

# Third Party Quality Audit (TPQA) for National Cyclone Risk Mitigation Project (NCRMP)

## Quality Assurance Plan Volume III 2015



**Third Party Quality Audit (TPQA)**  
**for**  
**National Cyclone Risk Mitigation Project (NCRMP)**

## Quality Assurance Plan Volume III 2015

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## A Technical Presentation

**D.V. Bhavanna Rao** M.Tech., F.I.E.,  
Retired R&B Chief Engineer  
E-mail: [bhavannarao@yahoo.co.in](mailto:bhavannarao@yahoo.co.in)  
Phone: +919494440202



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<http://aproadbuildqa.blogspot.com>

Construction and QC in Rigid Pavements for low volume roads  
as per MORD 2014 Specifications and IRC:SP:62-2014

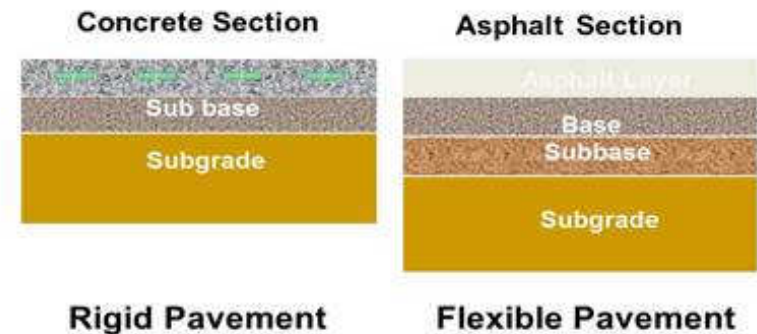
## Important Publications for Rural Roads

1. Specifications for Rural Roads, MORD (2014).
2. Rural Roads Manual IRC:SP:20-2002.
3. MORD Quality Assurance Handbook for Rural Roads Volume I and II: 2007
4. Hill Road Manual: IRC:SP:48-1998.
5. IRC:SP:72-2007/15: Guidelines for design of flexible pavements for low volume Rural Roads
6. IRC:SP:62-2014 Guidelines for Design of Rigid Pavements for Rural Roads

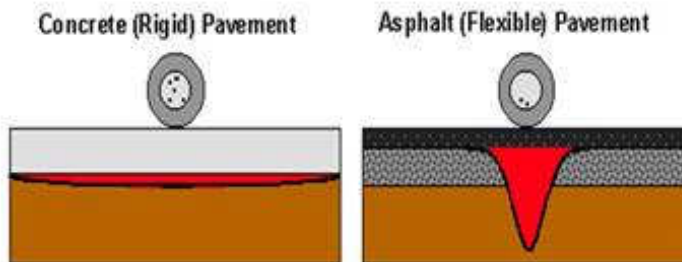
## ADVANTAGES OF CONCRETE ROADS

- Long Life
- Practically Maintenance-Free Performance
- Good Riding Quality
- Good Abrasion Resistance
- Withstand Extremes of Weather
- Exclusion of Water
- Effect of oil Spillage Avoided
- Skid Resistant
- Used in Areas where soils have Poor Engineering Properties
- Design Precision
- Pollution – Free Construction
- Good Foundation for Strengthening
- Fuel Saving
- Economy in Life-Cycle Cost

## Different Pavement Types

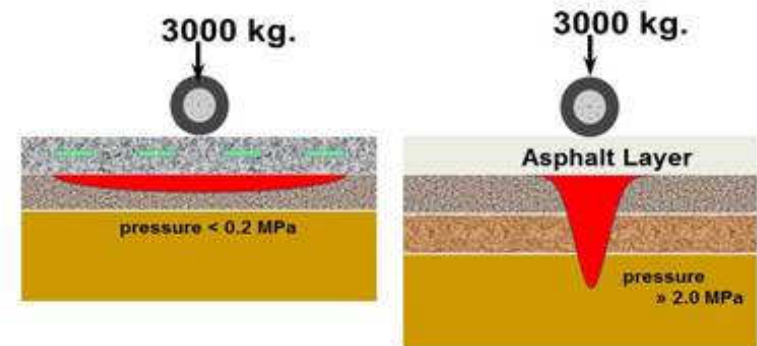






*Concrete acts more like a bridge over the subgrade. Inch-for-inch much less pressure is placed on materials below concrete than asphalt pavements.*

### How Pavements Carry Loads



**Concrete's Rigidness spreads the load over a large area and keeps pressures on the sub-grade low.**

### Disadvantages of Concrete Roads

- ❖ **Problems of Underground Utilities**
- ❖ **Do not Permit Stage Construction**
- ❖ **Energy Content of Concrete Pavements is high**

**Design Guidelines of IRC:58 are applicable for roads having a daily commercial traffic (vehicles with laden weight more than 3t) over 450**

**Design guidelines contained in IRC:SP:62-2014 are applicable only for low volume rural roads. It is also applicable for conventional screed-compacted pavements and roller compacted concrete pavements.**



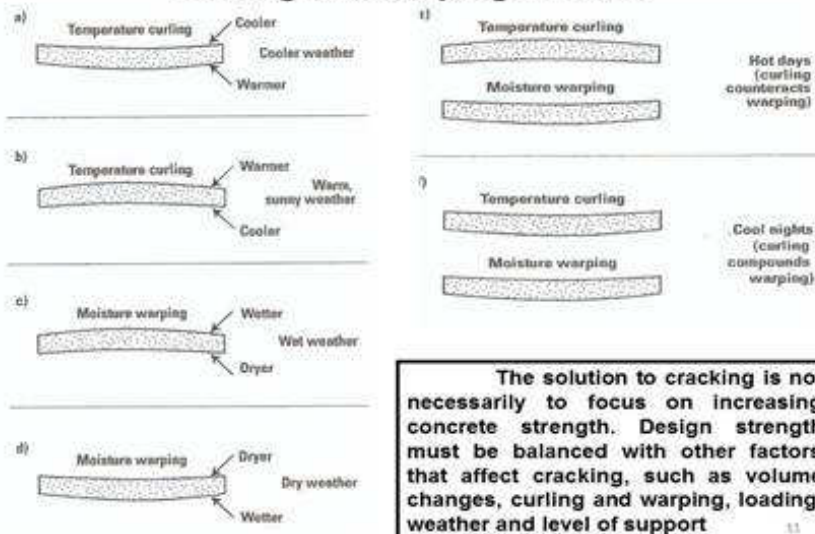
### Sub base for Rural Roads as per IRC:SP:62-2014

- 1) It provides an uniform and reasonably firm support
- 2) It supports the construction traffic even if the subgrade is wet
- 3) It prevents mud-pumping of sub-grade of clays and silts
- 4) It acts as a levelling course on distorted, non-uniform and undulating sub-grade
- 5) It acts as a capillary cut-off

### Recommended Temperature Differentials for Concrete Slabs as per IRC: SP:62-2014

Zone	States	Temperature Differential, °C		
		150 mm	200 mm	250 mm
I	Punjab, Haryana U.P., Uttaranchal, Manipur, Rajasthan, North M.P., Meghalaya, Mizoram, Nagaland, Sikkim, Arunachal Pradesh, Gujarat, Himachal Pradesh excluding hilly regions	12.5	13.1	14.3
II	Bihar, Jharkhand, West Bengal, Assam and Eastern Orissa excluding hilly regions and coastal areas	15.6	16.4	16.6
III	Maharashtra, Karnataka, South M.P., Chhattisgarh, Andhra Pradesh, Telangana, Western Orissa and North Tamil Nadu excluding hilly regions and coastal areas	17.3	19.0	20.3
iv	Kerala and South Tamil Nadu excluding hilly regions and coastal areas	15.0	16.4	17.6
v	Coastal areas bounded by hills	14.6	15.8	16.2
vi	Coastal areas unbounded by hills	15.5	17.0	19.0

### Curling and warping of slabs



### Modulus of sub-grade reaction K and Effective K values corresponding to CBR

CBR Values %	2	3	4	5	7	10	15	20	50
K-Value MPa/m	21	28	35	42	48	55	62	69	140
Effective K over GSB(150 to 250mm)	25	34	42	50	58	60	74	83	170
Effective K over cementitious sub base 150mm to 200mm	42	56	70	84	96	110	124	138	340

Effective k value may be taken as 20% more than sub-grade k value when sub base is provided.

Effective K value may be taken as twice the k value when cementitious sub base is provided

## Concrete Strength

Since concrete pavements fail due to bending stresses, design is based on flexural strength of concrete.

$$f_t = 0.7\sqrt{f_c}$$

Where  $f_c$  = characteristic compressive strength  
 $f_t$  = characteristic flexural strength  
 90 day flexural strength of concrete is taken for design.

$$90 \text{ day } f_t = 1.2 \times 28 \text{ day } f_t$$

Minimum 28 day flexural strength is 3.8MPa  
 Minimum Grade of concrete is 30MPa

M30(minimum flexural strength of 3.8MPa at 28days)  
 Concrete Pavement thickness for traffic between 50 to 150 CVPD and sub-grade CBR 4% as per IRC: SP:62-2014

Joint spacing in m	Pavement Thickness(mm)					
	Wheel load – 50 kN					
	Zone-i	Zone-ii	Zone-iii	Zone-iv	Zone-v	Zone-vi
4.00	180	180	190	180	180	180
3.25	170	170	170	170	170	170
2.50	160	160	160	160	160	160

GSB 100mm + WBM or WMM 75mm. Alternately 100mm thick Cementitious granular layer with minimum UCS of 3MPa at 7days with cement or at 28days with lime or lime-fly ash+100mm thick cementitious layer with natural material having minimum UCS of 1.5MPa at 7days with cement or at 28 days with lime or lime-fly ash

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Pavement Thickness for traffic up to 50 CVPD as per IRC:SP:62-2014

WBM or WMM 75mm thick over GSB(min.CBR=30, LL<25% and PI<6%) 100mm is considered. Alternately 150mm thick Cementitious granular layer using marginal aggregates with minimum UCS of 3MPa at 7days with cement or at 28days with lime or lime-fly ash

Sub-Grade CBR is 4%. Effective k is 35+7=42MPa(35+20%of 35).

Thickness for dual wheel load of 60KN is 160mm for all the joint spacing of 2.5m, 3.25m and 4m.

Temperature stresses not considered.

For other k values, excel sheet can be used to get thickness. A minimum thickness of 150mm is recommended for even higher values of effective k.

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M30(minimum flexural strength of 3.8MPa at 28days)  
 Concrete Pavement thickness for traffic of 250 CVPD and sub-grade CBR 8% as per IRC: SP:62-2014

Joint spacing in m	Pavement Thickness (mm)					
	Wheel load – 50 kN					
	Zone-i	Zone-ii	Zone-iii	Zone-iv	Zone-v	Zone-vi
4.00	180	180	190	180	180	180
3.25	170	170	170	170	170	170
2.50	160	160	160	160	160	160

(GSB 100mm+WBM/WMM150mm )  
 or Cementitious base 200mm (100+100)

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**TABLE 5 : CONCRETE PAVEMENT THICKNESS FOR RURAL ROADS as per IRC:SP 62-2004**

Concrete grade	Pavement Thickness(mm)					
	Low Traffic (Wheel Load-30 kN)			Heavy Traffic (Wheel Load-51kN)		
	Zone-I	Zone-II, IV,V,VI	Zone-III	Zone-I	Zone-II, IV,V,VI	Zone-III
	Temperature Differential °C					
	≤ 15°	15.1° to 17°	17.1° to 20°	<15°	15.1° to 17°	17.1° to 20°
30	150	160	170	190	190	200
35	150	150	160	180	180	190
40	150	150	150	170	180	180

Note: 1) maximum temperature is considered in the computation.  
 2) design thickness values are based on the 90-day strength.  
 CBR =4%, E=3.0X10<sup>4</sup> MPa,  $\mu$  (Poisson's ratio)=0.15,  
 Tyre Pressure=0.50MPa(For wheel load 30kN), 0.7MPa (for wheel load 51 kN),  
 Configuration of slab=3.75m x 3.75m

Cements that can be used as per

IRC: SP62-2014

Any of the following types of cements capable of achieving the design strength and durability may be used.

