Construction & Quality Control of Flexible Pavements

BITUMINOUS PAVEMENT CONSTRUCTION

Bituminous construction are classified into four categories

- **Interface Treatments**
- **Thin Bituminous surface Courses**
- **Bituminous Surface Courses**
- **Bituminous Binder Courses**

INTERFACE TREATMENTS

- Prime Coat
- Tack Coat
- Crack Prevention Courses
  - SAM and SAMI

- **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 60^0 C (centistokes)	Quantity per 10 m^2 (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)

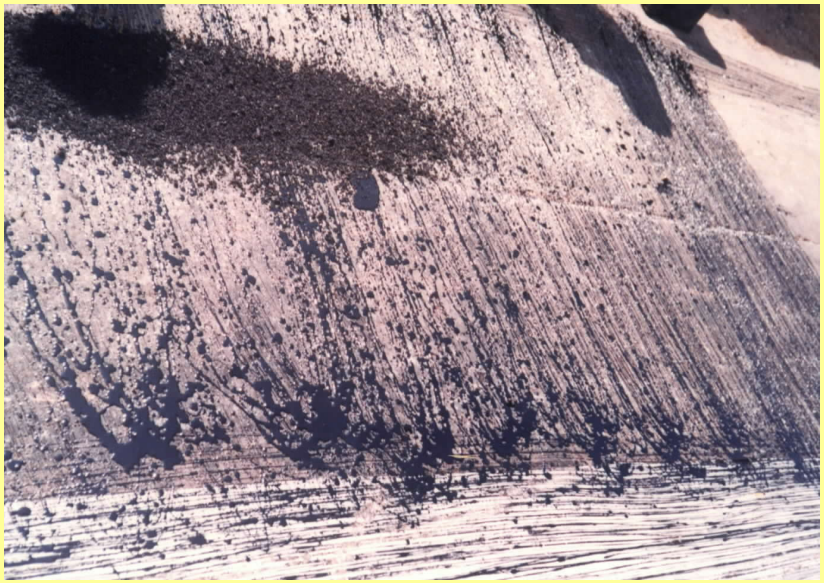
Use of Cutback:

- 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

WRONG PRACTICE OF TACK COAT



INSUFFICIENT TACK COAT

MECHANICAL PRESSURE SPRAYER FOR PRIME/TACK COAT

MECHANICAL PRESURE HAND SPRAYER FOR PRIME/TACK COAT

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 m^2 (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 m^2 area for type A and type B seal coat respectively

