresponding optimum bitumen content as determined in the laboratory, constitute the job mix formula for implementation during construction The job mix formula proposed for the use in the work shall give the following details:

1. Source and location of all materials
2. Proportions of all materials
3. Binder type and percentage by weight of total mixture
4. Coarse aggregate/fine aggregates/mineral filler as percentage by weight of total aggregate including mineral filler.
5. A single definite percentage passing each sieve for the mix aggregate
6. The individual grading of the individual aggregate fraction and the proportion of each in the combined grading.
7. The test results of mix design such as maximum specific gravity of loose mix (Gmm), compacted specimen densities, Marshall stability, flow, air voids, VMA, VFB and related graphs, and test results of AASHTO T283 Moisture Susceptibility Test.
8. In case of batch mixer, the individual weight of each type of aggregate and binder per batch.
9. Test results of aggregates.
10. Mixing and compacting temperatures

4.3.2 Approval of the job mix formula shall be based on independent testing by the Engineer on the samples furnished by the Contractor. It should be ensured that it is based on the truly representative samples of the material that will be used for the work New job mix formula shall be got approved whenever there is change in the material used for the work

4.4 Plant Trial

4.4.1 Plant trial shall be carried out to establish that the plant can produce uniform mix conforming to the job mix formula. The permissible variation of the various ingredients in the actual mix from the job mix formula shall be within the limits as given in Table 9. These variations are intended to apply to individual specimen taken for quality control test in accordance with Clause 6.

Table 9 Permissible Variation from the Job Mix Formula

Description	Permissible Variation	
	DBM	SDBC/BC
Aggregate passing		
19 mm or larger	± 8%	± 7%
13.2 mm/9.5 mm	± 7%	± 6%
4.75 mm	± 6%	± 5%
2.36 mm, 1.18 mm, 0.6 mm	± 5%	± 4%
0.3 mm, 0.15 mm	± 4%	± 3%
0.075 mm	± 2%	± 1.5%
Binder Content	± 0.3%	± 0.3%
Mixing Temperature	± 10°C	± 10°C

4.5 Laying Trials

4.5.1 Laying trials are carried out to establish that the proposed mix can be successfully laid and compacted. The laying trial shall be carried out in an area, which does not form a part of the work. The minimum area for laying trials shall be 100 sqm. This shall be similar to the project area on which the bituminous layer is to be laid. Methodology, equipment and mix shall also be similar to those proposed for the project

4.5.2 The trials establish that the proposed laying plan, compaction plan, and methodology are capable of producing satisfactory results. The density of finished paving layer should not be less than the 92% of the average density (Sample size N=2) based on theoretical maximum specific gravity of the loose mix (Gmm) obtained on the day of trial following ASTM D2041. See Annex B for the outline of ASTM D2041

5 CONSTRUCTION OPERATION

5.1 Preparation of Base

5.1.1 **Cleaning of the surface:** The surface shall be cleaned of all loose extraneous matter by means of mechanical broom and high-pressure air jet from compressor or any other approved equipment/method

5.1.2 **Filling-up of potholes and sealing of cracks:** Any potholes and/or cracks shall be repaired and sealed.

5.1.3 **Geosynthetics or stress absorbing layers:** Where required, layer of geosynthetics/ stress absorbing material shall be laid.

5.1.4 **Profile correcting course:** Depending upon requirement, profile-correcting course for correcting the existing pavement profile shall be laid either as a separate layer or as a composite layer with varying thickness. Where the maximum thickness of the profile corrective course is less than 40 mm, the profile corrective course shall be laid as an integral part of the overlaying layer. In other cases the profile corrective course shall be constructed as a separate layer. When it is laid as a separate layer, type of material for the use as the profile corrective course may differ.

5.2 Tack Coat

5.2.1 **Tack coat:** Tack Coat shall be as per IRC:16 "Standard Specification and Code of Practice for Prime and Tack Coat".

5.3 Mixing

5.3.1 Dense graded bituminous mixes shall be prepared in a hot mix plant of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregate. The essential features of the hot mix plant are given in Annex A of IRC: 27 "Specifications for Bitumen Macadam". Table 10 gives the mixing, laying, and rolling temperatures for dense graded mixtures. In case of modified bitumen, the temperature of mixing and compaction shall be higher than the mix with conventional bitumen as binder. The exact temperature depends upon the type and amount of modifier used and shall be adopted as per the recommendations of the manufacturer. In order to ensure uniform quality of mix the plant shall be calibrated from time to time.