1. Ordinary Portland Cement, 43 grade, IS: 8112
2. Portland Blast Furnace Slag Cement, IS: 455
3. Portland Pozzalona Cement (PPC) IS: 1489,
4. Ordinary Portland Cement, 53 grade (blended with fly ash) IS: 455

**Cement Content:** The mass of cementitious content (cement + fly ash/slag) or cement = 360 to 425kg/cum

### Physical characteristic requirement of cement

Characteristic	Requirements		
	33 grade IS: 269-1989	43 grade IS: 8112-1989	53 grade Is: 12269-1987
Minimum compressive strength in N/mm <sup>2</sup>			
3 days	16	23	27
7 days	22	33	37
28 days	33	43	53
Fineness (minimum) (M <sup>2</sup> /Kg)	225	225	225
Setting time (minutes)			
Initial – (minimum)	30	30	30
Final – (maximum)	600	600	600
Soundness, expansion			
Le Chatleier– (maximum) mm	10	10	10
Autoclave test–(maximum) %	0.80	0.80	0.80 <sup>9</sup>

**MORD Table 1500.1: Combined Gradation of Coarse and fine aggregates for CC roads**

IS Sieve Size	Percent by Weight Passing the Sieve
26.5mm	100
19 mm	80-100
9.5 mm	55-80
4.75 mm	35-60
0.600mm	10-35
0.075mm	0-8

**AIV ≤ 30%**  
**Maximum size is 25mm.**  
**Water Absorption ≤ 5%. If it exceeds 3%, soundness test as per IS:2386 part 5 shall be done. Loss shall not be more than 12% in Sodium Sulphate solution and 18% in Magnesium sulphate solution.**  
**FIV ≤ 35%**



### Requirements of Fly Ash as per IS:3812-2004

1	Specific Surface Area	Greater than 3,20,000 sq.mm/gm
2	Lime Reactivity	4.5MPa
3	Loss on Ignition	Maximum 5%

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### Fine Aggregate as per Table 4 of IS: 383 Applicable for CC roads and Buildings.

IS Sieve Designation	Percent passing for			
	Grading Zone-I	Grading Zone-II	Grading Zone-III	Grading Zone-IV
10mm	100	100	100	100
4.75mm	90 – 100	90 – 100	90 – 100	95 – 100
2.36mm	60 – 95	75 – 100	85 – 100	95 – 100
1.18mm	30 – 70	55 – 90	75 – 100	90 – 100
600microns	15 – 34	35 – 59	60 – 79	80 – 100
300microns	5 – 20	8 – 30	12 – 40	15 – 50
150microns	0 – 10	0 – 10	0 – 10	0 – 15

Zone IV is not allowable for RCC works and CD works as per MORT&H and MORD Specifications

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Zone-I sand



Zone-II sand

As per IS:383, all the four zones can be used in Plain Cement Concrete roads.



Zone-III sand



Zone-IV sand

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### Coarse (graded size) aggregate gradation as per table 2 of IS: 383 (MORD table 800.1 or MORT&H 1000-1) for concrete

IS Sieve Size	Percent by Weight Passing the Sieve		
	40 mm	20 mm	12.5 mm
63 mm	100	--	--
40 mm	95-100	100	--
20 mm	30-70	95-100	100
12.5 mm	--	--	90-100
10 mm	10-35	25-55	40-85
4.75 mm	0-5	0-10	0-10

Single size aggregates shall not be used for any Concrete item unless specified

Maximum size of Coarse aggregate may be as large as possible within the limits specified, but in no case greater than 1/4th of minimum thickness of member or 10mm less than the clear distance between individual reinforcement or 10mm less than clear cover to any reinforcement.

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**Water for mixing and curing as per IS:456 and IS:3025:** Potable water (pH value 6 to 8) is generally considered satisfactory for both mixing and curing. pH value shall not be less than 6

Permissible limits for solids in Water Cl. 5.4 of IS: 456-2000		
	Tested as per	Permissible limit maximum
Organic	IS 3025 part 18	200 mg/l
Inorganic	IS 3025 part 18	3000 mg/l
Sulphate as SO <sub>3</sub>	IS 3025 part 24	400 mg/l
Chloride as cl	IS 3025 part 32	2000 mg/l for PCC 500 mg/l for RCC
Suspended matter	IS 3025 part 18	2000 mg/l

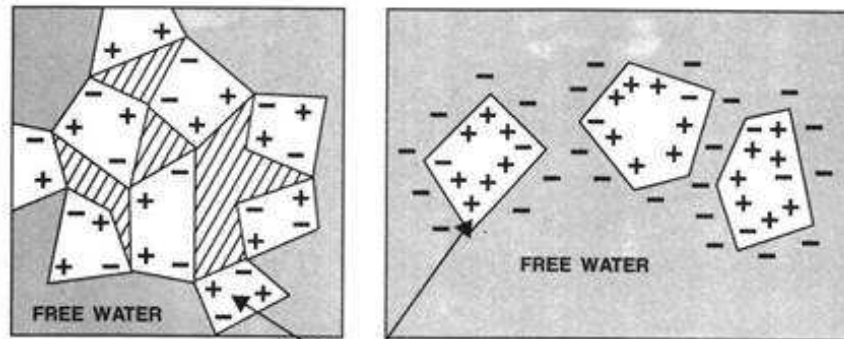
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## Function of Plasticizers

(Admixtures conforming to IS:6925 and IS:9103 may be used up to 2% by weight as per IS:456)

Fine cement particles being very small clump together and flocculate when water is added to concrete. This ionic attraction between the particles trap considerable volume of water and hence water required for workability of concrete mix is not fully utilised. Negative charges are induced on the fine cement particles causing flocks to disperse and release the entrapped water. Water reducing admixtures or plasticizers therefore help to increase the flow of the concrete mix considerably.

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Before

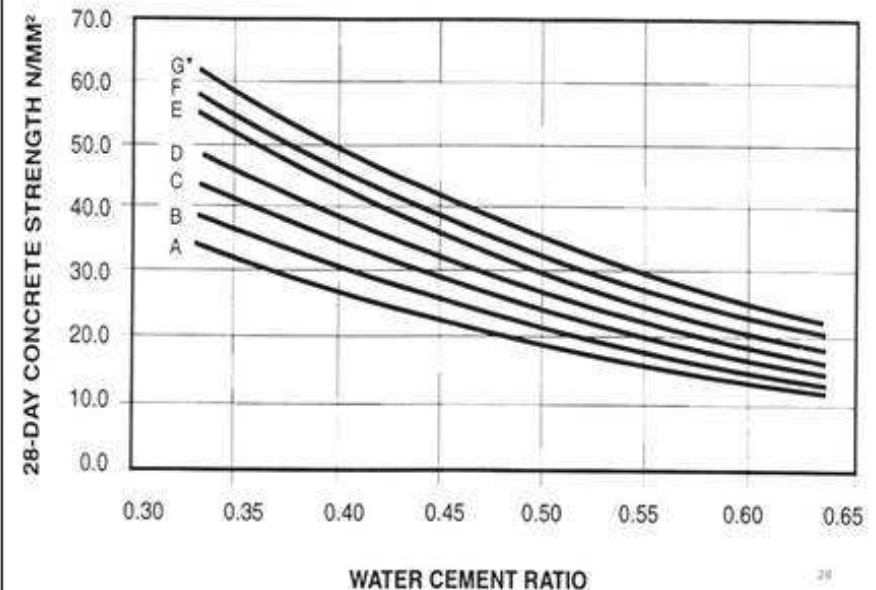
After

Cement Particles

Entrapped water

**Dispersion of entrapped air with the addition of plasticizer**

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### **Coefficient of Permeability for different W/C ratios**

S.No	W/C ratio	Coefficient of Permeability
1	0.35	$1.05 \times 10^{-3}$
2	0.50	$10.30 \times 10^{-3}$
3	0.65	$1000 \times 10^{-3}$

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### **Placing of concrete**

Concrete shall be deposited on the sub base to the required depth and width in successive batches and in continuous operation. Care shall be taken to see that no segregation takes place. Spreading shall be as uniform as possible and shall be accompanied by shovels. While being placed, the concrete shall be rodded with suitable tools so that formation of voids or honeycomb pockets are avoided.

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### **MORD 1501.13 concreting in hot weather**

No concreting shall be done when the concrete temperature is above 30°C measured at point of placing and or when ambient temperature is above 35°C. In adverse conditions, like high temperature, low relative humidity, excessive wind velocity, imminence of rains etc. freshly laid concrete shall be adequately protected by tarpaulins.

### **MORD 1501.14: Concreting in cold weather**

No concreting shall be done when the concrete temperature is below 5°C

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### **Compaction of Concrete**

Compaction is necessary to remove entrapped air present in concrete after it is mixed, transported and placed. Compaction also eliminates stone pockets and remove all types of voids. Consolidation is the process of making the freshly placed PCC into a more uniform and compact mass by eliminating undesirable air voids and causing it to move around potential obstructions.

Vibrators work by rotating an eccentric weight which causes the entire vibrator to move back and forth. This movement excites particles within the PCC mass, causing them to move closer together and better flow around obstructions. On vibration, concrete mix gets fluidized resulting in entrapped air raising to the surface and concrete becoming denser

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### Guidelines for compaction with Pin Vibrator

- 1) Insert poker quickly and allow it to penetrate by its own weight to the bottom of layer so that the entrapped air is removed uniformly.
- 2) Leave the poker in concrete for 10 seconds. Compaction time depends on slump.
- 3) Poker must be inserted quickly, but withdrawal must be slow so that the hole left by the poker is filled up as it is being withdrawn.
- 4) Locations of poker insertion should be staggered.
- 5) Avoid touching the form work (and reinforcement) with poker.
- 6) Poker should extend up to 100mm into the previous layer.

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### MORD 1501.17: Texturing

Just before the concrete becomes non plastic, the surface shall be textured with an approved long handled steel or fiber brush. The brush shall be pulled gently over the pavement surface transversely from one edge to the other. Adjacent strokes shall be slightly overlapped. Texturing shall be perpendicular to the center line of the pavement. The corrugations so produced will be uniform in character, width and about 1.5mm deep. Texturing shall be completed before the concrete reaches such a stage that the surface is likely to be torn or unduly roughened by the operation. Texturing shall be free from porous or rough spots, irregularities, depressions and small pockets.

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CC road with texture.

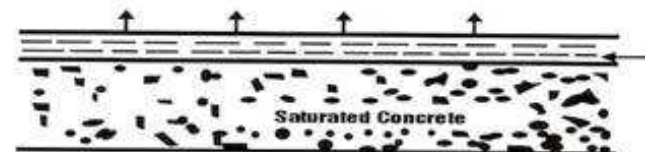


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### Concrete Curing

Curing is the process of maintaining a satisfactory moisture content and favorable temperature in the concrete during hydration of cementitious material so that the desired properties of the concrete are developed. Its objective is specifically to keep the concrete saturated until the water filled spaces in the fresh cement paste are filled to the desired extent by products of the hydration.

Water evaporation from  
concrete surface



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### **MORD 1501.18: Curing**

After finishing, the pavement surface shall be entirely covered with wet hessian cloth (minimum of 2 layers), burlap or jute mats. The coverings used shall be of such size that when laid, will extend by 500mm beyond the slabs. They shall be placed as soon as the concrete has set sufficiently to prevent marring of the surface. They shall be maintained fully wetted for 24 hours. The concrete slab shall not be exposed for more than 30 minutes for saw cutting of joints. After saw cutting of joints, it shall be covered and kept wet. Upon the removal of wet covers after 24 hours, the slabs shall be thoroughly wetted and then cured by ponding. Exposed edges shall be banked with substantial amount of earth.

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### **Effects of Improper Curing**

**Lowering of compressive and flexural strengths**

**Sanding and dusting of surface and lower abrasion resistance**

**Higher permeability and lower durability**

**Cracks due to plastic shrinkage, drying shrinkage and thermal cracking**

**Increased rate of Carbonation and chloride ingress**

**Lower weathering and frost resistance**

Gunny rolls used for primary curing.



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CC covered with wet gunny rolls.  
Side earth pushed to protect edges.