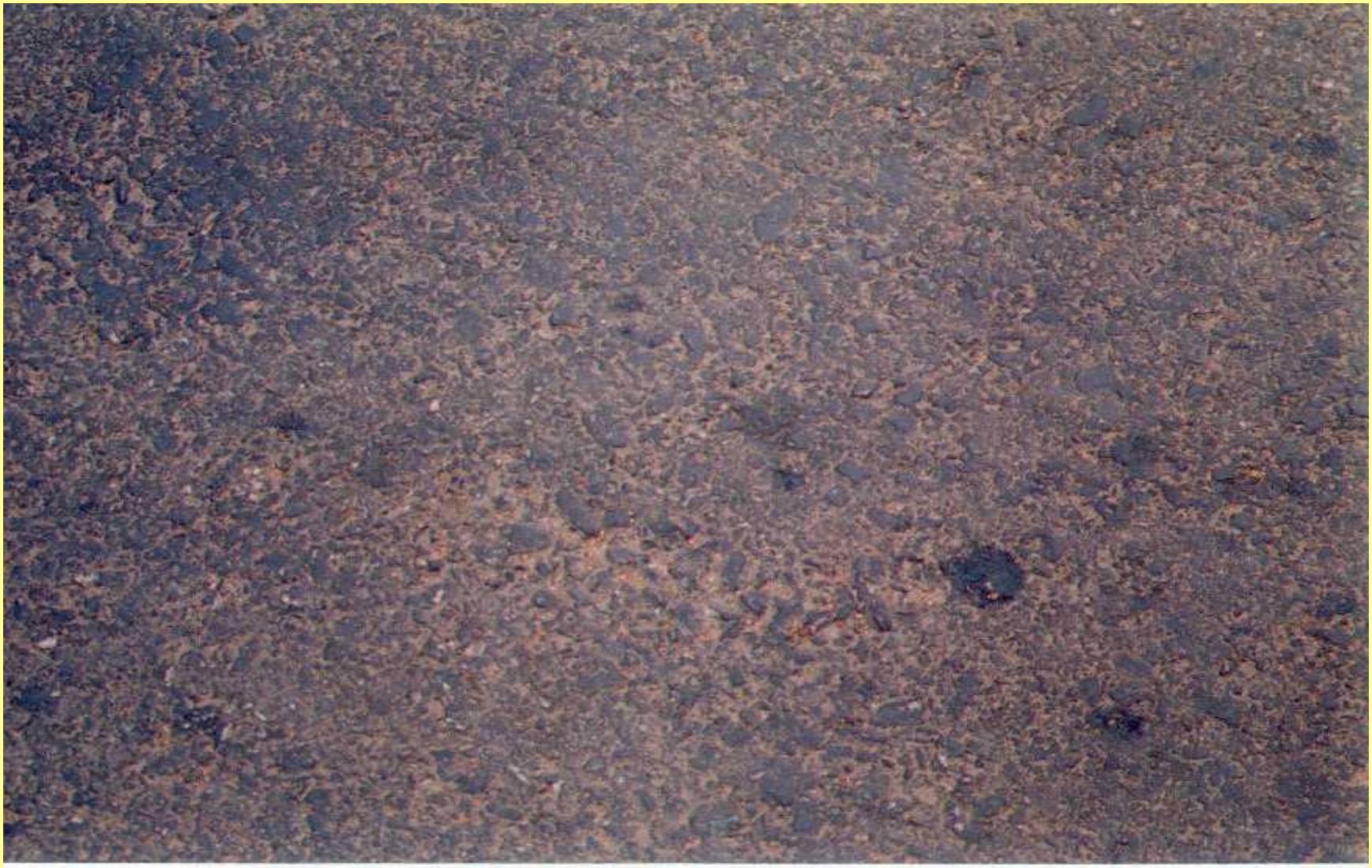
CLOSELY GRADED PREMIX CARPET/MIXED SEAL SURFACING

- Close-graded premix carpet is a fairly open graded mix
- It is an alternative to the open graded premix carpet and a seal coat
- It may be constructed in one operation

AGGREGATE GRADATION FOR MSS

IS Sieve mm	Cumulative % by wt. of total aggregate passing	
	Type A	Type B
13.2	-	100
11.2	100	88-100
5.6	52-88	31-52
2.8	14-38	5-25
0.09	0-5	0-5

POOR CONSTRUCTION OF MSS



Tack Coat on Cracked Bituminous Surface

Thin Layer of MSS over WBM

QUANTITY OF AGGREGATES AND BITUMEN

- The total quantity of aggregates used shall be 0.27 cum per 10 m^2 area

- The quantity of binder shall be 22.0 kg and 19.0 kg for 10m^2 area for Type A and Type B surfacing respectively

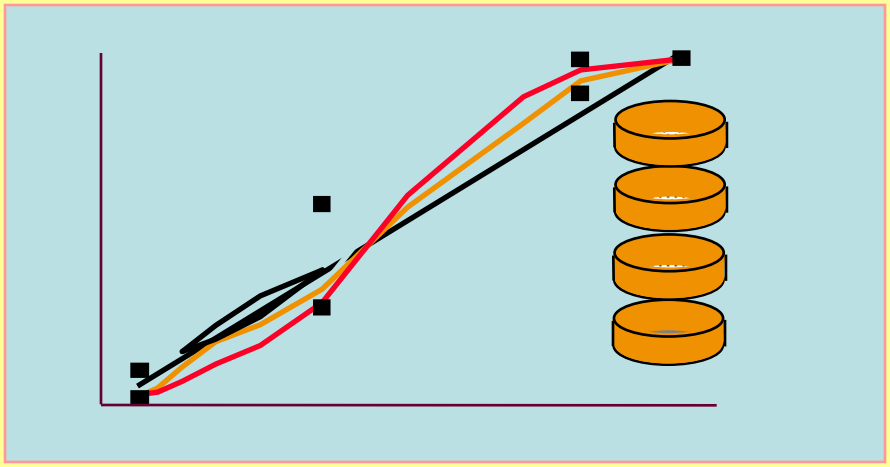
BITUMINOUS SURFACE COURSES

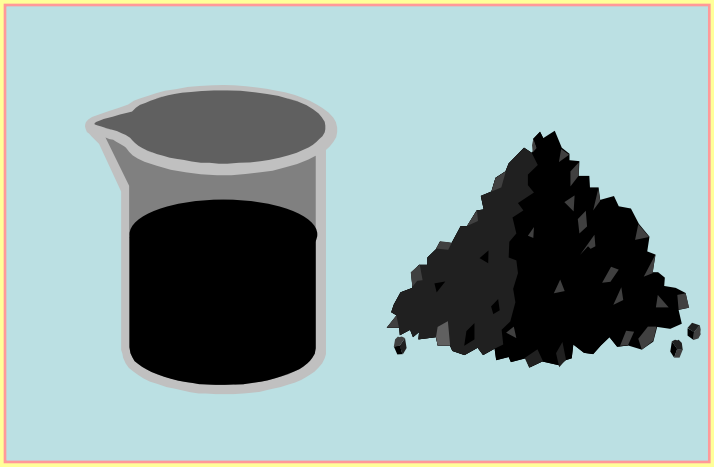
BITUMINOUS CONCRETE (BC)

