

TRANSPORTATION ENGINEERING-I

Unit 4: Construction of Pavements

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COMPONENT OF FLEXIBLE PAVEMENTS

- The component layer of a flexible pavement laid over subgrade are

Granular sub-base, Granular base course,
Bituminous binder course Bituminous
surface course

Granular Sub-Base

- ❖ Laying and compacting well-graded material on prepared sub-grade
- ❖ Material shall be laid in one or more layers
- ❖ The material to be used for the work shall be natural sand, moorum, gravel, crushed stone.
- ❖ Only crushed stone to be used in Mumbai Region.

Granular Sub-Base

- ❖ The material shall have a 10% fines value of 50 kN
- ❖ Water absorption value of the coarse aggregate: If this value is greater than 2%, the soundness test shall be carried on material delivered to site as per IS:383
- ❖ For grading II and III materials, the CBR shall be determined at a density relating to a uniform air voids content of 5%

Grading for Coarse-Graded Granular Sub-Base Materials

IS Sieve Destination	Percent by Wt passing the IS sieve		
	Grading I	Grading II	Grading III
75.0 mm	100	-	-
53.0 mm	-	100	-
26.5 mm	55-75	50-80	100
9.50 mm	-	-	-
4.75 mm	10-30	15-35	25-45
2.36 mm	-	-	-
0.425 mm	-	-	-
0.075 mm	<5	<5	<5
CBR Value (Min)	30	25	20

Spreading and Compacting

- ❖ The sub-base material of grading specified in the contract shall be spread on the prepared sub-grade with the help of a motor grader of adequate capacity
- ❖ Its blade having hydraulic controls suitable for initial adjustment and for maintaining the required slope and grade during the operation
- ❖ Moisture content of the loose material shall be checked in accordance with IS:2770 and suitably adjusted by sprinkling additional water
- ❖ It is from 1% above to 2% below the optimum moisture content
- ❖ After water has been added, the material shall be processed by mechanical or other approved means like disc harrows, rotavators until the layer is uniformly wet

Spreading and Compacting

- ❖ Immediately thereafter, rolling shall start

Thickness of Compacted layer	Roller
100 mm	Smooth wheel roller of 80 to 100 kN
225 mm	Vibratory roller of 80-100 kN static weight with plain drum or pad foot-drum or heavy pneumatic tyred roller of 200-300 kN with tyre pressure of 0.7 MN/m ²

Spreading and Compacting

- ❖ Rolling shall commence at the lower edge and proceed towards the upper edge longitudinally for portions having unidirectional cross fall and super-elevation
- ❖ And shall commence at the edge and progress towards the center for portions having cross fall on both sides
- ❖ Each pass of roller shall uniformly overlap not less than one-third of track made in the preceding pass
- ❖ Rolling shall be continued till the density achieved is at least 98% of maximum dry density as per IS:2720

Wet Mix Macadam

- ❖ Laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on prepared sub-grade or existing pavement
- ❖ Thickness of single compacted Wet Mix Macadam layer shall not be less than 75 mm
- ❖ Coarse aggregate shall be crushed stone
- ❖ If crushed gravel is used, not less than 90% by Wt of gravel pieces retained on 4.75 mm sieve shall have at least two fractured faces
- ❖ If water absorption value of coarse aggregate is greater than 2%, the soundness test shall be carried out as per IS:2386(Part-5)

GRANULAR BASE COURSE

- The granular sub base course is considered as the most important component of flexible pavement layer which sustains the wheel load stresses and disperses through larger area on the GSB layer below.

The base course must have sufficient quality and thickness to prevent failure in the subgrade and/or sub base, withstand the stresses produced in the base itself.