Primary curing. It can be used for secondary curing also



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#### **MORD 1501.7 Separation membrane**

A separation membrane shall be used between the concrete slab and sub-base. It shall be impregnable plastic sheet 125 microns thick laid without creases. Before placing it, the sub-base shall be swept clean of all extraneous materials

#### **MORD 1501.8.1 Formation Of Joints**

Saw cutting of joints of pavement slab as per stipulated dimensions should be done when concrete is neither too soft nor too hard. Sawing operations should start as early as possible depending upon the season. The initial saw cutting shall be done with the help of saw cutting machine with diamond studded blade.

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#### **Types Of Joints**

- a) **Contraction Joints (Transverse)**  
To be spaced at 2.5m to 4m
- b) **Construction Joints (Transverse)**  
To be provided at the end of day's work or work suspended for more than 90 minutes
- c) **Expansion Joints (Transverse)**  
To be provided when CC pavement abuts bridge or slab culvert
- d) **Longitudinal joints**  
To be provided when the width is more than 4.5m

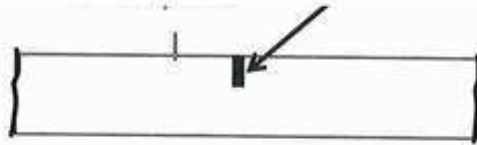
#### **Contraction joints as per IRC:SP:62-2014:**

Contraction joints may be spaced at 2.5m to 4m. They may be formed by sawing the pavement slabs within 24 hours of concrete casting. Practice abroad indicates the narrow contraction joints 3 to 5mm wide perform well with better riding quality. HDPE strips 3mm to 5mm thick with suitable tensioning and intermediate support for keeping the strip in position can be also used for creating joints. The strips are kept in place. Metal strips and T section are the other options. Joint depth can be extended from  $1/4^{\text{th}}$  to  $1/3^{\text{rd}}$  depth of slab.

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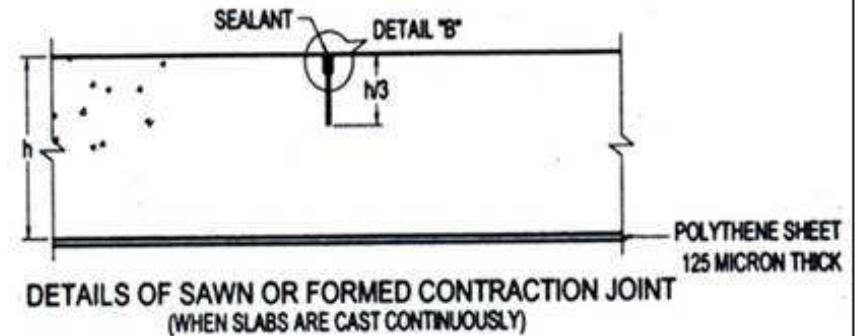


Plastic strip 3mm to 5mm thick to  $\frac{1}{3}$ rd of slab depth  
Or  
Modified bitumen filled into sawed joint 3 to 5mm wide over  
back up thread



Contraction Joints with plastic strip or Sawn Joint filled with  
hot modified bitumen

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Details of Contraction/Construction(L/S) and longitudinal joints.  
Crumb Rubber Modified Bitumen or bitumen based sealant may  
be used as sealant

Joints may be saw cut, placing and leaving HDPE strips, using  
metal strips or T sections

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### Dowel bars as per IRC:SP:62-2014:

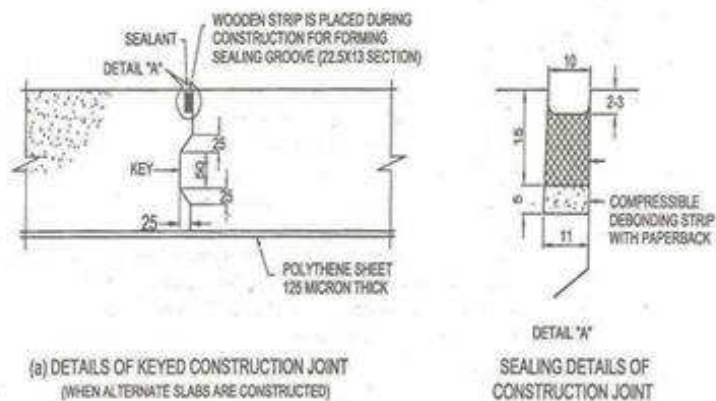
Dowel bars of MS 25mm dia, 450mm length and  
spaced at 250mm center to center are to be  
provided at expansion joints. Thickness of  
expansion joint is about 20mm.

Dowel bars are not necessary at contraction joints  
for rural roads.

Construction joints shall be provided at the end of  
day's work or when work is suspended for more  
than 90 minutes at the location of contraction joint  
only. Keyed construction joint is preferable. 3mm  
to 5mm joint is sufficient.

Expansion joints are to be provided when the CC  
road abuts bridge or slab culvert.

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Construction Joint details

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#### MORD1501.11.4.3.4 Paving near culverts and bridges

**Pipe culverts:** Slab shall be carried over pipe culverts.

**New culvert/ bridge:** Structural slab of culvert/ bridge shall be extended over full width of abutment cap. During casting dowel bars shall be fixed at the end near expansion joint with the CC road. Exposed dowels are covered with sheathing and cap etc. 12mm thick filler board in case of culvert and 20mm thick filler board in case of bridge shall be inserted before laying the pavement slab. Filler board, with holes for dowels, shall be for full pavement width and shall be in one length.

**Existing bridge:** Expansion joint shall be provided at either end between the paving slab and the culvert/ bridge slab/approach slab

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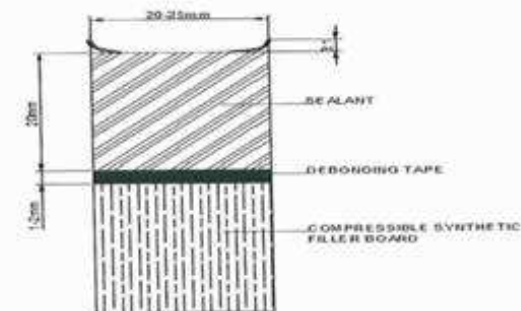
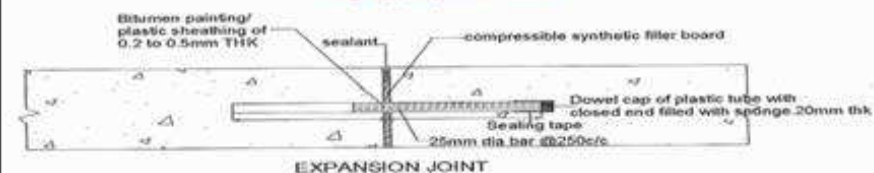
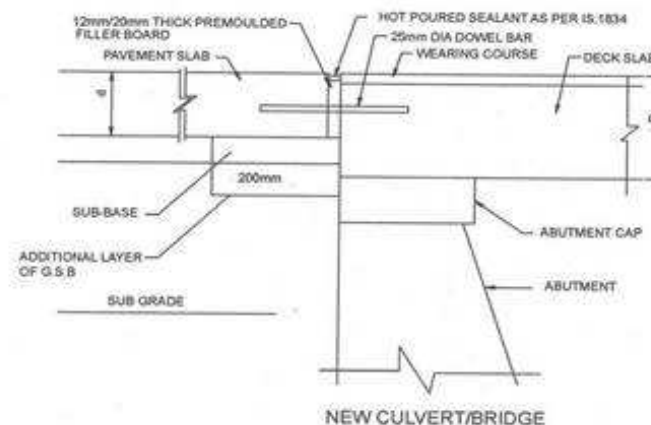


Fig. 5(c) Expansion Joint

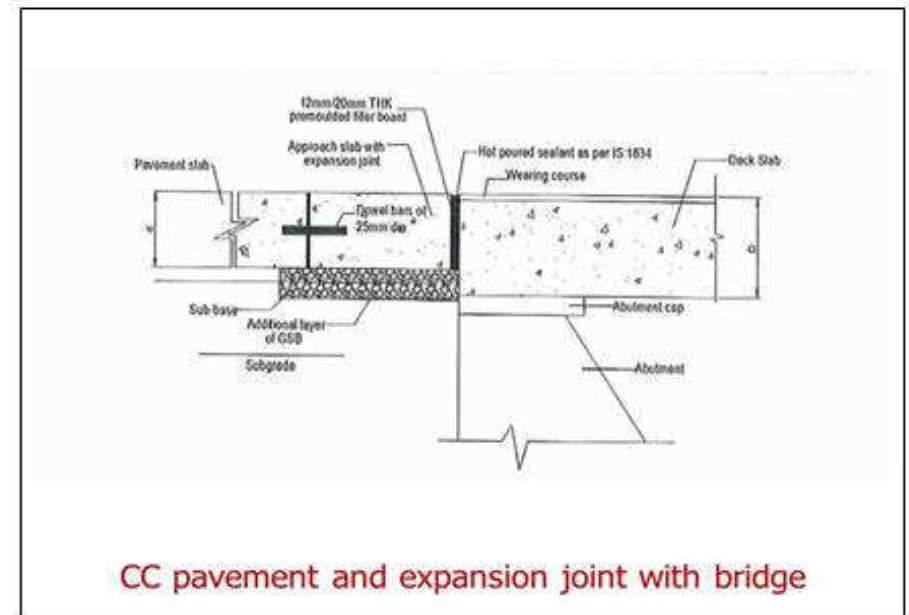
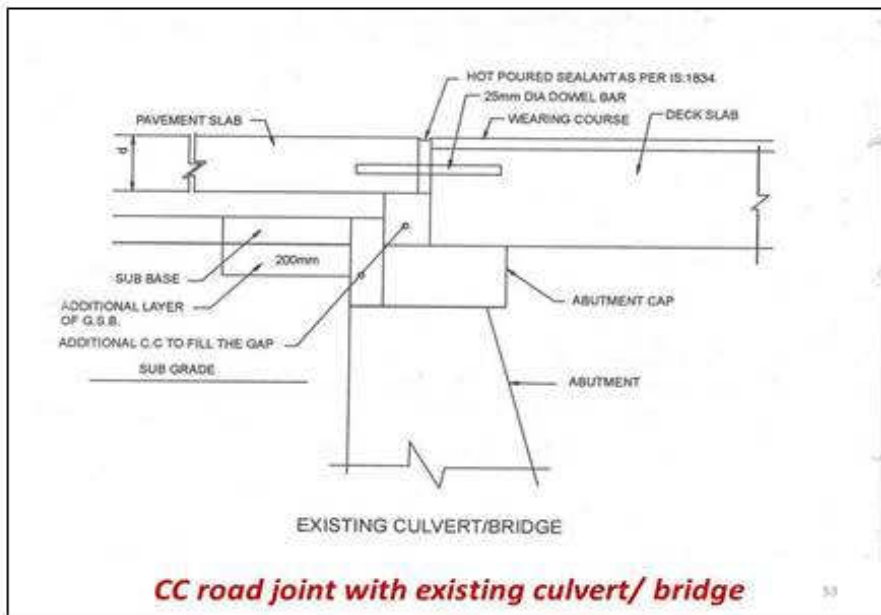


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CC road joint with new bridge

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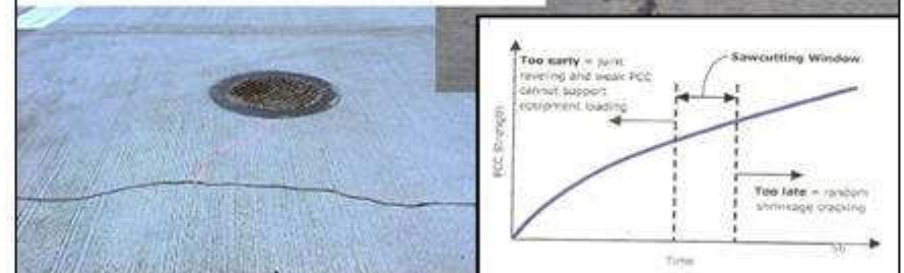


## Causes of cracking in concrete roads

- 1) Plastic shrinkage of concrete surface due to rapid loss of moisture
- 2) Drying shrinkage
- 3) High wind velocity associated with low humidity
- 4) High ambient temperature
- 5) Delayed sawing of joints

## Shrinkage cracking probably due to late sawing (left) Joint raveling due to early sawing (right)

**Timing the Sawing Window:** Joints are usually constructed by saw-cutting the concrete a few hours after placing. The optimum period of time to saw contraction joints is known as the sawing window. The sawing window for conventional saws generally begins when concrete is strong enough not to ravel excessively along the saw cut. The window ends when significant shrinkage occurs that induces uncontrolled cracking.