- 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**

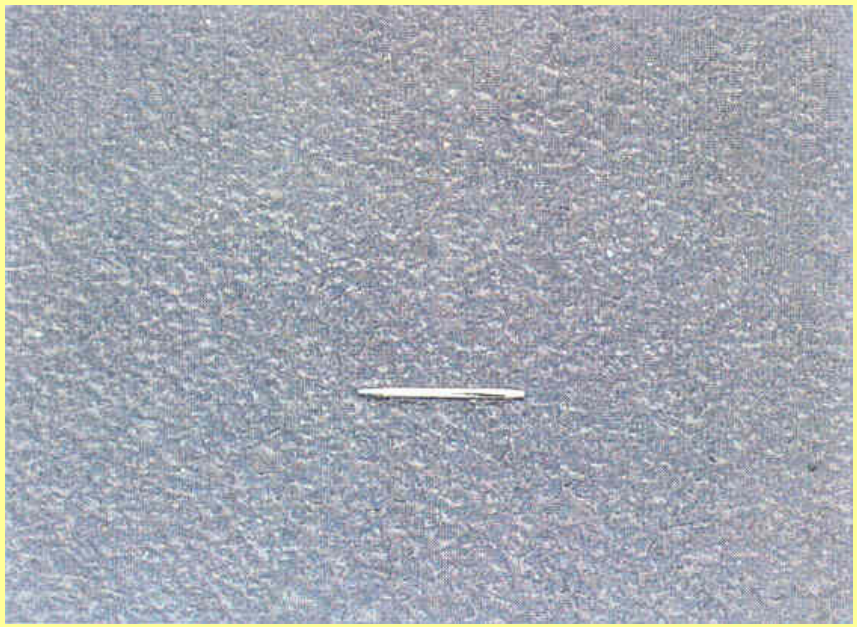
CRITERIA OF MINIMUM VOIDS IN MINERAL AGGREGATE (VMA) FOR DENSE MIXES

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 %

SDBC LAYER

MASTIC ASPHALT

- Mastic Asphalt is a mixture of Bitumen, Filler and Fine Aggregates in suitable proportions designed to yield a void less compact mass
- It is heated to 200^{o}C
- It solidifies into a dense mass on cooling to normal temperature
- No compacting effort required

MASTIC ASPHALT AS WEARING COURSE

- Heavy-duty pavement
- City street carrying high volume of traffic
- Bus stops where heavy tangential forces are expected
- Junctions
- Bridge Decks

GRADING OF COARSE AGGREGATE FOR MASTIC ASPHALT

Application	Thickness Range (mm)	Nominal size of coarse Aggregate	Coarse Aggregate content % by mass of total mix
Road and carriageways	25-50	13	40±10
Heavily Stressed Area, Junctions	40-50	13	45±10
Nominal Size of Coarse Aggregate IS Sieve (mm)	13 mm Per cent passing by weight		
19.0	100		
13.2	88-96		
2.36	0-5		

GRADING OF FINE AGGREGATE FOR MASTIC ASPHALT (INCLUSIVE OF FILLER)

IS sieve	Percentage by weight of aggregate
Passing 2.36 mm but retained on 0.60 mm	0-25
Passing 0.60 mm but retained on 0.212 mm	10-30
Passing 0.212 mm but retained on 0.075mm	10-30
Passing 0.075 mm*	30-55

*limestone powder shall have a calcium carbonate content of not less than 80 percent by weight

REQUIREMENTS FOR PHYSICAL PROPERTIES OF BINDER IN MASTIC ASPHALT

Property	Requirement	
Penetration 25°C	IS: 1203	15±5
Softening Point °C	IS: 1205	65±10
Loss on heating for 5h at 163°C, per cent by mass	IS: 1212	Max 2.0
Solubility in trichloroethylene, per cent by mass	IS: 1216	Min 95
Ash (Mineral Matter), per cent by mass	IS: 1217	Max 1.0

Bituminous Binder Courses

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

SIZE AND QUANTITY OF AGGREGATES FOR MPM

Aggregate Size	Rate of application for 10 m^2 area			
	75 mm		50 mm	
	On Asphalt Surface	On W. B. M. Surface	On Asphalt Surface	On W. B M. Surface
40 mm size hand broken metal	0.9 cum	0.9 cum	0.6 cum	0.6 cum
12 mm size chips	0.18 cum	0.18 cum	0.18 cum	0.18 cum

QUANTITY OF BITUMEN FOR MPM

Grade of Bitumen	Rate of application for 10 m^2 area			
	75 mm		50mm	
	On Bituminous Surface	On W. B. M. Surface	On Bituminous Surface	On W. B M. Surface
Bitumen for grouting S-35 or S-65	20 kg.	20 kg.	17.5 kg.	17.5 kg.
Tack coat (60/70 grade bitumen)	5 kg	-	5 kg	-

BUILT-UP SPRAY GROUT

- Two Layer Composite Construction of Compacted Coarse Aggregates
- Application of Binder after each layer
- Key aggregates on top of each layer
- Thickness = 75 mm
- Single Course in Pavement Structure