Table 10 Mixing, Laying and Rolling Temperatures for Dense Mixtures (Degree Celcius)

Bitumen Viscosity Grade	Bitumen Temperature	Aggregate Temperature	Mixed Material Temperature	Laying Temperature	*Rolling Temperature
VG-40	160-170	160-175	160-170	150 Min.	100 Min.
VG-30	150-165	150-170	150-165	140 Min.	90 Min.
VG-20	145-165	145-170	145-165	135 Min.	85 Min.
VG-10	140-160	140-165	140-160	130 Min.	80 Min.

*Rolling must be completed before the mat cools to these minimum temperatures

5.4 Transportation

5.4.1 Bituminous material shall be transported in clean, insulated covered vehicles. An asphalt release agent, which does not adversely affect the bituminous mix may be applied to the interior of the vehicle to prevent sticking and to facilitate discharge of the material

5.5 Laying

5.5.1 **Weather and seasonal limitations:** Dense graded bituminous mixes shall not be laid:

- in presence of standing water on the surface,
- when rain is imminent and during rains, fog, or dust storm
- when the base/binder course is damp,
- when the air temperature on the surface on which it is to be laid is less than 10°C for mix with conventional bitumen as binder and is less than 15°C for mix with modified bitumen as binder
- When the wind speed at any temperature exceed the 40 km/h at 2 m height.

5.5.2 **Preparation of the base:** Base shall be prepared by carrying out all or some of the operations as per Clause 5.1, depending upon the site conditions.

5.5.3 **Spreading:** Except in areas where paver cannot access, bituminous material shall be spread, leveled and tamped by self-propelled hydrostatic paver finisher preferably with sensor. As soon as possible after arrival at site the material shall be supplied continuously to the paver and laid without delay. The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously The travel rate of paver and the method of operation shall be adjusted to ensure even and uniform flow of bituminous material across the screed, free from dragging, tearing and segregation.

Restricted areas (such as confined space, footways, irregular shape and varying thickness, approaches to expansion joints etc.) where paver cannot be used, the material shall be spread, raked and leveled with suitable hand tool by trained staff

When laying dense graded bituminous mixes near expansion joint, the machine laying shall be stopped about 300 mm short of joint. The remainder of the pavement up to the joint and the corresponding area beyond it shall be laid manually. Table 10 gives the minimum laying temperatures. Bituminous material, with temperature greater than 145°C shall not be laid or deposited on bridge deck waterproofing system unless precautions against the heat damage have been taken.

5.6 Compaction

5.6.1 Compaction shall commence as soon as possible after laying and shall be completed before the temperature falls below the minimum rolling temperatures given in Table 10. Rolling of the longitudinal joints shall be done immediately behind the paving operation. After this the rolling shall commence at the edge and progress towards the center longitudinally except at sections with unidirectional camber, where it shall progress from lower edge to upper edge parallel to centerline of the pavement.

5.6.2 All deficiencies in the surface after laying shall be made good by the attendant behind the paver, before initial rolling is commenced. The initial or breakdown rolling shall be done with the 8 to 10 tonnes dead weight or vibratory steel wheel roller. The intermediate rolling shall be done with 8 to 10 tonnes dead weight or vibratory roller or with a pneumatic roller of 12 to 15 tonnes, with a tire pressure of at least 0.56 MPa. The finished rolling shall be done with 6 to 8 tonnes smooth wheel roller. Rolling shall continue till all the roller marks are removed from the surface and the minimum specified field density is achieved.

5.6.3 The dense graded bituminous mixes shall be rolled in the longitudinal direction, with the roller as close as possible to the paver. The overlap on successive passes should be at least one-third of the width of the rear roll or in the case of pneumatic wheeled rollers, at least the nominal width of 300 mm. The roller should move at a speed of no more than 5 km /hour. The roller shall not be permitted to stand on pavement, which has not been fully compacted. All precautions shall be taken to prevent dropping of oil, grease, petrol or other foreign material on the pavement. The wheel of the rollers shall be kept moist with the water or spray system provided with the machine to prevent the mixture from adhering to the wheels. Minimum moisture to prevent adhesion between wheels and mixture shall be used and surplus water shall not be allowed to stand on the partially completed pavement.