MATERIAL USED IN BASE COURSE

The common types of base course materials used in

- India for the construction of flexible pavement are 'wet mix macadam', 'water bound macadam', soil aggregate mixes and stabilized soil mixes.
- The flexible pavements of most of the important highways are being constructed these days using WMM as the base course.
- 'Crusher run macadam' also used for base course. (Providing crushed stone aggregate, depositing on a prepared surface by hauling vehicles, spreading and mixing with a motor grader, watering and compacting with a vibratory roller)

CONSTRUCTION OF BASE COURSE

- Construction of base course is done by either WMM or WBM.



QUALITY CONTROL FOR WMM

- Los Angeles abrasion value : less than 40% Or Aggregate impact value : less than 30%
- Combined flakiness and elongation index : less than 30%
- Plasticity index of material finer than 0.425 mm sieve : less than 6
- MORTH have suggested that min of one set of aggregate impact, flakiness index and elongation index tests are to be conducted per 200 m³ of aggregate and minimum of one density test per 500 m² on each compacted layer.

BITUMINOUS PAVEMENT LAYER

- Bituminous pavement layers form an important part of the flexible pavement layer system. Different types of bituminous layers are being used as surface course of flexible pavement. Thin bituminous surface are provided for low traffic load and thicker surface is provided of heavier traffic load.
- It is essential to provide an appropriate type of interface treatment before laying any type of bituminous layer over the another layer. If the bituminous layer is to be laid over a sub-base layer, the prime coat and tack coat are applied. If the bituminous layer is to be laid over an existing bituminous surface then only tack coat is applied.

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- Bituminous layer is consist of three different components,

1 Base course

2 Binder course

3 Surface course

PREPARATION FOR BITUMINOUS LAYER

- Over GSB
- The surface is thoroughly cleaned free of dust.
- Prime coat is applied by spraying liquid bituminous binder of low viscosity.
- After curing of the prime coat , a tack coat is applied by spraying liquid bituminous binder of low viscosity.
- After that desired type of bituminous pavement layer is constructed.
- on construction of existing bituminous

INTERFACE TREATMENTS

- ❖ **Prime Coat**
- ❖ **Tack Coat**
- ❖ **Crack Prevention Courses**

❖ Purpose Of Priming:

- ❖ To plug the capillary voids
- ❖ To coat and bond loose materials on the surface
- ❖ To harden or toughen the surface
- ❖ To promote adhesion between granular and the bituminous layer

❖ Choice of Primer

- The primer shall be bitumen emulsion, complying with IS 8887 of a type and grade as specified (SS-1)
- The use of medium curing cutback as per IS 217 shall be restricted only for sites at sub-zero temperatures or for emergency applications

REQUIREMENT FOR PRIMING MATERIAL

Porosity	Type of Surface	Viscosity at 60° C (centistokes)	Quantity per 10 m² (Kg)
Low	WMM, WBM	30-60	6-9
Medium	Gravel base	70-140	9-12
High	Cement Stabilised soil base	250-500	12-15

TACK COAT

Purpose of Tack Coat:

➤ To ensure a bond between the new construction and the old surface

Material for Tack Coat:

➤ The primer shall be bitumen emulsion, complying with IS 8887 of a type and grade as specified (RS-1)

Use of Cutback:

➤ It should be restricted for sites at subzero temperatures or for emergency applications

RECOMMENDED QUANTITIES OF MATERIAL FOR TACK COAT

Type of Surface	Quantity in kg per m ² area
Bituminous Surface	0.20 to 0.25
Dry and hungry bituminous surfaces	0.25 to 0.30
Primed granular surface	0.25 to 0.30
Unprimed granular base	0.35 to 0.40
Cement concrete pavement	0.30 to 0.35

Properly Done Tack Coat



20-30% more quantity of tack coat for milled surface

Thin Bituminous Surface Courses

OPEN GRADED PREMIX SURFACE

Quantities of materials required for 10 m² (20 mm)