A saw cut that has cracked through as planned



Shuttering sheets for MS dowels just removed. Observe the steel bulkhead used to retain concrete. At construction joint using bulkhead gives a neat joint and ugly finish can be avoided.



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Contraction joint 3 to 5 mm wide and 1/3rd in depth



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Groove before sealant fill.



Sealing compound filling.



View after filling sealant.



Preparation for slump test, casting cubes (150 mm) and beams (70 x 15 x 15 cm)



### Concrete Cores in CC roads:

Crushing strength of cylindrical specimens  $= 0.8 \times$  crushing strength of cubes when the height to diameter ratio of core is 2.

Crushing strength of cylinders with height to diameter ratio between 1 and 2 may be multiplied by a correction factor  $f = 0.11n + 0.78$  where  $n$  is height to diameter ratio.

Number of cores = minimum 3

The concrete in the core test shall be considered acceptable if the average equivalent cube strength of the cores is at least 85% of the cube strength of the grade of concrete specified for the corresponding age and no individual core has a strength less than 75%.



### Acceptance Criteria for Cracked Concrete Slabs

Slabs with full depth cracks are totally unacceptable as it amounts to structural failures.

Other cracks which are deep and are likely to progress in depth with time are also to be considered as serious in nature. Fine crazy cracks are not serious.

Slabs with cracks having depth more than half slab depth shall not be accepted.

Following type of cracked slabs are acceptable:

- 1) Length of single crack shall not be more than 750mm, even though its depth is less than half of slab depth.
- 2) Cumulative length of cracks with depth of crack less than half depth of slab in a panel not more than 1250mm

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Core cutting to verify inner depth and compressive strength.



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Concrete overlay over bituminous surface is known as white-topping

IRC:SP:76-2015: Tentative Guidelines for Conventional and Thin White Topping

### Types of White-topping

Conventional	200mm or more	Used on Heavily Trafficked Corridors
Thin	More than 100mm and less than 200 mm	Used for Collector Streets
Ultra Thin	Up to 100 mm	Used for Collector And Local Streets



### Thin White-topping

- Thickness 100-200 mm
- Joint Spacing 1.0 x 1.0 m (0.6m to 1.25m as per IRC: 76)
- Existing Bituminous Layer is Milled to Bond Well to Ensure Composite Action
- Polypropylene Fibers (0.2-0.4% Weight of Cement) Added
- M-40 Concrete is Used

### Ultra Thin White-topping

- Thickness 50-100 mm
- Joint Spacing about 1.0 x 1.0 m (0.6m to 1.25m as per IRC: 76)
- Existing BT is Milled and Concrete is Made to Bond Well to Ensure Composite Action
- Polypropylene Fibers added (0.2-0.4% Weight of Cement)
- M-40 Concrete is Used

150mm thick white topping over existing BT road laid for 1km on Banjara Hills road no.10 in Hyderabad



150mm thick white topping over existing BT road laid for 1km on Banjara Hills road no.10 in Hyderabad. Joint spacing is 1m by 1m



**MORD Table 1800.8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Levels and Alignment**

Level Tolerance	To be checked for each day's work (clause 1802.3)
Surface Regularity Longitudinal & Transverse	Regularly
Width of Pavement and position of paving edges	To be checked for each day's work (clause 1802.3)
Pavement Thickness	Regularly at grid points
Alignment of joints	To be checked for each day's work
Depth of Dowel bars	To be checked for each day's work

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**MORD Table 1800.8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Cement and Water**

Item	Test method	frequency
Cement: Physical and Chemical tests	IS: 269, IS: 455, 1489, IS:8112 IS: 12269	One for each source of supply and occasionally when called for in case of long/ improper storage. Besides, the contractor shall also submit daily test data on cement released by the manufacturer.
Water Chemical Tests	IS: 456	Once for Approval of source of supply, subsequently in case of doubt

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**MORD Table 1800.-8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Coarse and Fine Aggregates**

Test	Test Method	Frequency
AIV	IS: 2386-part 4	1 test per source
FIV	IS: 2386-part 1	1 test per source
Deleterious constituents	IS: 2386 part 2	1 test fo each day's work
Water Absorption/ Content	IS: 2386-part 3	Regularly as required subject to a minimum of 1 test a day for coarse aggregate and 2 tests a day for fine aggregates.
Soundness	IS: 2386-part 5	1 test per source
Gradation	IS: 2386-part 1	1 test per each day's work
Alkali Aggregate Reaction	IS: 2386-part 7	1 test per source

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**MORD Table 1800-8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Concrete for pavement**

Strength of Concrete	IS:516	Minimum 6 cubes and 6 beams per day's work (3 each for 7 day 28 day strength).
Workability of fresh concrete Slump test	IS: 1199	1 test per 3 cubic meters of concrete at paving site or 1 test for each dumper laid at plant site

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# A Technical Presentation

**D.V.Bhavanna Rao** M.Tech., F.I.E.,  
Retired R&B Chief Engineer  
E-mail: [bhavannarao@yahoo.co.in](mailto:bhavannarao@yahoo.co.in)  
Phone: +919494440202



Construction and Quality Control in Flexible Pavements  
for low volume roads as per MORD 2014 Specifications

## Important Publications for Rural Roads

1. Specifications for Rural Roads, MORD (2004 and 2014).
2. Rural Roads Manual IRC:SP:20-2002.
3. MORD Quality Assurance Handbook for Rural Roads Volume I and II :2007
4. Hill Road Manual: IRC:SP:48-1998.
5. IRC:SP: 72-2015: Guidelines for design of flexible pavements for low volume Rural Roads
6. IRC:SP: 62-2014 and 2014 Guidelines for Design of Rigid Pavements for Rural Roads

## Section 300 Earth works

- 301 Embankment construction
- 302 Earth work in cutting
- 303 Subgrade construction
- 304 Rock cutting
- 305 Excavation for structures
- 306 Fly ash Embankment construction
- 307 Surface drains
- 308 Soil erosion and sedimentation control
- 309 Turfing with sods
- 310 Seeding and mulching

## Section 400 Granular Sub-bases, Bases & surfacings

- 401 Granular/Gravel Sub – Base
- 402 Gravel/Soil – Aggregates base and surface course
- 403 Lime treated soil for improved Sub – Grade / sub base
- 404 Cement treated Soil sub-base/ base
- 405 Water Bound macadam sub-base/ bases/surfacing
- 406 Wet Mix Macadam base
- 407 Shoulder construction
- 408 Local materials for road construction
- 409 Lime – Fly ash stabilised soil sub-base
- 410 Industrial wastes for road construction
- 411 Crusher – Run macadam base
- 412 Brick soling
- 413 Stone set pavement



### **Section 500 Bituminous construction(2014)**

- 501 Preparation of surface.**
- 502 Prime coat over Granular Base**
- 503 Tack coat**
- 504 Bituminous Macadam**
- 505 Surface dressing**
- 506 Open Graded Premix Carpet**
- 507 Mix Seal Surfacing**
- 508 Seal Coat**
- 509 25mm thick Semi Dense Bituminous Concrete**
- 510 Supply of Stone aggregates for pavement courses**
- 511 Modified bitumen**
- 512 Bituminous Wearing Courses using waste plastic**

### **Section 800 Concrete structures**

- 802.2 Cement**
- 802.3 Coarse Aggregates**
- Table 800.1: Grading of Coarse Aggregates**
- 802.4 Fine Aggregates**
- Table 800.2: Grading requirements of fine aggregates**
- 802.5 Water**
- 803 Grades of Concrete**
- 804.3 Requirements of design Mix**
- 804.4 Nominal Mix Concrete**
- 808 Concreting under water**
- 809 Concreting in Extreme Weather**
- 810 Protection and curing**
- 811 Finishing**
- 812 Construction Joints**
- 815 Tests and standards of Acceptance**

### **1501 Plain Cement Concrete Pavement**

- 1501.2.2 Cement**
- 1501.2.3 Admixture**
- 1501.2.4 Aggregates**
- Table 1500.1 Combined Gradation of aggregates for Concrete**
- 1501.2.5 Dowel bars**
- 1501.2.6 Water**
- 1501.2.7 Pre-moulded joint Filler**
- 1501.2.8 Joint Sealing Compound**
- 1501.3 Mix Design**
- 1501.4 Workability**
- 1501.8 Joints**
- 1501.10 Side Forms**
- 1501.15 Compaction of concrete**
- 1501.18 Curing**
- 1501.22 Sealing joints**
- 1501.23.5 Acceptance Criteria**
- 1501.26 Acceptance criteria for cracked concrete slabs**

### **Other Important Sections in MORD Specifications**

- 200 Site Clearance**
- 600 Brickwork for Structures**
- 700 Stone masonry for Structures**
- 800 Concrete for Structures**
- 900 Formwork and surface finish for structures**
- 1000 Steel reinforcement**
- 1100 Pipe culverts**
- 1200 RCC slab culverts and minor bridges**
- 1400 Cement Concrete Causeways**
- 1500 Cement Concrete Pavement**
- 1600 Hill Road Construction**
- 1800 Quality Control**
- 1900 Maintenance**

### Important Sections in IRC:SP:20-2002

Chapter 1: Planning and Alignment  
 Chapter 2: Geometric Design Standards  
 Chapter 3: Climate and Environment  
 Chapter 4: Road Materials  
 Chapter 5: Pavement design  
 Chapter 6: Road Drainage  
 Chapter 7: Culverts and Small Bridges  
 Chapter 8: Construction and Specifications  
 Chapter 9: Use of Waste materials  
 Chapter 10: Quality Control in Construction  
 Chapter 11: Maintenance  
 Chapter 12: Sources of Finance

### Extra Width Requirements of pavement at curve locations

Radius of curve (M)	Up to 20	21 - 60	Above 60
Extra widening for 3.75m wide single lane carriageway (M)	0.9	0.6	nil

### Recommended Vertical Gradients

Nature of terrain	Ruling gradient	Limiting gradient
Plain and rolling	3.3%	5.0%
Mountainous	5.0%	6.0%
Steep	6.0%	7.0%