BUILT-UP SPRAY GROUT

IS SIEVE (mm)	CUM % PASSING	
	COARSE	KEY
53	100	-
26.5	40-75	-
22.4	-	100
13.2	0-20	40-75
5.6	-	0-20
2.8	0-5	0-5

BUILT-UP SPRAY GROUT

- Preparation of Base to the Required Camber and Shape
- Application of Primer
- Application of Tack Coat
- Spreading and Rolling First Layer of Coarse Aggregates (0.5 cu.m/10 sq.m)
- Application of Binder - First Spray (15 kg/10 sq.m)

BUILT-UP SPRAY GROUT

- Spreading and Rolling of Coarse Aggregates for the Second Layer
- Application of Binder - Second Spray (15 kg/10 sq.m)
- Application of Key Aggregates (0.13 cu.m/10 sq.m)
- Roll and Apply Additional key aggregates, if required
- Cover with a Seal Coat before opening to Traffic

BITUMINOUS MACADAM (BM)

- BM is carried out in a Hot Mix Plant, laid and compacted mechanically
- There are two sets of grading, Grade I & II
- Quality control measures involves percentage of Bitumen & Mixing, Laying and Compaction temperature

GRADATION REQUIREMENTS FOR BM

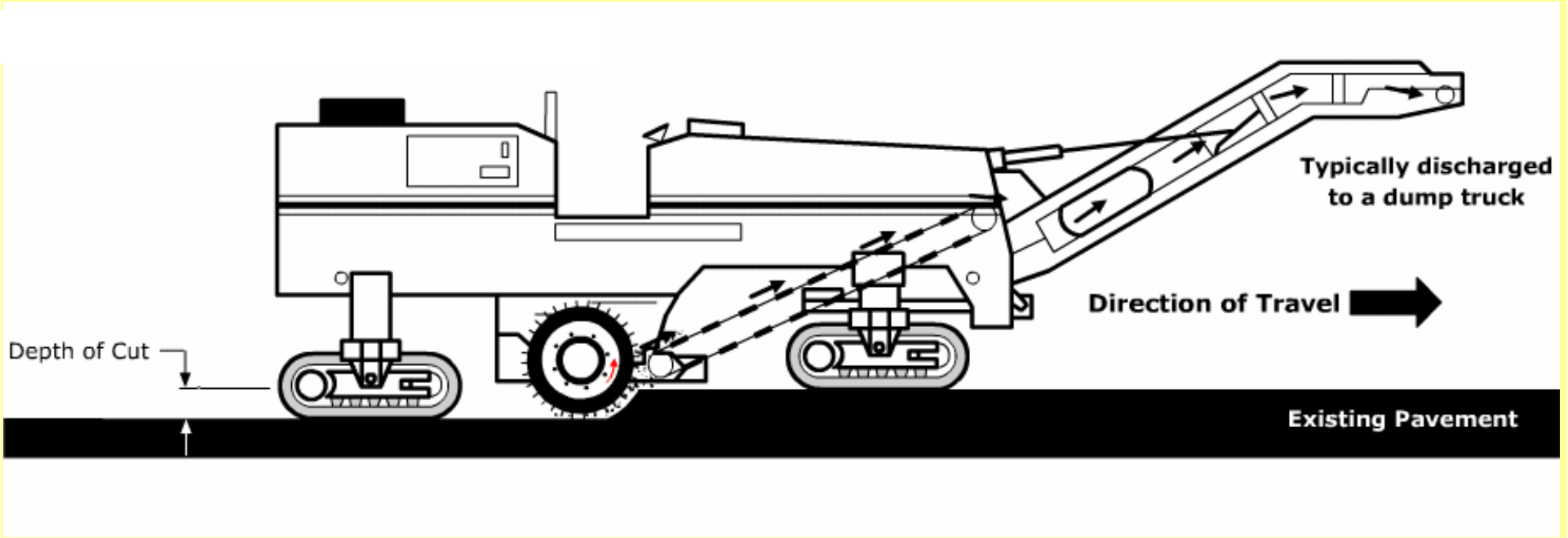
Grading	I	II
Nominal	40 mm	19 mm
Layer Thickness	75-100 mm	50-75 mm
IS Sieve (mm)	Per cent Passing	
45.0	100	--
37.5	90-100	--
26.5	75-100	100
19.0	--	90-100
13.2	35-61	56-88
4.75	13-22	16-36
2.36	4-19	4-19
0.300	2-10	2-10
0.075	0-8	0-8
Bitumen, per cent by weight of mix	3.1 to 3.4	3.3 to 3.5
Bitumen Grade	S 35-90	S 35-90

CRACKED SURFACE

Map/Alligator Cracking

Transverse Cracking

Typical Milling Machine



Milling Operation in Progress

COMPACTION OF BITUMINOUS MIXES

- Lack of adequate compaction in field leads to reduced pavement life
- Inadequate compaction of hot mix leads to early oxidation, ravelling, cracking and disintegration before its life expectancy is achieved
- 1% excess voids results in approximately about 10% reduction in life