5.6.4 The density of the finished paving layer shall be determined by taking 150 mm diameter cores. The density of finished paving layer shall not be less than the 92% of the average (sample size N=2) theoretical maximum specific gravity of the loose mix (Gmm) obtained on that day in accordance with ASTM D2041. See Annex B for the outline of ASTM D2041

5.7 Joints

5.7.1 Where joints are made, the material shall be fully compacted and the joint made flush in one of the following ways.

a) All joints shall be cut vertical to the full thickness of the previously laid mix. All loosened material shall be discarded and the vertical face be coated with any viscosity grade bitumen, or cold applied emulsified bitumen. While spreading the material along the joint the material spread shall overlap 25 mm to 50 mm on the previously laid mix beyond the vertical face of the joint. The thickness of the loose overlap material should be approximately a quarter more than the final compacted thickness. The overlapped mix should be dragged back to the hot lane so that the roller can press the small excess into the hot side of the joint to obtain a high joint density

b) By using two or more pavers in echelon, where this is practicable and in sufficient proximity for adjacent width to be fully compacted by continuous rolling.

5.7.2 In multi-layer construction the longitudinal joint in one layer shall offset the joint in the underneath layer by about 150 mm

5.7.3 For transverse joints method a) above can apply. Transverse joints in the successive and adjoining layers should have a minimum offset of 2 m

5.8 Arrangement for Traffic

5.8.1 It shall be ensured that traffic is not allowed on the surface until the paved mat has cooled below a temperature of 60°C in its entire depth.

6 CONTROLS

6.1 Surface Finish

6.1.1 The levels of the dense graded bituminous mixes shall not vary from those calculated with reference to longitudinal and cross profile of the roads as per the Contract beyond ± 6 mm provided that the negative tolerance shall not be permitted in conjunction with the positive tolerance for the base course if the thickness of the former is thereby reduced by more than 6 mm

6.1.2 For checking the compliance with the above requirement measurements of the surface level shall be taken on a grid of points spaced 6.25 m along the length and 0.5 m from the edges and at the centre of the pavement. The compliance shall be deemed to be met for the final road surface only if the tolerance given above is satisfied for any point on the surface.

6.1.3 In case where surface levels fall outside the specified tolerance, the Contractor shall be liable to rectify these by replacing the full depth of layer. In all cases of replacement the area treated shall not be less than 5 m in length and not less than 3.5 m in width.

6.2 Surface Evenness

6.2.1 The measurement and checking of surface unevenness shall be done by a 3 m straight edge in accordance with the procedures in IRC:SP:16.

6.2.2 The maximum permissible surface unevenness in longitudinal profile shall be 6 mm for SDBC and 5 mm for BC. The maximum permissible unevenness in transverse profile shall be 4 mm for both SDBC and BC.

6.2.3 The maximum permissible frequency of surface unevenness in 300 m length in longitudinal profile shall be as per Table 11.

Table 11 Maximum Permissible Frequency of Unevenness
Maximum Number of Surface Unvenness

Type of Surface	Unevenness, mm	NH/SH	MDR and Lower Category
Semi-Dense Bituminous Concrete	4–6	20	40
Bituminous Concrete	3–5	15	30

6.2.4 Where the surface unevenness falls outside the tolerance, in either case i.e. the surface is low or high, the full depth of the layer shall be removed and replaced with fresh material and compacted to the specification.

6.2.5 In all cases of removal and replacement the area treated shall not be less than 5 m in length and 3.5 m in width

6.3 Surface Roughness

6.3.1 Surface roughness shall be checked in accordance with procedures in IRC:SP:16.

6.3.2 The maximum permissible values of surface roughness measured with a bump integrator are given in Table 12. Newly constructed surface are expected to give roughness values corresponding to Good category. While the Average and Poor categories indicate level of service and the intervention criteria.

Table 12 Maximum Permissible Values of Roughness (mm/km) for Surface with Dense Graded Bituminous Mixes

S.No	Type of Surface	Condition of Road Surface (mm / km)		
		Good	Average	Poor
1.	SDBC	< 2500	2500–3500	> 3500
2.	BC	< 2000	2000–3000	> 3000

6.4 Quality Control during Construction

6.4.1 The material supplied and the work shall conform to the specifications prescribed in the preceding Clauses. To ensure the quality of the material and the work, control tests shall be conducted during the execution of the paving project. The tests and minimum frequency for each test is indicated in Table 13.