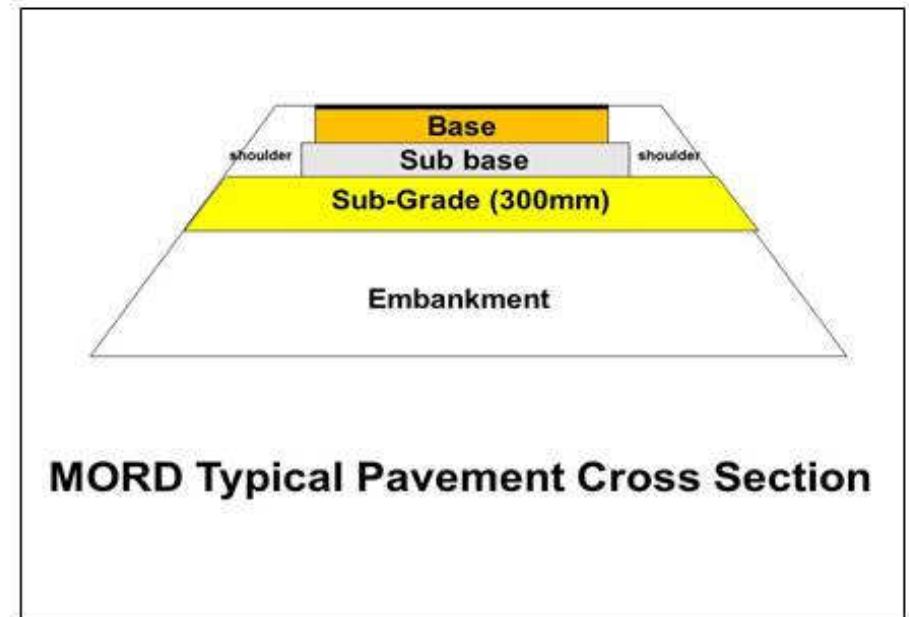
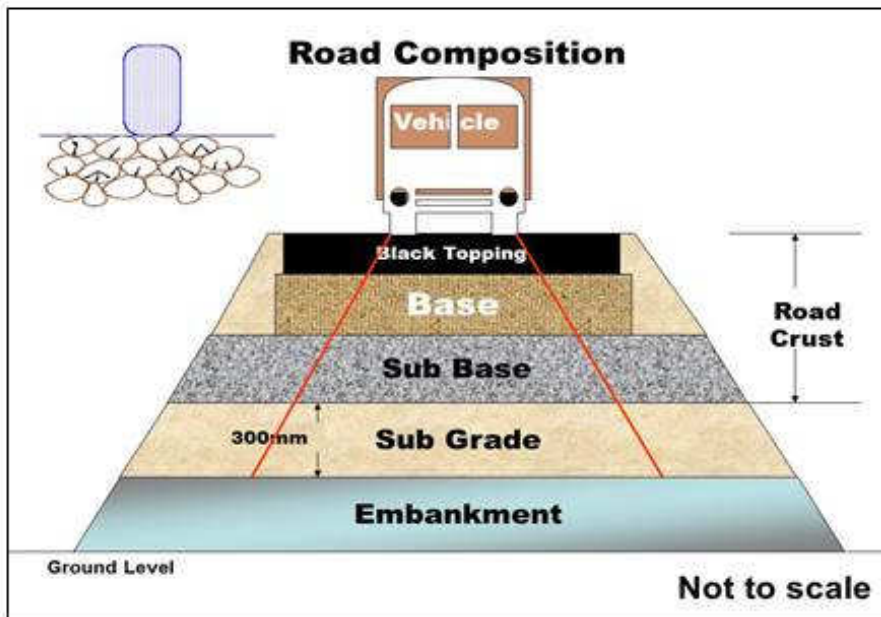
The vertical alignment should provide for a smooth longitudinal profile.

Gradients up to ruling gradients shall be adopted as far as possible.

Limiting gradients shall be adopted only in very difficult situations and for short lengths

### Design service volume of two-lane highway in PCUs per day

Nature of terrain	Design Service volume in PCUs per day	
	Without paved shoulder	With 1.5m paved shoulder
Plain	15,000	18,000
Rolling	11,000	13,000
Mountainous and Steep	7,000	9,000



**Important Quality Control Tests in Selecting soil or earth for embankment, sub-grade and shoulders**

Liquid Limit in% (water absorbing nature)

Plasticity Index in% = L.L - P.L (Softening Nature)

Free Swell Index in% (expansive nature)

Maximum Dry Density (indirect strength indicator)

Optimum Moisture Content in% (enables effective compaction at site)

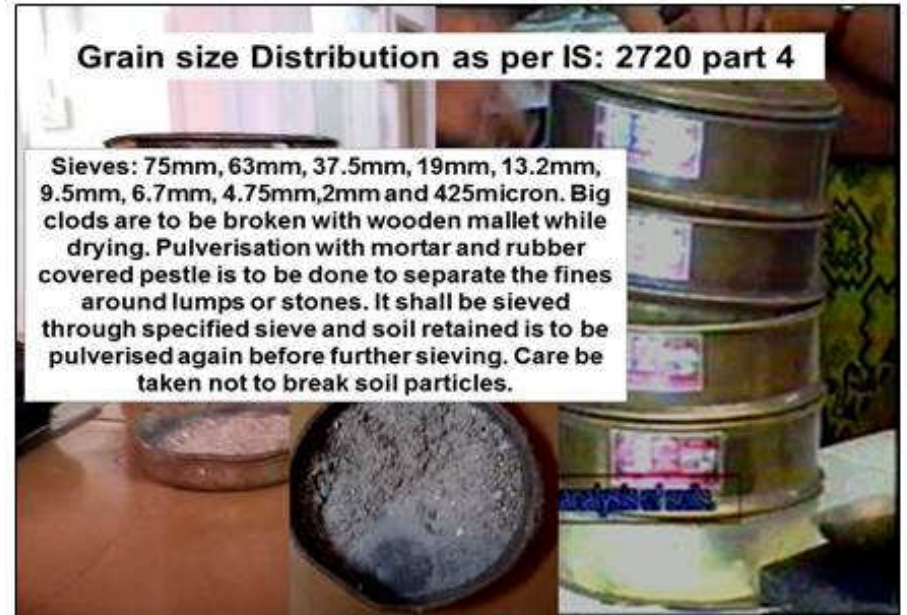
Standard Procter's Compaction for low traffic roads

Modified Procter's Compaction for high traffic roads

California Bearing Ratio (CBR in%) indicates strength or bearing capacity

**Grain size Distribution as per IS: 2720 part 4**

Sieves: 75mm, 63mm, 37.5mm, 19mm, 13.2mm, 9.5mm, 6.7mm, 4.75mm, 2mm and 425micron. Big clods are to be broken with wooden mallet while drying. Pulverisation with mortar and rubber covered pestle is to be done to separate the fines around lumps or stones. It shall be sieved through specified sieve and soil retained is to be pulverised again before further sieving. Care be taken not to break soil particles.





## Material passing 425 micron IS sieve



## Free Swell Index test IS: 2720 part 40

2 Graduated glass cylinders 100ml  
Sample (passing 425 micron sieve)  
10mg each, kerosene in one and  
distilled water in another cylinder

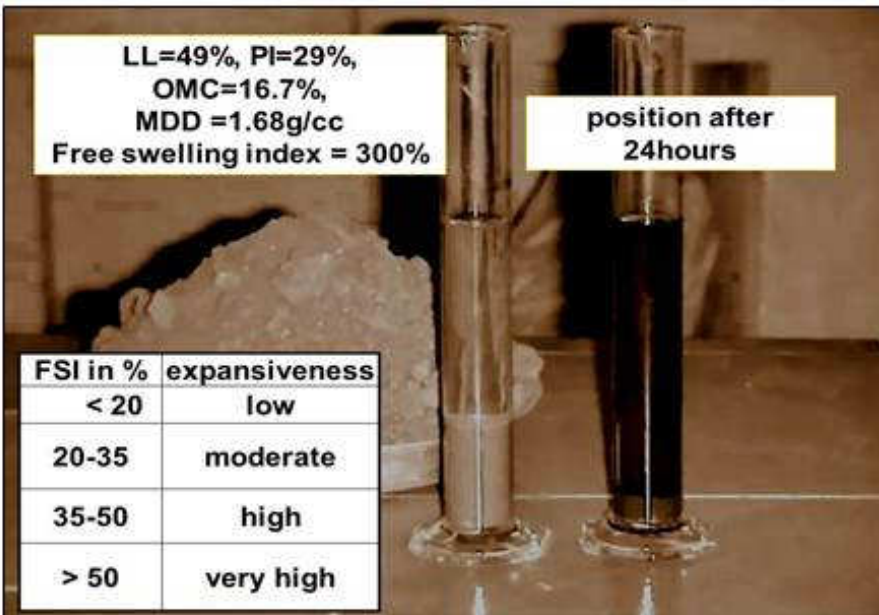
**Free Swell Index:**  
It indicates the Expansive  
qualities of soil. It gives the  
amount of volume increase  
of soil on coming in contact  
with water