COMPACTION OF MIXES contd…

- **Lack of attention to the air voids requirement of compacted dense graded bituminous mixes is the most common cause of poor pavement performance**
- **Laboratory compaction produces more density, hence 95-98% of laboratory density or 92% of theoretical density is preferred in the field**

Factors Affecting Compaction

Environmental Factors

Temperature

- Ground temperature
- Air temperature
- Wind speed
- Solar flux

Mix Property Factors

Aggregate

- Gradation
- Size
- Shape
- Fractured faces
- Volume

Asphalt Binder

- Chemical properties
- Physical properties
- Amount

Construction Factors

Rollers

- Type
- Number
- Speed and timing
- Number of passes
- Lift thickness

Other

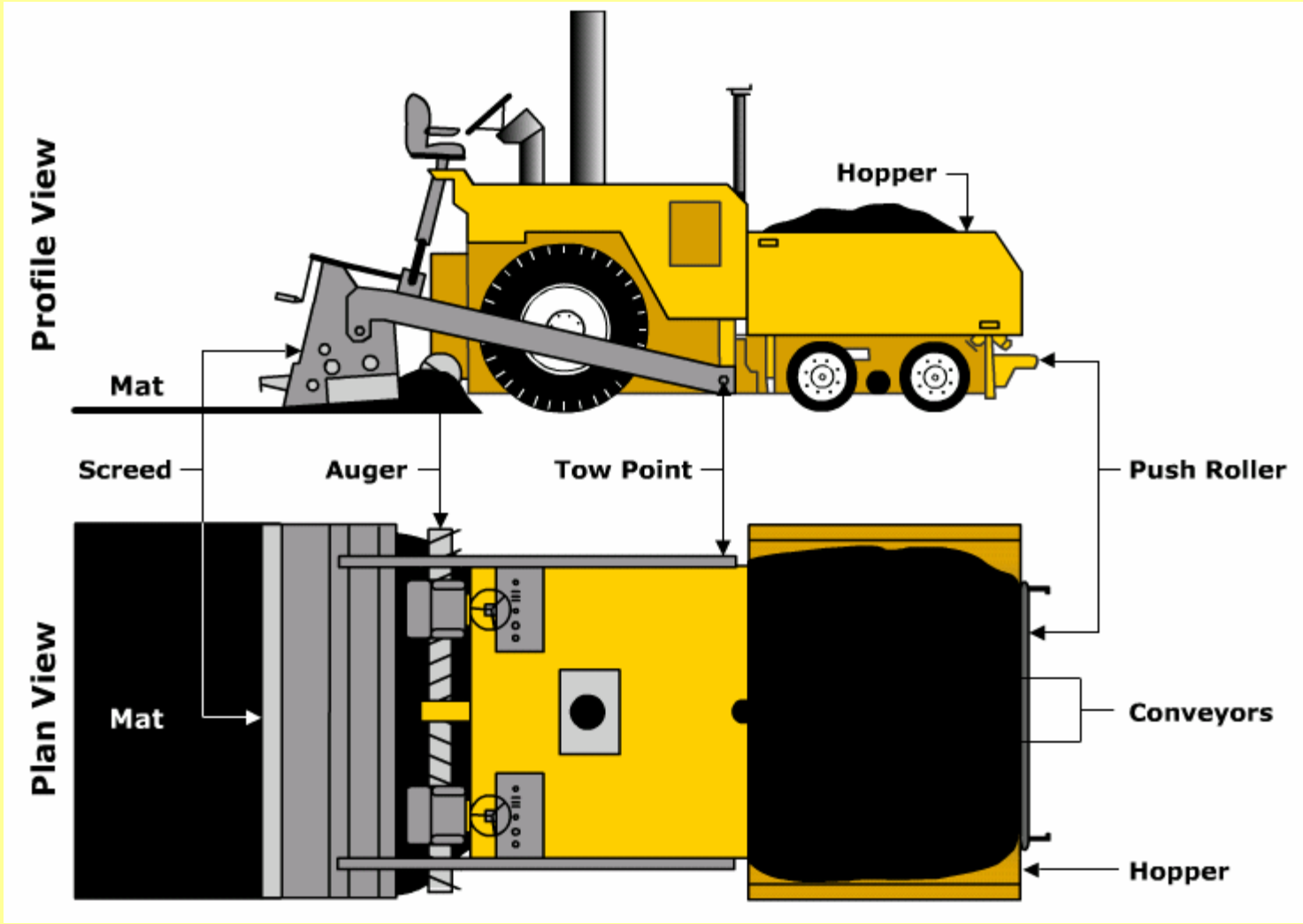
- HMA production temperature
- Haul distance
- Haul time
- Foundation support