Aggregates		
a.	Nominal stone 13.2 mm (22.4-11.2)	0.18 m ³
b.	Nominal stone 11.2 mm (13.2-5.6)	0.09 m ³
	Total	0.27 m ³
Binder		
a.	For 0.18 m ³ of 13.2 mm nominal size at 52 kg bitumen per m ³	9.5 kg
b.	For 0.09 m ³ of 11.2 mm nominal size at 56 kg bitumen per m ³	5.1 kg
	Total	14.6 kg

SEAL COAT

A. Liquid Seal Coat:

comprising of a layer of binder followed by a cover of stone chipping

Stone chips shall be of 6.7mm size defined as 100 per cent passing through 11.2 mm sieve and retained on 2.36 mm sieve. The quantity used for spreading shall be 0.09 cubic metre per 10 square metre area.

B.Premixed Seal Coat:

a thin application of fine aggregates premixed with bituminous binder

The quantity of bitumen shall be 9.8 kg and 6.8 kg per 10

BITUMINOUS BASE COURSE

- TYPES

1 Bituminous Macadam

2 Penetration Macadam

3 Built up Spray Grout

Property	Test	Requirement	Test method
Cleanliness	Grain size analysis	Max. 5% passing 0.075 micron	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices	Max. 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or	Max. 40%	IS:2386 Part IV
	Aggregate Impact Value	Max. 30%	IS:2386 Part IV
Durability	Soundness (Sodium or Magnesium)	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	Min. Retained Coating 95%	IS:6241
Water sensitivity	Retained Tensile strength*	Min. 80%	AASHTO 283

- The aggregate to be used for the BM layer shall fulfil the specified gradation. Two type of aggregate gradation have been specified by the IRC which is as given below table

Grading	1	2
Nominal maximum aggregate size*	40 mm	19 mm
Layer thickness	80 -100 mm	50 -75 mm
IS Sieve size (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	90-100	
26.5	75-100	100
19	–	90 – 100
13.2	35-61	56 – 88
4.75	13 – 22	16 – 36
2.36	4 – 19	4 – 19
0.3	2 – 10	2 – 10
0.075	0 – 8	0 – 8
Bitumen content ** percent by mass of total mix	3.3**	3.4**

CONSTRUCTION

- The base on which bituminous macadam is to be laid shall be prepared, shaped and compacted to the required profile.
- The prime coat and take coat are applied as specified.

- The BM mix is prepared in a hot mix plant at specified temperature, depending on the grade of the bitumen used.

- The hot mix is transported to the construction site in insulated covered truck.

- The BM mix is spread using a mechanical paver.

Bituminous materials shall be laid and compacted in layers, which enable the specified thickness, surface level, regularity requirements and compaction to be achieved.

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- The ***initial*** or breakdown rolling shall be done with 8- 10 tonne static weight smooth-wheel rollers. The ***intermediate*** rolling shall be done with 8-10 tonne static weight or vibratory roller or with a pneumatic tyre roller of 12 to 15 tonne weight, with a tyre pressure of at least 0.56 Mpa. ***The finish*** rolling shall be done with 6 to 8 tonne smooth wheel tandem rollers. Rolling shall continue until the specified
- compaction is achieved. The bituminous macadam shall be *covered* with either the next *pavement* course or wearing course, as the case may be, within a maximum of forty-eight hours.

BITUMINOUS PENETRATION MACADAM BASE COURSE

This base course may be used as base course of flexible pavement in certain short road or in small road project where hot mix plant is not available.

The coarse aggregate of specified size are first spread and compacted well in dry state.

After compaction, hot bitumen binder of specified grade is sprayed in large

BUILT UP SPRAY GROUT(BUSG)

- BUSG consist of a two layer composite construction of compacted crushed stone aggregate with bituminous binder applied after each layer and key aggregate placed on the top surface of the second layer.
- After first layer is compacted, the bitumen binder is sprayed at specified rate which penetrate into layer; then second layer is spayed and compacted, binder sprayed, key aggregates sprayed and compacted.