Table 13 Control Tests for Dense Graded Bituminous Mixes and their Minimum Frequency

S.no	Test	Frequency
1	Quality of binder	Number of samples per lot and tests as per IS: 73 or IRC:SP: 53
2.	Aggregate impact value/Los Angeles Abrasion value	One test per 350 m^3 of aggregate for each source and whenever there is change in the quality of aggregate
3.	Flakiness index	One test per 350 m^3 of aggregate for each source and whenever there is change in the quality of aggregate
4.	Soundness test (Sodium and Magnesium Sulphate test)	1 test for each source and whenever there is change in the quality of aggregate
5	Water absorption of aggregate	1 test for each source and whenever there is change in the quality of aggregate
6	Sand equivalent test	1 test for each source and whenever there is change in the quality of aggregate
7	Plasticity Index	1 test for each source and whenever there is change in the quality of aggregate
8.	Polished stone value	1 test for each source and whenever there is change in the quality of aggregate
9	Percent of fractured faces	One test per 350 m^3 of aggregate when crushed gravel is used.
10.	Mix grading	One set for individual constituent and mixed aggregate from dryer for each 400 tonnes of mix subject to minimum of two tests per day per plant
11.	Stability and voids analysis of mix including theoretical maximum specific gravity of loose mix	3 tests for stability, flow value, density and void contents for each 400 tonnes of mix subject to minimum of two tests per day per plant
12.	Moisture Susceptibility of mix (AASHTO T283)	1 test for each mix type whenever there is change in the quality or source of coarse or fine aggregate
13.	Temperature of binder in boiler, aggregate in dryer and mix at the time of laying and compaction	At regular intervals
14.	Binder content	One set for each 400 tonnes of mix subject to minimum of two tests per day per plant
15.	Rate of spread of mix material	After every 5th truck load
16.	Density of compacted layer	One test per 700 m^2 area

6.5 Acceptance Criteria

6.5.1 The acceptance criteria for test on density (N = 3 minimum) and Marshall stability (N = 2 minimum) shall be subjected to the condition that the mean value of N samples is not less than the specified value plus [1.65 – 1.65/(No. of samples)$^{0.5}$] x standard deviation.

6.5.2 Table 9 will govern the permissible variation in the mix and temperature.

ANNEX A
(*Clause* 3.4.2)

Outline of AASHTO T283, "Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage"

A. Scope and Summary of Test Method

This method covers preparation of compacted bituminous mixtures and the measurement of the change of diametral tensile strength resulting from the effects of water saturation and laboratory accelerated stripping phenomenon with a freeze-thaw cycle. The result may be used to predict long-term stripping susceptibility of bituminous mixtures and evaluate liquid anti-stripping additives that are added to bitumen or pulverized mineral materials such as hydrated lime, which are added to the mineral aggregate.

Each set of 6 compacted specimens is divided into two equal subsets. One subset is tested in dry condition for indirect tensile strength. The other subset is subjected to vacuum saturation and a freeze-thaw cycle (thawing in a hot water bath) before testing for indirect tensile strength. Numerical indices of retained indirect tensile strength properties are calculated from the test data obtained by testing the two subsets: dry and conditioned.

B. Testing Equipment

1. Vacuum container, vacuum pump, manometer, and other accessories as specified in ASTM D2041, "Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures"
2. Balance or scale accurate to 0.1 percent of the test load
3. Two water baths capable of maintaining temperatures of 60°C ± 1°C and 25°C ± 0.5°C
4. Freezer maintained at –18°C ± 3°C
5. 10-ml graduate cylinder
6. Loading jack and ring dynamometer (Marshall stability testing machine can be used) to provide a vertical rate of deformation of 50 mm (2 inches) per minute and capable of reading the maximum failure load
7. Steel loading strips with a concave surface having a radius equal to the normal radius of the test specimen. The loading strips shall be 12.7 mm (0.5 inch) wide for specimens 100 mm (4 inches) in diameter. The loading strips for 150 mm (6 inches) diameter specimens shall be 19.05 mm (0.75 inch) wide. The length of the loading strips shall exceed the

thickness of the specimens. Steel strip are provided at the top and bottom of specimens during indirect tensile testing.