Compaction Sequence

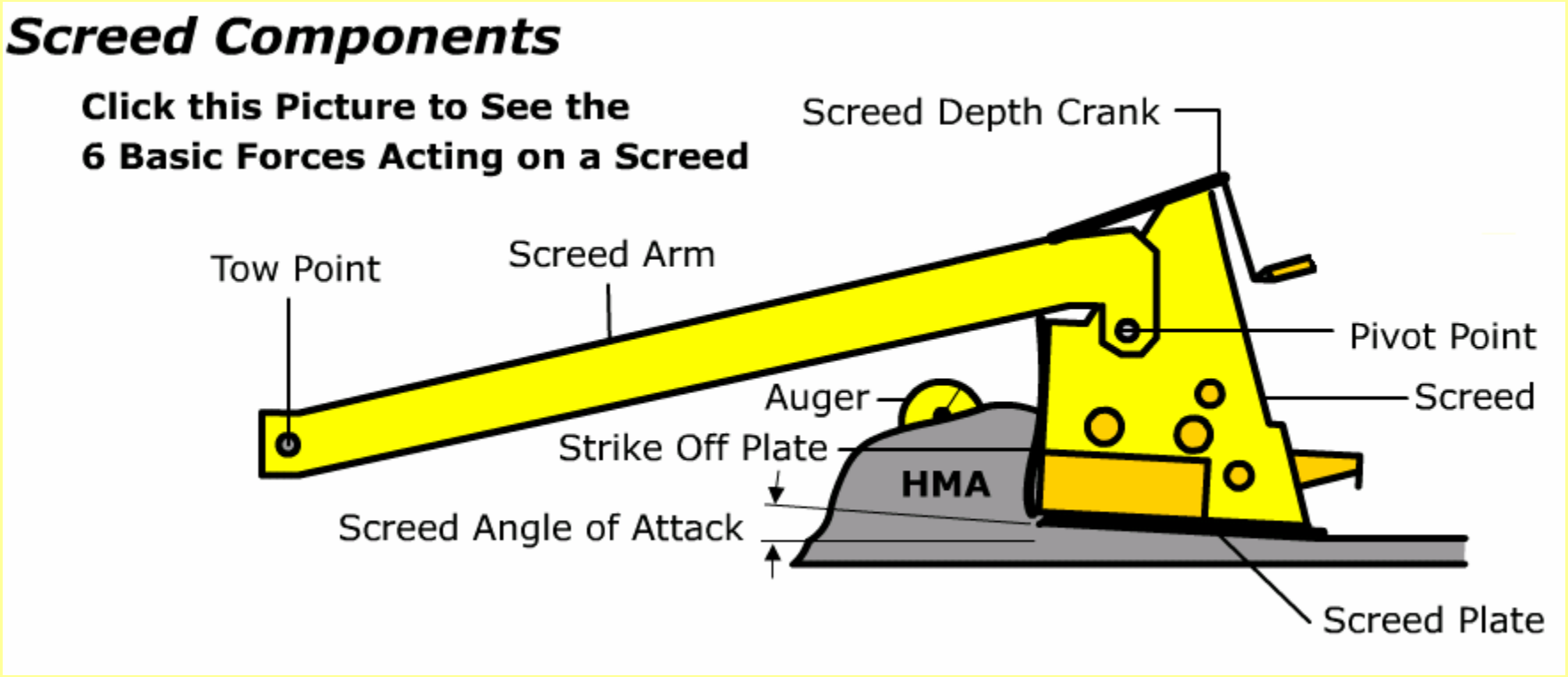
SCREED

The screed is the first device used to compact the mat and may be operated in the vibratory mode. Approximately 75 to 85 percent of Theoretical Maximum Density (TMD) will be obtained when the mix passes out from under the screed.

Schematic of a Paver



Screed Components



Compaction Sequence

ROLLERS

- Generally a series of two or three rollers is used.
- Contractors can control roller compaction by varying things such as the types of rollers used, the number of roller used, roller speed, the number of roller passes over a given area of the mat, the location at which each roller works, and the pattern that each roller uses to compact the mat.
- Approximately 92 to 95 percent TMD will be obtained when all rollers are finished compacting the mat.

Steel Wheel and Pneumatic Tyre Rollers

Compaction Sequence

Typical roller position used in compaction are:

- ***Breakdown Roller*** The first roller behind the screed. It generally effects the most density gain of any roller in the sequence. Breakdown rollers can be of any type but are most often ***vibratory steel wheel***.
- ***Intermediate Roller*** Used behind the breakdown roller if additional compaction is needed. ***Pneumatic tire rollers*** are sometimes used as intermediate rollers because they provide a different type of compaction (kneading action) than a breakdown steel wheel vibratory roller, which can help further compact the mat or at the very least, rearrange the aggregate within the mat to make it receptive to further compaction.
- ***Finish Roller*** The last roller in the sequence. It is used to provide a smooth mat surface. Although the finish roller does apply compactive effort, by the time it comes in contact with the mat, the mat may have cooled below cessation temperature. ***Static steel wheel rollers*** are almost always used as finishing rollers because they can produce the smoothest surface of any roller type.