THIN BITUMINOUS SURFACING

- **Object**

- A thin bituminous surface course is laid over the base course to prevent the entry of surface water into the pavement layers during rains.
- And also serve as a wearing course.

- **Types of thin bituminous surfacing**

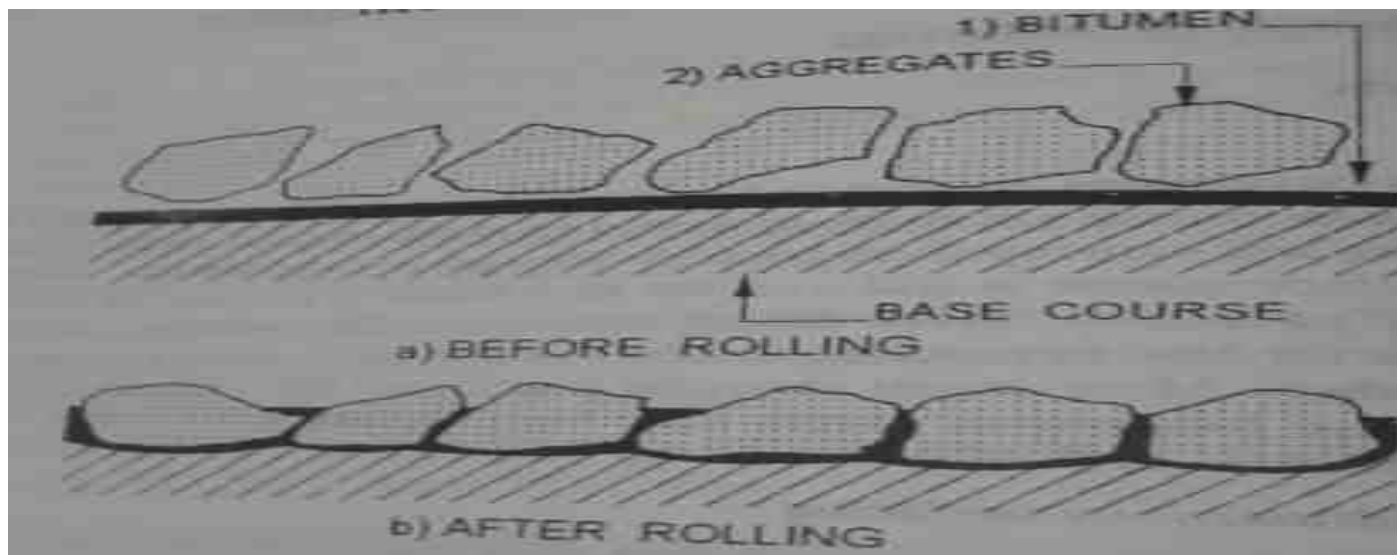
- (i) Surface Dressing
- (ii) 20 mm thick "open Graded Pre-mixed Bituminous Carpet" with seal coat and
- (iii) 20 mm thick "Mixed being Surface" or "Close Graded Pre-mix"

Bituminous surface

- General features
- Bituminous surface Dressing' (BSD) is provided over a prepared base course or existing pavement to serve as thin wearing coat.
- The surface dressing does not add to the structural stability or strength of the pavement nor will it improve the existing riding quality of the pavement surface. The DBS is a cost effective surface treatment to provide a dust free and impermeable pavement surface.
- The IRC has provided specification for two types of surface dressing work,
 - 1 single coat surface dressing
 - 2 two coat surface dressing

Single coat surface dressing

- Material
- Bituminous binder and aggregates are taken as per IRC specification.
- **Principle of surface dressing**



material

Table 500-20 : Recommended Nominal Size of Aggregates (mm)

Type of Surface	Traffic Intensity in Terms of Number of Vehicles Per Day in the Lane Under Consideration		
	1000-2000	200-1000	20-200
Very hard	10	6	6
Hard	13	10	6
Normal	13	10	6
Soft	19	13	13
Very soft		19	13