LL=49%, PI=29%,  
OMC=16.7%,  
MDD =1.68g/cc  
Free swelling index = 300%

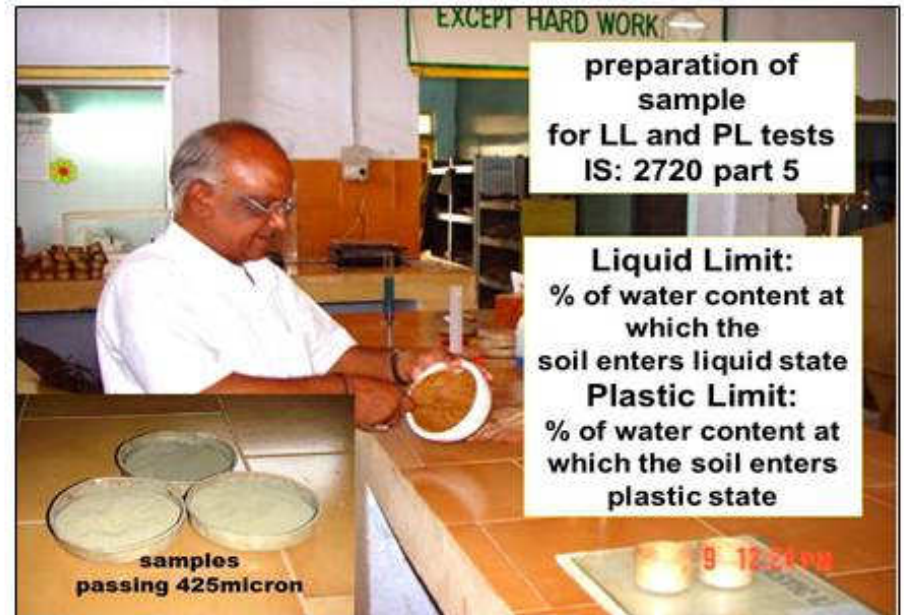
position after  
24hours

FSI in %	expansiveness
< 20	low
20-35	moderate
35-50	high
> 50	very high



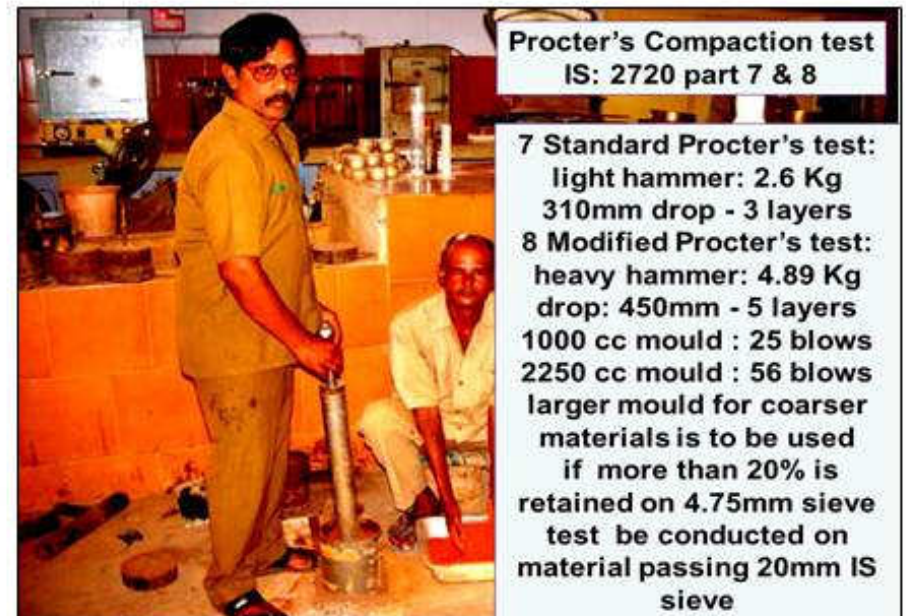
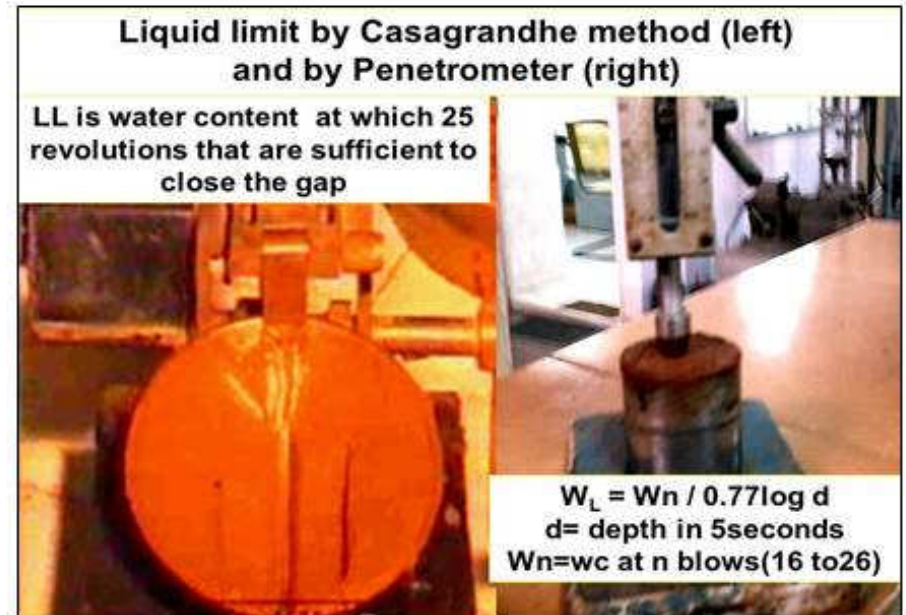
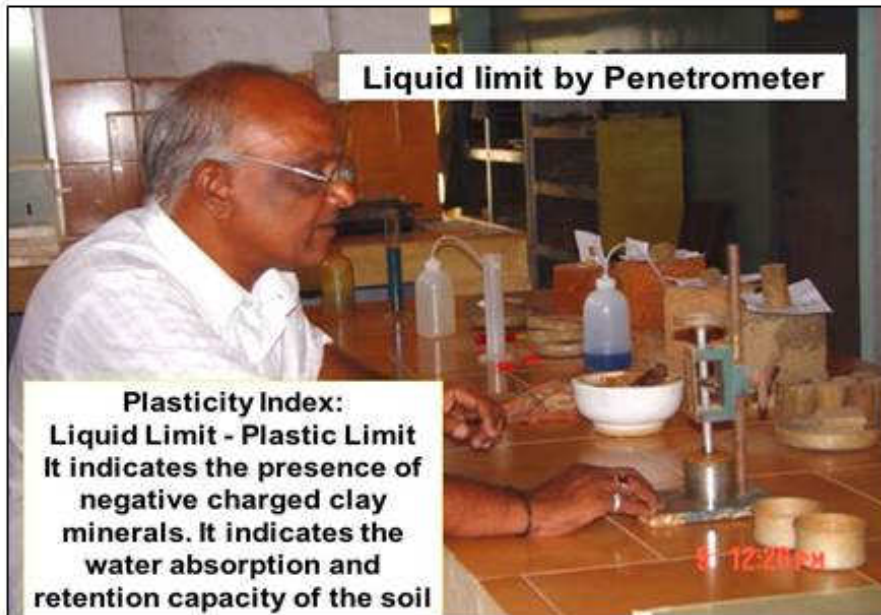
preparation of  
sample  
for LL and PL tests  
IS: 2720 part 5

**Liquid Limit:**  
% of water content at  
which the  
soil enters liquid state  
**Plastic Limit:**  
% of water content at  
which the soil enters  
plastic state

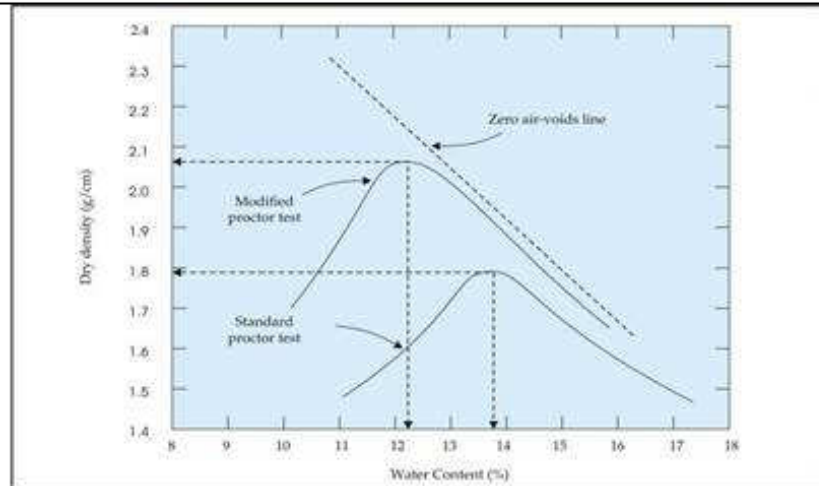


samples  
passing 425micron









Note :  $1 \text{ g/cm}^3 = 9.81 \text{ kN/m}^3$

Proctor Test Curve (Dry Density vs Moisture Content)

Material retained on 20mm sieve is to be replaced by material of equal weight passing 20mm sieve and retained on 4.75mm sieve

CBR testing at STC Vijayawada  
IS: 2720 part 16

CBR is the ratio of force per unit area required to penetrate a soil mass with a circular plunger 50 mm dia at the rate of 1.25 mm/minute to that required for corresponding penetration of a standard material.

Ratio is determined for 2.5 mm & 5 mm penetrations.

If 5 mm value is more, test is to be repeated. if it is again higher, then 5mm value is taken



### Flakiness Index Test

IS: 2386 part 1  
Thickness of flaky material is less than 0.6 times mean size

IS sieves:  
63,50,40,31.5,2  
5,20,16,12.5,10  
and 6.3mm



### Elongation Index Test

Is: 2386 part 1  
Length of elongated materials more than 1.8 times mean size

IS sieves:  
63,50,40,31.5,2  
5,20,16,12.5,10  
and 6.3mm







**Aggregate Impact test**  
IS: 2386 part 4  
material passing 12.5 mm sieve and retained on 10 mm sieve is placed in mould in 3 layers by tamping 25 times for each layer.  
After 15 blows, material passing 2.36 mm sieve is weighed and compared with sample weight in %.

### Bitumen penetration test IS: 1203-1978 to find bitumen grade



Measured at 25°C in 1/10<sup>th</sup> of millimeter after 5 seconds. sample: 100g  
Average of 3 observations at 10mm apart



Note: Standard Proctor's compaction is necessary to find out MDD and OMC.  
RC: Relative Compaction = Field Dry Density/ laboratory MDD (Maximum Dry Density).  
OMC: Optimum Moisture Content, FSI: Free Swell Index, LL: Liquid Limit, PI: Plasticity Index, EIV: Elongation Index Value, FIV: Flakiness Index Value, AIV: Aggregate Impact Value.  
MDD and OMC values obtained in Standard Proctor Compaction test as per IS: 2720 part 7  
For GSB, % passing 75 micron sieve shall be restricted to 5% on clayey sub-Grades.  
Max. Liquid Limit and plasticity index for sub grade are modified as 50% and 25% vide IRC:36-2010

**Typical cross section of road showing the required pavement composition as per MORD(2014) guidelines**

### Typical Road Cross Section as per MORD(2014) specifications along with requirements



## BLACK TOPPED SURFACINGS

**Strengthening layers  
Bituminous Macadam**

**Wearing Courses  
Surface Dressing  
OGPC with seal coat  
Mix Seal surfacing  
25mm thick SDBC**

### Recommended use of Cationic Emulsions as per IS 8887: 2004

Type	Recommended uses
Rapid Setting RS 1	Tack Coat
Rapid Setting RS 2	Surface Dressing
Medium Setting MS	Pre mixes and plant mixes
Slow Setting SS 1	Fog seal, Crack Seal, Prime Coat
Slow Setting SS 2	Slurry Seal and mixes with higher fine aggregate %

**Cost of SS1 emulsion is very much higher than others.**

Stipulations of IS: 73 in selection of VG grade bitumens in place of Penetration Grade (prevailing) bitumens

Viscosity Grade	General Applications
VG-40 (40 to 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 to 70 penetration)	Use for paving for most parts of India in lieu of old 60/70 penetration grade.
VG-20 (60 to 80 penetration)	Use in cold climatic, high altitude regions of North India
VG-10 (80 to 100 penetration)	Use in spraying applications such as surface dressing and paving in very cold climatic region in lieu of old 80/100 penetration grade

**MORD 502. Prime Coat over granular base**  
Application of single coat of low viscosity liquid bituminous material to an absorbent granular surface to any superimposed bituminous treatment

MORD Table 500-1A, Primer requirements		
Porosity	Surface	Quantity kg/10sqm
Low	WBM/WMM	7 - 10
Medium	Stabilised base	9 - 12
High	Gravel base/CRM	12 - 15

- 1) It coats and bonds loose mineral particles of granular surface
- 2) It water proofs the surface of the base by plugging capillary or un connected voids
- 3) It provides adhesion or bond between the granular base and bituminous layers



**MORD 502.Prime Coat with cutback bitumen  
for areas of sub zero temperatures**

MORD Table 500-1B, Type and Quantity Primer requirements

Porosity	Surface	Type of Cutback	Quantity kg/10sqm
Low	WBM/WMM	MC 30	7 - 10
Medium	Mechanical Stabilised Soil base, Lime stabilized soil,	MC 70	9 - 12
High	Gravel base/ Crusher Run Macadam/ Crusher Rock Base	MC 270	12 - 15

**Primed WMM surface with sand flushing.**



**MORD 503 Tack Coat**

**Binder used for tack coat shall be Rapid Setting RS-1 conforming to IS: 8887**

MORD Table 500-2, Rate of application of tack coat

Type of surface	Bitumen emulsion Kg/sqm
Nominal bituminous surfaces	0.20 to 0.25
Dry and hungry bituminous surfaces	0.25 to 0.30
Granular surfaces treated with primer	0.25 to 0.30
Cement concrete pavement	0.30 to 0.35

**Rate of application of tack coat as per  
table – 4 of IRC:SP: 78-2008**

S.No	Type of surface	Rate of spray (emulsion) Kg/M <sup>2</sup>	Rate of spray (Bitumen-VG-10) Kg/M <sup>2</sup>
i	Bituminous surface	0.20 to 0.30	0.30 to 0.40
ii	Granular surface treated with primer	0.25 to 0.30	0.35 to 0.40



**MORD table 500.5: Mixing, laying and rolling temperatures for VG grade paving bitumen and modified binder**

Bitumen	Bitumen Temp. °C	Aggregate Temp. °C	Mix Temp. °C	Laying Temp. °C	Rolling Temp. °C
VG - 40	160 - 170	160 - 170	160 – 170	150 min.	100 min.
VG - 30	150 - 165	150 – 165	150 – 165	140 min.	90 min.
VG - 20	145 – 165	145 – 165	145 – 165	135 min.	85 min.
VG - 10	140 – 160	140 – 160	140 – 160	130 min.	80 min.