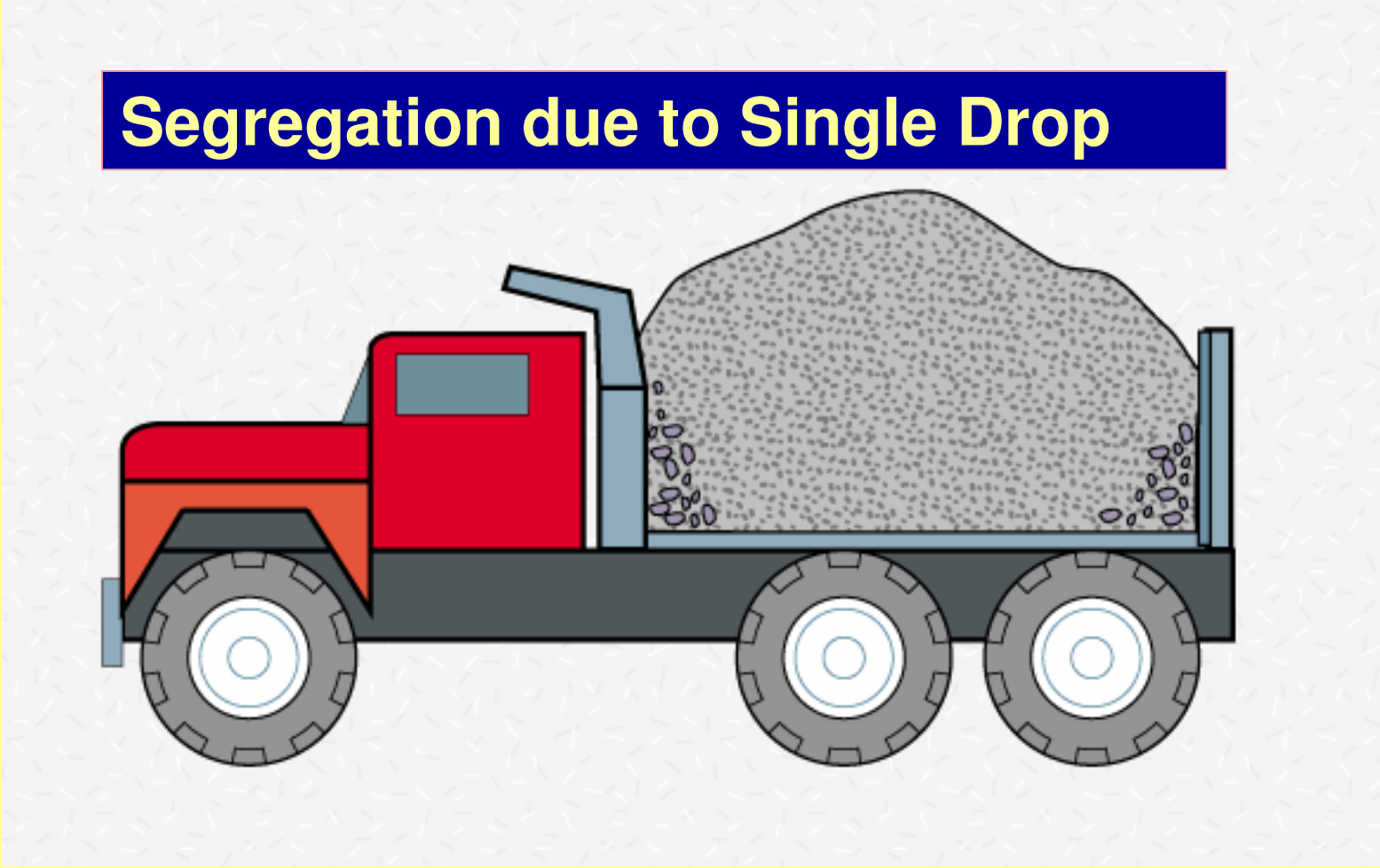
Breakdown and Intermediate Rollers Lined up for Effective Compaction