Table 500-21 : Grading requirements for Aggregates used for Surface Dressing

IS Sieve Designation (mm)	Cumulative Percent by Weight of Total Aggregates Passing for the Following Nominal Sizes (mm)			
	19	13	10	6
26.5	100			
19	85-100	100		
13	0-40	85-100	100	
9.5	0-7	0-40	85-100	100
6.3		0-7	0-35	85-100
4.75			0-10	
3.35				0-35
2.36	0-2	0-2	0-2	0-10
0.60				0-2
0.075	0-1.5	0-1.5	0-1.5	0-1.5
Minimum 65% by weight of aggregate	Passing 19 and retained on 13.2	Passing 13.2 and retained on 9.5	Passing 9.5 and retained on 6.3	Passing 6.3 and retained on 3.35

Construction

- The receiving surface is prepared by patching the pot- holes.
- The surface is cleaned with a mechanical broom to remove loose material and dust.
- Bituminous binder of specified grade is heated to the specified temp and is uniformly sprayed using a mechanical sprayer at the specified rate.
- Immediately after the application of the binder, the selected aggregate for surface dressing is spread using a mechanical grit spreader at specified rate.

Immediately after spreading the aggregates, the entire surface is rolled using a pneumatic

Cont...

- When paving bitumen is used as binder the finished surface may be opened to traffic on the next day.

Two coat surface dressing

- In the case of two-coat surface dressing, after first coat as given above is allowed for two to three weeks before the application of the second coat.
- The binder is applied at the same specified rate and immediately the aggregate of next smaller size is spread at the specified rate. Rolling is done as before, soon after spreading the aggregates.

Open graded premix carpet

- Open graded premix carpet (Pc) consists of coarse aggregates of nominal size 13.2 (passing 22.4 mm and retained on 11.2 mm) premixed with a suitable type and grade of bituminous binder, spread and compacted to a thickness of 20 mm followed by application of seal coat, to serve as a thin surface course of the pavement.

Mixed seal surfacing or close graded premix surfacing



surfacing'. This consists of aggregates of specified gradation premixed with a suitable grade of paying grade bitumen binder in a hot mix plant, spread with a mechanical paver and compacted to a thickness of 20 mm to form a thin surfacing.

- As the premix is prepared using close graded aggregates with adequate bitumen binder content, the MSS forms non-porous surface course and there is no need to apply seal coat as in the case of open graded premix carpet.

DENSE BITUMINOUS MACADAM (DBM)

- ❖ **DBM is Closely Graded**
- ❖ **DBM is used as a Binder Course for pavements subjected to heavy traffic**
- ❖ **Hydrated Lime or Cement shall be used as filler, if the mix fails to meet the water sensitivity requirement**

PHYSICAL REQUIREMENTS OF COARSE AGGREGATES FOR DBM

Test	Test Method	Requirement
Los Angeles Abrasion Value*	IS: 2386 (Part-4)	35 % Max
Aggregate Impact Value *	IS: 2386 (Part-4)	27 % Max
Flakiness and Elongation Indices (Total)	IS: 2386 (Part-1)	30 % Max
Coating and Stripping of Bitumen Aggregate Mixture	IS: 6241	Min Retained Coating 95%
Soundness Loss with Sodium Sulphate Loss with Magnesium sulphate	IS: 2386 (Part-5) 5 Cycle 5 Cycle	12 % Max 18 % Max
Water Absorption	IS: 2386 (Part-3)	2 % Max
Retained Tensile Strength	AASHTO T283	Min 80 %

* Either of the two is required

GRADATION REQUIREMENTS FOR DBM

Grading	I	II
Nominal Aggregate Size	40 mm	25 mm
Layer Thickness	75-100 mm	50-75 mm
IS Sieve (mm)	Percent Passing	
45.0	100	-
37.5	95-100	100
26.5	63-93	90-100
19.0	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.30	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen content per cent by wt of total mix	Min 4.0	Min 4.5
Bitumen Grade	S 65-90	S 65-90