**MORD 505: Table 500.6 grading requirements of aggregates used for Surface Dressing**

IS Sieve Designation mm	Cumulative % by weight of total aggregates passing for the following nominal sizes in 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 aggregates	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

**Table 500.7 Notional rates of application of binder and aggregates for surface dressing**

Nominal aggregate size mm	Binder Kg/Sq.m			Aggregates Cum/Sq.m
	Uncoated aggregates		Coated aggregates	
	Bitumen	Emulsion	bitumen	
19	1.2	1.8	1.0	0.014 to 0.015
13	1.0	1.5	0.8	0.009 to 0.011
10	0.9	1.3	0.7	0.007 to 0.009
6	0.75	1.0	0.6	0.003 to 0.005

Note: In the case of 2 coat surface dressing using emulsion, emulsion quantity for each coat may be added and 40 to 45% total quantity is applied on 1<sup>st</sup> coat and the balance quantity on 2<sup>nd</sup> coat. Bitumen for coated aggregates excludes bitumen required for coating

**Table 500.4, COMPOSITION OF BITUMINOUS MACADAM (4<sup>th</sup> Revision)**

IS Sieve (mm)	Cumulative % by weight of total aggregate passing
26.5	100
19	90 – 100
13.2	56 – 88
4.75	16 – 36
2.36	4 – 19
0.30	2 -10
0.075	0-5
Bitumen content, %	3.30 – 3.50
Bitumen Grade	VG10 to VG30

AIV < 30%, FIV < 25% and WA < 2% for coarse aggregates. Thickness: 50 to 75mm. Bitumen content shall be within a tolerance of  $\pm 0.20\%$  by weight of the mix for individual specimens taken for quality control tests

**MORD 509: Table 500.15 Composition Of Semi Dense Bituminous Concrete**

Layer Thickness	25 mm
IS Sieve (mm)	Cumulative %by weight of total aggregate passing
13.2	100
9.5	90-100
4.75	35-51
2.36	24-39
1.18	15-30
0.3	9-19
0.075	3-8
Bitumen content % by mass of total mix	Min 5.0

AIV = 27% Max. FIV+EIV = Max 35%  
Water Absorption = Max 2%

**Table 500.14, Grading Requirements of mineral filler**

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

The filler shall be free from organic impurities and have a Plasticity Index not greater than 4. *The Plasticity Index requirement shall not apply if filler is cement or lime. When the coarse aggregate is gravel, 2 per cent by weight of total aggregate, shall be Portland cement or hydrated lime and the percentage of fine aggregate reduced accordingly. Cement or hydrated lime is not required when the limestone aggregate is used. Where the aggregates fail to meet the requirements of the water sensitivity test in Table 500-8, then 2 per cent by total weight of aggregate, of hydrated lime shall be added without additional cost.*

**Table 500-16, Requirements of SDBC layer**

Description	Requirements
Minimum stability (KN at 60°C)	9.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each face of the specimen
Percent air voids	3-5
Percent voids in mineral aggregate (VMA)	14%
Percent voids filled with bitumen (VFB)	65-75

**Table 500-17, Permissible variations from job mix formula for SDBC**

Description	Permissible variation
Aggregate passing 13.2mm, 9.5mm	± 6%
Aggregate passing 4.75mm	± 5%
Aggregate passing 2.36mm, 1.18mm, 0.6mm	± 4%
Aggregate passing 0.3mm, 0.15mm	± 3%
Aggregate passing 0.075mm	± 1.5%
Binder content	± 0.3%
Mixing temperature	±10°C

For SDBC, compaction is to be done to achieve 92% of theoretical maximum specific gravity of loose bituminous mix used on that day. Density is to be obtained by cutting 150mm diameter cores.



SDBC rolling is in progress. 2 plain passes, 1 vibratory pass and 1 plain pass are necessary. Low amplitude and high frequency are to be set in vibratory settings of roller as it is a thin layer

### MORD 506 Open Graded Pre Mix Carpet (OGPC) 20 mm thick pre mix carpet

#### Aggregate

13.2mm chips = 0.18cum

11.2mm chips = 0.09cum

(13.2mm = passing 22.4 & retained on 11.2mm sieves)  
(11.2mm chips passing 13.2mm retained on 5.6mm sieves)

#### Binder

Bitumen @ 14.6 kg/10sqm  
Emulsion @ 21.5 kg/10sqm

AIV < 30%, FIV < 25% and  
WA < 1% for coarse aggregates.



### MORD 508 Seal Coat

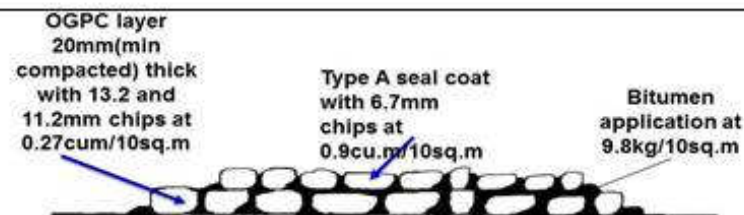
Table 500.12, Requirement of materials for seal coat

Type of seal coat	Per 10sqm	
	Bitumen kg	Emulsion kg
Type A Liquid seal coat	9.8	12 to 14
Type B Pre mix seal coat	6.8	10 to 12
Type C Pre mix seal coat using 6.7mm chips	4.5% by weight of total mixture	9 to 11

#### Quantity of chips per 10sqm as per cl.510.2.2

6.7mm chips (passing 11.2 mm and retained on 2.36mm sieve) for type A	0.09cum
Sand or grit (for type B) passing 2.36mm sieve and retained on 180 micron sieve	0.06cum
6.7mm for type C	0.09cum

If OGPC+SC type A are done, 50% of chips shall be retained on 11.2mm sieve. Quantity of chips per 10sq.m is 0.36 cu.m. Nowhere, contractors are doing type A seal coat.



OGPC with a mixture of 13.2mm and 11.2mm chips at the rate of 0.27cum and pre mixed with 14.6kg/10sq.m of bitumen >spreading > sectioning > compacted to a minimum thickness of 20mm > application of bitumen at the rate of 9.8kg/10sq.m on OGPC layer > application 0.09 cum /10sq.m of 6.7mm chips retained on 2.36mm IS sieve > rolling

#### OGPC with Type A Liquid seal coat.

Total quantity of chips: 36mm loose thickness.  
Compacted thickness in the range of 26 to 28mm  
24.4kgs bitumen and 0.36cum of chips to be used in 10sq.m area  
A total 24.4 kgs of bitumen is required for 0.36Cum of chips per 10sq.m



**Thickness, Quantity of chips obtained, bitumen requirement in different OGPC+SC(A) layers per 10sq.m from some QC test pits**

Observed thickness in mm	Quantity of chips per 10sq.m extracted	Bitumen requirement at @ 24.4 per 0.36 cu.m	% retained on 11.2mm sieve
20	0.26 cu.m	17.62kg	9%
21	0.27 cu.m	18.29kg	11%
22	0.275 cu.m	18.63kg	12%
23	0.29 cu.m	19.66kg	12%
24	0.31 cu.m	21.01kg	14%
25	0.33 cu.m	22.36kg	15%
26	0.35 cu.m	23.72kg	17%
27	0.355 cu.m	24.06kg	26%
28	0.365 cu.m	24.74kg	32%

A total Bitumen content of **24.4kg** is required per a total quantity of **0.36cum** of chips but not for a total compacted thickness of **20mm**

**Bitumen Content (BC) assessment in OGPC + SC in AP PRED**

(This practice not followed in NCRMP and PMGSY works)

Present practice in AP PR Quality wing is to cut a square cake of 150mm×150mm in OGPC + Type A seal coat and extracting bitumen from it and calculating bitumen per 10sq.m proportionally. Thickness is also noted and it is used in arriving at the bitumen content by multiplying with a factor of 20mm/observed thickness. They assume that more is the thickness more is the bitumen requirement. They are not considering quantity of chips to be used. For 20mm compacted thickness, loose thickness required is 25mm to 27 mm only. They can also find out the quality and quantity of chips (0.36 cum is required in 10sq.m) used after bitumen extraction. It is not being done.

Bitumen requirement of 24.4 kg/10sq.m is for 0.36cum of chips (36mm loose thickness) in 10sq.m area but not for 20mm thickness. If full quantity and size of chips are used, compacted thickness is likely to be in the range of 26 to 28mm or even more.

Due to the assumption of 20mm total thickness requirement, which is nowhere specified, contractors are forced to use 25 to 27 mm (instead of 36mm) loose thick quantity only in execution of OGPC+SC causing immense lose to the Department.

**Disadvantages in using OGPC+ type A Seal Coat**

1) 13.2mm chips are not available in most of the crushers. Hence correct sized chips are not being used in OGPC.

2) 6.7mm dry chips fully retained on 2.36mm sieve of 9mm loose thickness shall be applied on bitumen applied @9.8kg/10sq.m on OGPC surface. Nowhere, it is being done. Mostly pre-coated chips (mostly passing 2.36mm sieve) of about 3mm loose thick quantity is being used.

3) Approximate bitumen content in OGPC is 3.3% and type A seal coat is 6.5%. By not doing seal coat as specified, heavy loss is incurred to Govt.

4)In AP PRED, it is wrongly assumed that the total compacted thickness of OGPC+SC must be 20mm only. If more thickness is observed, they reduce the assessed bitumen content by multiplying with a factor of 20mm/observed thickness. This forces the contractor to execute OGPC+SC using less quantity of chips. It is leading to sub standard work.

5)If the seal coat is done manually as specified, the surface is uneven because required skilled workers are not available. Now, nobody likes the BT surface done without paver as they are accustomed to paved finish.

All these factors are responsible for some contractors executing 20mm MSS instead of OGPC+SC(A) duly causing a loss of Rs2 lakhs per Km to the Department. QC/field engineers shall be responsible if they allow such work and cause loss to the Government.

**Bitumen Content (BC) assessment in OGPC only as per thickness method**

Example: One contractor executed an OGPC work with 27mm loose quantity of chips of correct size with bitumen at 14.6kg per 10sq.m. Compaction is done well and the compacted thickness is varying from 21mm to 23mm.

Average compacted thickness observed of 150mm×150mm cake  
= 22mm

Assessed bitumen content as per thickness method  
=  $20/22 \times 14.6 = 13.27$  kg per 10sq.m

Here, the contractor has done using correct sized chips, correct chips quantity, full quantity of bitumen and compaction is also very good. But deficiency in bitumen content is assessed as per thickness method.

Another contractor executed OGPC with 24mm loose thick quantity, bitumen at the rate of 14.6kg per 10sq.m and compaction is good.

Average compacted thickness observed of 150mm×150mm cake= 19mm

Assessed bitumen content as per thickness method  
=  $20/19 \times 14.6 = 15.37$  kg per 10 sq.m

From the above, there is no justification in using thickness method in assessing bitumen content.

All IRC, MORD or MORTH publications specify that bitumen content shall be assessed in % only but not with thickness method.

**Bitumen Content (BC) assessment in OGPC + SC in AP PRED(QC)**

Example of bitumen content assessment as per the thickness method being adopted in AP PRED:

Example: One contractor executed an OGPC+SC work with 26mm loose quantity of chips in one single operation. Bitumen content used is 90% of the total requirement (14.6+9.8=24.4ks/10sq.m).

Compacted thickness observed of 150mm×150mm cake  
= 19.5mm

bitumen content as per thickness method  
=  $20/19.5 \times 90 = 92.3\%$

Another contractor executed OGPC of 27mm loose thick quantity and seal coat of 9mm loose thick quantity separately with 90% of the total bitumen content.

Compacted thickness observed of 150mm×150mm cake  
= 28mm

bitumen content as per thickness method  
=  $20/28 \times 90 = 64.3\%$  (Rs2 lakhs/km more spent)

Due to this method of bitumen assessment, no contractor dares to execute the work with full quantity of chips in AP PRED.

All IRC, MORD or MORTH publications specify that bitumen content shall be assessed in % only but not with thickness method.

### Comparative cost of different bituminous courses per km of 3.75m carriageway (2014-15 rates)

S.No	Description of Item	Amount
1	SDBC 25 mm thickness With 5.00 % BT	1050060.00
2	MSS Type A 25 mm thickness	941813.00
3	MSS Type B 25 mm thickness	874538.00
4	MSS Type B 20 mm thickness	758438.00
5	OGPC 20 mm thickness+Seal coat Type A	992851.00
6 *	OGPC 20 mm thickness+Seal coat Type B	922951.00
7 **	OGPC 20 mm thickness+Seal coat Type C	919763.00

\* Bitumen content is 6.80 kgs/10sqm

\*\* Bitumen content is 6.5kgs/10sq.m. i.e., 4.50 % by weight of mix as Per MORD.