C. Test Procedure

1. Make at least 6 compacted specimens for each mixture, 3 to be tested dry and 3 to be tested after partial saturation and moisture conditioning with a freeze-thaw cycle. Some extra specimens will need to be made to establish compaction procedures in order to obtain specified air void contents in the test specimens by trial and error

2. Compact the 6 specimens with a Marshall compactor so that the compacted specimens have air voids of 7.0 ± 0.5 percent. This level of high air voids can be obtained by adjusting the number of Marshall blows applied on each side of the specimen by trial and error (start at about 10 blows as a starting point). Air void content must be calculated from the bulk specific gravity of the compacted specimen (determined by saturated surface dry method as per procedure given in the Asphalt Institute MS-2) and the maximum theoretical specific gravity of the loose bituminous mixture obtained by ASTM D2041.

3. Separate the 6 specimens into 2 subsets so that the average air voids of the two subsets are approximately equal.

4. One set will be tested dry. Keep it at room temperature and then place in a 25°C ± 0.5°C water bath for 2 hours prior to determining their indirect tensile strength.

5. The other subset will be conditioned as follows:

   a) Place and submerge the 3 specimens in the vacuum container filled with water at room temperature. Apply a vacuum of 13-67 kPa absolute pressure (10-26 inches Hg partial pressure) for 30 minutes. Remove the vacuum and leave the specimens submerged in water for 5 to 10 minutes. [Note: The water saturation procedure noted above deviates from AASHTO T283, which obtains a specified degree of saturation. The above procedure keeps the time of saturation constant.]

   b) Wrap a plastic film around each saturated specimen and place the wrapped specimen in a plastic bag containing 10 ml of water and seal the plastic bag. Place the plastic bag in a freezer at temperature of −18°C ± 3°C for a minimum of 16 hours. Remove the specimens from the freezer

   c) Place the specimens in a water bath maintained at 60°C ± 1°C for 24 hours. Remove the plastic bag and the plastic film from each specimen after placing the specimens under water.

   d) Remove the specimens from hot water bath and place in a water bath maintained at 25°C ± 0.5°C for 2 hours.

e) Remove the conditioned specimens and test for indirect tensile strength.

6 Determine the indirect tensile strength of the 3 dry and 3 conditioned specimens at 25°C ± 0 5°C after removing from water bath. First, measure their mean thicknesses (t). Then place the two steel loading strips on the bottom and top of the specimens across diameter and place in the Marshall testing machine or a compression-testing machine. Apply load to the specimens diametrally at a vertical rate of 50 mm (2 inches) per minute.

7. Record the maximum compressive strength noted on the testing machine and continue loading until a vertical crack appears in the specimen. Remove the cracked specimen from the machine and visually estimate the approximate degree of moisture damage (extent of stripped or bare aggregate) on the fractured faces of the specimen on a scale of 0 to 5 (5 being the most stripping).

8. Calculate the tensile strength of each specimen as follows in SI units:

$$St = 2000\ P/\ \pi\ t\ d$$

Where,

St	=	tensile strength, kPa
P	=	maximum loads, N
t	=	specimen thickness, mm
d	=	specimen diameter, mm

9. Express the numerical index of resistance of bituminous mixture to the detrimental effects of water as the ratio of the original strength that is retained after accelerated moisture and freeze-thaw conditioning.

Calculate the tensile strength ratio (TSR) as follows:

$$\text{Tensile strength ratio (TSR)} = S_2 / S_1$$

Where,

S_1 = average tensile strength of the dry subset, kPa

S_2 = average tensile strength of the conditioned subset, kPa

ANNEX B
(*Clause* 4.5.2)

Outline of ASTM D2041, "Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures"

A. Scope and Summary of the Test Method

This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted bituminous paving mixtures at 25°C. The theoretical maximum specific gravity (Gmm) is used: (a) to calculate air voids in compacted bituminous mixtures, (b) to calculate the amount of bitumen absorbed by the aggregate, and (c) to provide target value for the compaction of paving mixtures in the field.

A sample of loose paving mixture is placed in a tared vacuum vessel. Water at 25°C is added to completely submerge the sample. A specified amount of vacuum is gradually applied to remove the air bubbles entrapped between asphalt mix particles. After the vacuum is released, the volume of the sample of the voidless paving mixture is obtained by either immersing the vacuum container with the sample in a water bath and weighing or by filling the calibrated vacuum container level full of water and weighing in air.