DESIGN REQUIREMENTS FOR DBM

Minimum Stability (kN at 60°C)	9.0
Flow	2-4
Compaction Level (Number of blows)	75 on each face
Per cent air voids	3-6
Per cent voids in mineral aggregate (VMA)	VMA Table
Per cent voids filled with bitumen (VFB)	65-75

MODIFIED PENETRATION MACADAM (MPM)

- ❖ **Grouted/ Penetration type of construction**
- ❖ **It can be laid in 50 mm or 75 mm thickness**
- ❖ **Commonly practiced in Maharashtra**

BITUMINOUS CONCRETE

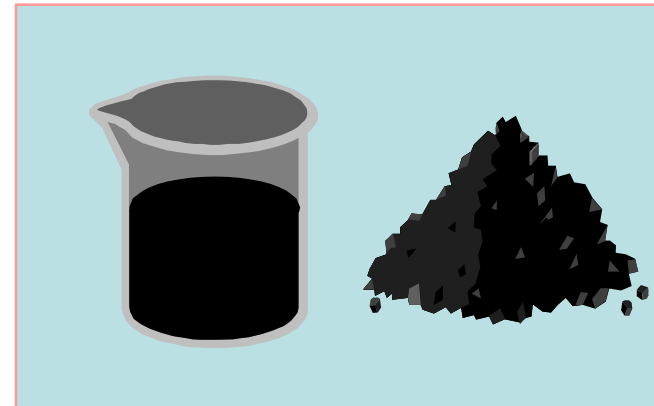
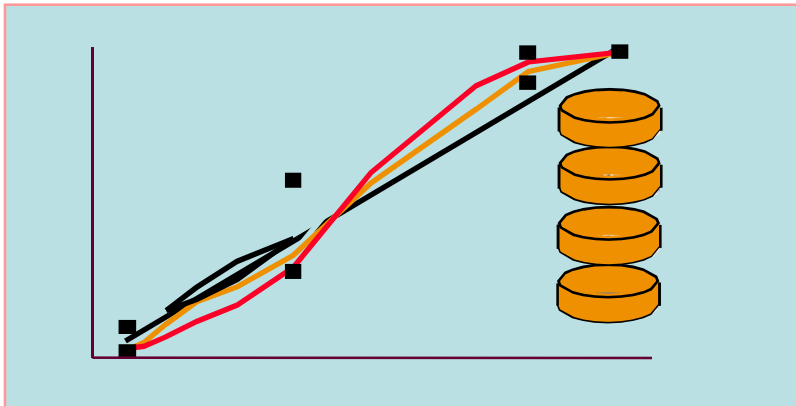
- This work shall consist of construction of Bituminous Concrete, for use in wearing courses. This work shall consist of construction in a single layer of bituminous concrete on a previously prepared bituminous bound surface.
-
- Material:
Bitumen, Coarse Aggregates, fine aggregates, Filter (shall consist of finely divided mineral matter such as rock dust, hydrated lime or Cement)

BITUMINOUS CONCRETE (BC)

- ❖ **BC is a Dense Graded Bituminous Mix used as Wearing Course for Heavily Trafficked Roads**

BITUMINOUS CONCRETE (BC)

- ❖ **BC Mix consists of Coarse Aggregates, Fine Aggregates, Filler and Binder blended as per Marshall Mix Design**



GRADING REQUIREMENTS OF BC

Sieve Size mm	I	II
	50-65 mm	30-45 mm
26.5	100	-
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	42-58
0.60	15-27	26-38
0.30	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content per cent by mass of total mix	5.0-6.0	5.0 – 7.0

BITUMINOUS CONCRETE (BC)

Quality control operations involved are:

- ❖ Design of mix in laboratory, and control of mixing, laying and rolling temperatures**
- ❖ Density, Marshall Stability, Flow, Air Voids, Retained Stability, Bitumen Content, Gradation of aggregates are controlled**
- ❖ Riding quality is a control**

CRITERIA OF MINIMUM VOIDS IN MINERAL AGGREGATE (VMA) FOR DENSE MIXES

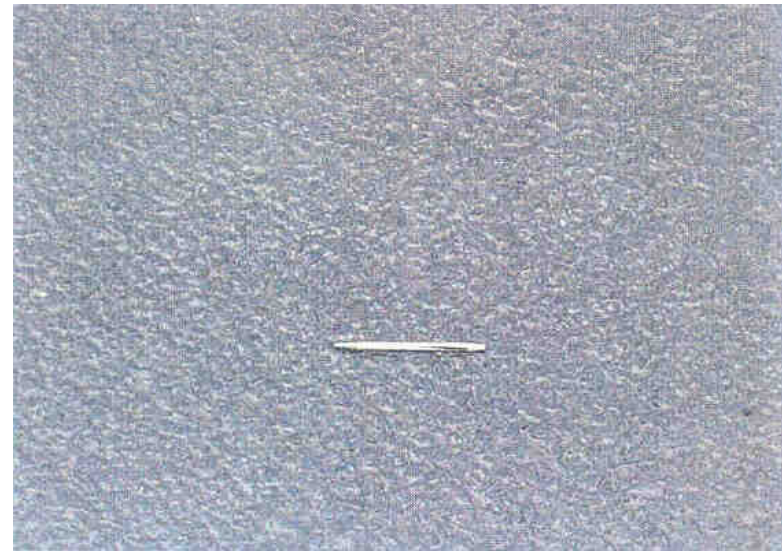
Nominal Maximum Particle Size (mm)	Minimum VMA, per cent Related to Design Air Voids, Per cent		
	3.0	4.0	5.0
9.5	14.0	15.0	16.0
12.5	13.0	14.0	15.0
19.0	12.0	13.0	14.0
25.0	11.0	12.0	13.0
37.5	10.0	11.0	12.0

DESIGN REQUIREMENTS FOR BC

Minimum Stability (kN at 60°C)	9.0
Flow	2-4
Compaction Level (Number of blows)	75 on each face
Per cent air voids	3-6
Per cent voids in mineral aggregate (VMA)	VMA Table
Per cent voids filled with bitumen (VFB)	65-75
Loss of stability on immersion in water at 60°C (ASTM D 1075)	Minimum 75 %



Freshly Laid BC layer



BC Layer after Traffic Movement

SEMI DENSE BITUMINOUS CONCRETE (SDBC)

- ❖ **Wearing course on roads carrying moderate traffic, generally less than 10 msa**
- ❖ **Lesser binder content when compared to BC**

THE GRADING REQUIREMENTS OF SDBC

Grading	I	II
Nominal Aggregate Size	13.2 mm	10 mm
Layer Thickness	35-40 mm	25-30 mm
IS Sieve (mm)	Per cent Passing	
19.0	100	-
13.2	90-100	100
9.5	70-90	90-100
4.75	35-51	35-51
2.36	24-39	24-39
1.18	15-30	15-30
0.6	-	-
0.30	9-19	9-19
0.15	-	-
0.075	3-8	3-8
Bitumen content per cent by wt of total mix	Min 4.5	Min 5.0
Bitumen grade	65*	65*

DESIGN REQUIREMENTS FOR SDBC

Minimum Stability (kN at 60°C),	8.2
Flow	2-4
Compaction level (Number of blows)	75 on each face
Per cent air voids	3-5
Per cent voids in mineral aggregate (VMA)	VMA Table
Per cent voids filled with bitumen (VFB)	65-78
Loss of stability on immersion in water at 60°C (ASTM D 1075)	Minimum 75 %