Steel Wheel Roller Giving the Finish

Density – Air Voids Measurement by Extracting Cores

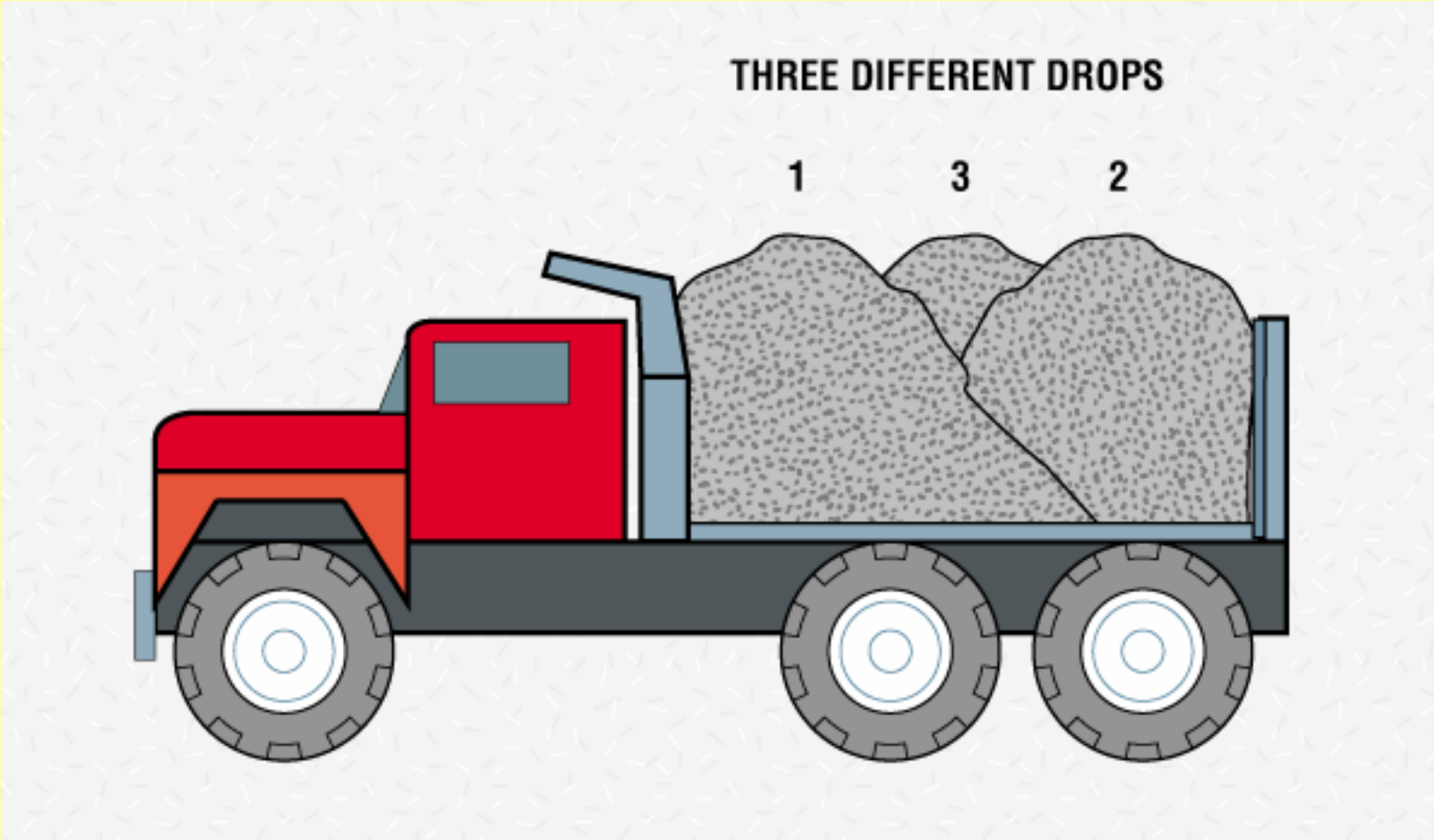
Nuclear Density Gauge

SEGREGATION IN MIX



SEGREGATION IN BM MIX

PROPER LOADING



GOOD PAVEMENT SURFACE

TEMPERATURE

Grade	Bitumen	Agg.	Mix	Laying	Rolling
35	160 - 170	160 - 175	170 Max	130 Min	100 Min
65	150 - 165	150 - 170	165 Max	125 Min	90 Min
90	140 - 160	140 - 165	155 Max	115 Min	80 Min

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 Close-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	80-100	100	-
26.5 mm	55-90	70-100	100
9.50 mm	35-65	50-80	65-95
4.75 mm	25-55	40-65	50-80
2.36 mm	20-40	30-50	40-65
0.425 mm	10-25	15-25	20-35
0.075 mm	3-10	3-10	3-10
CBR Value (Min)	30	25	20

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)

Physical Requirement of Coarse Aggregate for WMM

Test	Test Method	Requirement
1. Los Angeles Abrasion Value or	IS:2386(Part-4)	40%
Aggregate Impact Value	IS:2386(Part-4) or IS:5640	30%
2. Combined Flakiness and Elongation indices (Total)	IS:2386(Part-1)	30%

Grading Requirement for WMM

IS Sieve Destination	Percent by Wt Passing the IS Sieve
53.00 mm	100
45.00 mm	95-100
26.50 mm	-
22.40 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600 micron	8-22
75 micron	0-8

Materials finer than 425 micron shall have Plasticity Index (PI) not exceeding 6.

Spreading and Compacting

- **Preparation of mix**

  WMM shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water

  Optimum moisture for mixing shall be determined in accordance with IS: 2720 (Part-8) after replacing the aggregate fraction retained on 22.4 mm sieve with material of 4.75 mm to 22.4 mm size.

- **Spreading of mix**

  Immediately after mixing, the aggregate shall spread uniformly and evenly upon the prepared sub-grade in required quantities by paver or motor grader

- **Compaction**

  After the mix has been laid to the required thickness, grade and cross fall/camber the same shall be uniformly compacted to the full depth with suitable roller