B. Testing Equipment

1. Container (either a or b below)
   a) **Vacuum bowls** – Either a metal or plastic bowl with a diameter ranging from 180 to 260 mm and a bowl height of at least 160 mm. The bowl shall be equipped with a stiff, transparent cover fitted with a rubber gasket and a connection for the vacuum line. The hose connection shall be covered with a small piece of fine wire mesh to minimize loss of any fine material from the mix.
   b) **Vacuum flask for weighing in air only** – A thick-walled volumetric glass flask with a capacity of approx. 4000 ml, fitted with a rubber stopper with a connection for the vacuum line. The hose connection shall be covered with a small piece of fine wire mesh to minimize loss of any fine material from the mix.
2. Balance capable of being read to the nearest 0.1 gram. If weighing is to be done under water, a suitable suspension arrangement shall be provided for weighing the sample while suspended from the center of the balance.
3. Vacuum pump, capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30 mm of Hg) or less. Provide a suitable trap between the pump and container to minimize water vapour entering the vacuum pump.

4. Residual pressure manometer or calibrated absolute pressure gauge with a bleed valve to adjust the vacuum level.

5. Water bath capable of maintaining a constant temperature of 25 ± 1°C and suitable for immersion of the suspended container.

C. Calibration of Containers

1. **Bowls** – Determine the mass (B) of the container immersed in water at 25 ± 1°C. If the bowl is used for weighing in air, place the volumetric lid on the bowl while under water. Remove the water-filled bowl with the lid in place and dry prior to determining the combined mass of the bowl, lid and water. Repeat 3 times and average the 3 masses. Designate the average mass as D

2. **Flasks** – Calibrate the volumetric flask by accurately determining the mass of the flask filled with water at 25 ± 1°C. Use a glass cover plate to ensure the flask is completely full.

D. Test Procedure

1. Separate the particles of the loose paving mixture (while it is warm) by hand so that the particles are not larger than about 6 mm. Don't fracture the aggregate. Place the mix sample directly into the tared bowl or flask. Weigh the container with the sample and designate the net mass of the sample only as A [Note: The minimum sample size shall be 1500g for mixes with nominal maximum aggregate sizes of 12.5 mm or smaller; and shall be 2500g for mixes with nominal maximum aggregate sizes from 19 to 25 mm.]

2. Add sufficient water at 25°C to cover the sample completely. Place the cover (bowls) or stopper (flasks) on the containers.

3. Place the container with the sample and water on a mechanical agitation device or agitate manually at frequent intervals (2 to 3 minutes). Begin removing entrapped air by gradually applying vacuum and increasing the vacuum pressure until the residual manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mm of Hg). After achieving this level within 2 minutes, continue the vacuum and agitation for 15 ± 2 minutes. Gradually release the vacuum with the bleed valve.

4. Weighing in water – Suspend the bowl (without lid) and contents in water for 10 ± 1 minutes and then determine mass. Designate the mass under water of the bowl and sample as °C.

5. Weighing in air

a) **Bowl** – Submerge the bowl and sample slowly in the 25 ± 1°C water bath. Keep it there for 10 ± 1 minutes. Immerse the lid in water and slide it onto the bowl without removing water from the bowl so that no air is trapped inside the bowl. Remove the bowl with the lid in place from the water bath. Dry the bowl and lid with a dry cloth. Determine the mass of the bowl, sample, and lid and designate it as E.

b) **Flask** – Fill the flask slowly with water ensuring not to introduce any air into the sample. Place the flask in water bath for 10 ± 1 minutes to stabilize the temperature at 25°C without submerging the top of the flask. Completely fill the flask with water using a cover plate without entrapping air beneath the cover plate. Wipe the exterior of the flask and cover plate. Determine the mass of the flask, plate and its contents completely filled with water. Designate this mass as E.

6. Calculations

Calculate the maximum specific gravity of the sample of loose paving mixture as follows:

a) Bowls Used Under Water Determination:

$$Gmm = A / [A-(C-B)]$$

Where,

Gmm	=	maximum specific gravity of the mixture
A	=	mass of the dry sample in air, g
B	=	mass of bowl under water, g
C	=	mass of bowl and sample under water, g

b) Bowls in Air Determination:

$$Gmm = A / (A+D-E)$$

Where,

Gmm	=	maximum specific gravity of the mixture
A	=	mass of dry sample in air, g
D	=	mass of lid and bowl with water at 25°C, g
E	=	mass of lid, bowl, sample and water at 25°C, g

c) Flask Determination

$$Gmm = A /(A+D-E)$$

Where,

Gmm	=	maximum specific gravity of the mixture
A	=	mass of dry sample in air, g
D	=	mass of cover plate and flask filled with water at 25°C, g
E	=	mass of flask, cover plate, sample, and water at 25°C, g

(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)