### MORD Table 1800.7, Frequency of Quality Control Tests for OGPC or Mix Seal Surfacing

Test	Test Method	Frequency
AIV	IS: 2386-part 4	1 test per 250 cu.m per source
FIV	IS: 2386-part 1	1 test per 250 cu.m per source
Stripping	IS: 6241-1971	1 set of 3 representative specimens per source
Water Absorption	IS: 2386-part 3	1 set of 3 representative specimens per source
Soundness	IS: 2386-part 5	1 test per source
Grading	IS: 2386-part 1	1 test per 50 cu.m of aggregates
Binder Content	Appendix 10.8 of IRC: SP: 20	1 test per 500 cum or per day
Thickness	-	regularly

Here, it is clearly specified that bitumen shall be assessed in percentage. But QC wing of AP PRED, is following thickness method

IRC:SP:20-2002

Appendix-10.8

### Determination of Bitumen Content in Bituminous Mix

The test is intended for determination of bitumen content in the bituminous mix by cold solvent extraction method. The mineral aggregates recovered from the test can be used for checking their gradation. A representative bituminous mix sample of about 500 gm by weight is accurately weighed and placed in the bowl of extraction apparatus and covered with commercial grade of trichloroethylene. Sufficient time (not more than one hour) is allowed for dissolving the bitumen in solvent. The filter ring of the extractor is dried, weighed and then fitted around the edge of the bowl. The cover of the bowl is clamped tightly. A beaker is placed under the drain to collect the extract. The machine is revolved slowly and then gradually the speed is increased to a maximum of 3600 rpm. The speed is maintained till the solvent ceases to flow from the drain. The machine is allowed to stop, 200 ml of solvent is added and the above procedure is repeated. A number of 200 ml solvent additions (not less than three) are used till the extract is clear and not darker than a light straw colour. The filter ring from the bowl is removed, dried first in air and then in oven at 115°C to constant weight, and weighed. The fine materials that might have passed through the filter paper are collected back from the extract preferably by centrifuging. The material is washed and dried to constant weight as before. The percentage of binder in the bituminous mix sample is calculated as follows:

$$\text{Percentage of Binder} = \frac{W_1 - (W_2 + W_3 + W_4)}{W_1} \times 100$$

Where,

$W_1$  = weight of sample, gm  
 $W_2$  = weight of sample after extraction, gm  
 $W_3$  = weight of fine material recovered from the extract, gm  
 $W_4$  = increase in weight of filter ring, gm

## 507 Mix Seal surfacing

Table 500.11, aggregate gradation

IS sieve designation (mm)	Cumulative per cent by weight of total aggregate passing	
	Type A	Type B
13.2 mm	-	100
11.2 mm	100	88 - 100
5.6 mm	52 - 88	31 - 52
2.8 mm	14 - 38	5 - 25
0.090 mm	0 - 5	0 - 5
Bitumen	22 kg / 10 sqm	19 kg / 10 sqm

As per Manual for construction and supervision of bituminous works Type A grading may be used for 25mm thick MSS also, by proportionately increasing bitumen content

Suggestions for bituminous wearing coat for low volume rural roads

Type A seal coat is not being done as specified as the skilled labour are not available. Most people prefer Type A seal coat to save bitumen as it is having more bitumen. But in execution they do MSS to get maximum benefit. Due to ignorance departmental engineers are co-operating.

OGPC+SC can be done as specified with type B or Type C seal coat but without paver finish nobody likes the BT surface.

The best alternative for low volume roads is 25mm thick MSS(type A) or SDBC. In SDBC, mix design and other requirements are difficult to follow in rural roads.

Over primed WBM or WMM surfaces, it is very difficult to lay 20mm thick MSS with paver. Also traffic on rural roads consist of iron wheeled tractors and other agricultural machines. 20mm BT layer may not be able to withstand such traffic.

Hence MSS may be slightly modified as follows:

Type A MSS for 25mm and 30mm thick with 4.75% bitumen

Type B MSS for 35mm and 40mm thick with 4.5% bitumen

By specifying bitumen in percentage, the problem of applying thickness method and the confusion in the minds of quality engineers can be eliminated. For some roads we may require higher thickness of BT wearing coat also.

### Calculation of percentage of bitumen for combined layer of O.G.P.C + Type A Liquid Seal coat.

MORD table 1800.7( Appendix 10.8 of IRC:SP:20)

All the IRC publications IRC:SP:20, IRC:SP:11: Hand book for quality control and PMGSY Quality Assurance Manuals stipulate that bitumen content is to be assessed on percentage for OGPC and MSS also.

#### Calculation of Density of chips:

Diameter of the Cylinder	100mm
Height of Cylinder	113mm
Volume of Cylinder	0.0008871cuM
Weight of 13.2mm and 11.2mm chips	1.332Kg
Weight of 6.7mm chips	1.308Kg
Density of 13.2mm and 11.2mm chips	1501.606Kg/cuM
Density of 6.7mm chips	1474.550Kg/cuM

### Calculation of percentage of bitumen for O.G.P.C in 10 SqM

Volume of OGPC chips (13.2mm and 11.2mm)	0.27cuM
Weight of OGPC chips	= 0.27×1501.606= 405.334Kg
Weight of Bitumen	= 14.6Kg
Weight of OGPC Mix	= 419.934Kg

$$\text{Percentage of Bitumen in OGPC mix} = 100 \times 14.6 \div 419.934 = 3.476\%$$



**Calculation of percentage of bitumen for Type A seal coat**  
**in 10 SqM**

**MORD Table 400.7, Physical Requirements of Coarse Aggregates for WBM**

Test	Sub-base	Base	Surfacing
AIV	< 50%	< 40%	< 30%
FIV	< 30%	< 25%	< 20%
Soundness Test when water absorption > 2%			
Loss with sodium sulphate		< 12%	
Loss with magnesium sulphate		< 18%	

For Screenings: LL < 20%, PI < 6% and % passing 75 micron sieve < 10% (405.2.8)

For binder: PI < 6% for sub base and base. PI shall be from 4 to 10% for binder for surfacing (405.2.9)

**MORD 405 Water Bound Macadam**

Coarse Aggregates: Gr-I to Gr-III,

Screenings: Type-A: 6mm and 10mm,

Type-B: Stone Dust and 6mm

Binder: Stone Dust. Gravel for WBM as wearing course

✦ **Process of WBM**

Spreading Metal > Sectioning and Dry Rolling > Light Sprinkling of Water > Rolling > Application of Screenings > Brooming > Rolling > Watering & Sweeping > Rolling > Application of Binder > Sprinkling of Water & Sweeping > Rolling > Setting and Drying

**Grade II HBG metal as per table 400.8**



IS Sieve	Cumulative % passing	specified
75mm	100	100
63mm	94	90 - 100
53mm	50	25 - 75
45mm	7	0 - 15
22.4mm	3	0 - 5

**Grade III HBG metal as per table 400.8**



IS Sieve	Cumulative % passing	specified
63mm	100	100
53mm	97	95 - 100
45mm	80	65 - 90
22.4mm	8	0 - 10
11.2mm	2	0 - 5

**MORD Table 400.9**

Type of screenings	IS Sieve	% passing
<b>Type A 13.2mm (6mm &amp; 10mm chips)</b>	<b>13.2mm</b>	<b>100</b>
	<b>11.2mm</b>	<b>95-100</b>
	<b>5.6mm</b>	<b>15-35</b>
	<b>180 micron</b>	<b>0-5</b>
<b>Type B 11.2mm (stone dust and 6mm chips)</b>	<b>11.2mm</b>	<b>100</b>
	<b>9.5mm</b>	<b>80-100</b>
	<b>5.6mm</b>	<b>50-70</b>
	<b>180 micron</b>	<b>15-35</b>



**Type A screenings**



**Type B screenings dust  
and 6mm chips**

## MORD 406 WET MIX MACADAM

**Table 400.12, WMM Grading**

IS Sieve Designation	Per cent by weight passing the IS Sieve
53.00 mm	100
45.00 mm	95-100
22.4 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



**MORD Table 400.11  
Physical Requirements of  
Aggregates for WMM  
as per table 400.11**  
**AIV: 40% (Max)**  
**FIV: 25% (Max)**  
**Water Absorption: 2% (Max)**  
**Soundness test is necessary  
if W.A. exceeds 2%**

**Materials : 40mm, 20mm , 12mm, 6mm & Stone Dust Mixing at  
Pug Mill with Water, Conveyed to Site, Spreading by Paver  
and Rolling.**

**Relative Compaction = 100 %**

## WET MIX MACADAM as per IRC:109-2015

IS Sieve Designation	Per cent by weight passing the IS Sieve
53.00 mm	100
45.00 mm	95-100
22.4 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600 micron	6-18
75 micron	4-8



IRC:109 states that "WMM construction is an improvement upon the conventional WBM and is intended to be as an alternative and more durable pavement layer"

**Rolling WMM. 2 plain passes, one vibratory pass and final plain pass are necessary. High amplitude and low frequency settings are recommended.**





### 411 Crusher Run Macadam (MORD) 53 mm maximum size

Aggregate gradation  
requirement for Crusher Run  
Macadam 53mm max size

IS Sieve, mm	Per cent passing by weight
	53 mm max size
63	100
45	87 - 100
22.4	50 - 85
5.6	25 - 45
0.710	10 - 25
0.090	2 - 5



### 411 Crusher Run Macadam (MORD) 37.5mm maximum size

Aggregate gradation  
requirement for Crusher Run  
Macadam 37.5mm max size

IS Sieve, mm	Per cent passing by weight
	37.5 mm max size
63	--
45	100
22.4	90 - 100
5.6	35 - 55
0.710	10 - 30
0.090	2 -



**Table 400.1- A, MORD Specifications  
for Rural Roads  
Grading for Granular Sub-Base materials.**

IS Sieve Designation	Percent by weight passing designated sieve		
	Grading I	Grading II	Grading III
75.0 mm	100	--	--
53.0 mm	--	100	--
26.5 mm	55-75	50-80	100
4.75 mm	10-30	15-35	25-45
0.075 mm*	< 15	< 15	< 15

\*On clayey subgrades where otherwise drainage conditions are encountered, the percent passing IS Sieve 0.075mm shall not exceed 5

**Table 400.1- B MORD Specifications for Rural Roads  
Grading for Gravel Sub-Base.**

IS Sieve Designation	Percent by weight passing IS sieve	
53.0 mm	100	--
37.5 mm	100	--
26.5 mm	75-95	--
19.0mm	80-100	--
9.5mm	40-75	55-80
4.75 mm	30-60	40-60
0.425	15-30	15-30
0.075 mm	< 15	<15

**Table 400.1-C, MORD Specifications for Rural Roads  
Plasticity Requirements for sub base materials**

Climate	Liquid Limit	Plasticity Index	Remarks
Areas having average rainfall more than 1000mm	<35	<10	Design traffic up to 1msa
Areas having average rainfall less than 1000mm	<40	<15	Design traffic up to 1msa
All areas irrespective of rainfall	<25	<6	Design traffic more than 1msa

**Physical requirements of materials for sub base:**

- a) Material shall have a minimum soaked CBR value of 20%
- b) Wet Aggregate value shall not exceed 50

**Table 400.2-A, MORD: Grading requirements of  
gravel for sub base/Base course**

IS Sieve Designation	Percent by mass passing IS Sieve		
	A	B	C
53mm	100	--	--
37.5mm	97-100	100	
26.5 mm		97-100	100
19mm	67-81		97-100
9.5mm		56-70	67-79
4.75 mm	33-47	39-53	47-59
425µm	10-19	12-21	12-21
75µm	4-15	4-15	4-15

**Table 400.2-B, MORD: Grading requirements of soil-  
aggregate mixture for sub base/Base course**

IS Sieve Designation Nominal Maximum size	Percent by mass passing IS Sieve		
	80mm	40mm	20mm
80mm	100	--	--
40mm	80-100	100	
20mm	60-80	80-100	100
10mm	45-65	55-80	80-100
4.75mm	30-50	40-60	50-75
2.36mm	--	30-50	35-60
600µm	10-30	15-30	15-35
75µm	5-15	5-15	5-15

**Note:** Less than 10% should be retained on each pair of successive sieves specified for use except for the pair comprising the first two sieves

**Table 400.3-A, MORD Specifications for Rural Roads  
Grading for Gravel for surface course**

IS Sieve Designation	Percent by weight passing designated sieve
26.5 mm	100
19.0mm	97-100
4.75 mm	41-71
0425	12-28
75 µm	9-16

**Table 400.3-B MORD Specifications for Rural Roads**  
Grading requirements for soil-aggregate mixtures for surface course

IS Sieve Designation	Percent by mass passing designated service
10 mm	100
4.75 mm	80-100
2.36mm	50-80
1.18mm	40-65
300µm	20-40
75µm	10-25

Note: Less than 10% should be retained on each pair of successive sieves specified for use except for the pair comprising the first two sieves

**Plasticity Requirements for Gravel and Soil-Aggregate mixture as surface courses**

Climate	Liquid Limit	Plasticity Index
High Rainfall Areas average rainfall more than 1500mm	<35	4-9
Medium rainfall Areas Average rainfall 750mm to 1500mm	<40	6-15
Low Rainfall areas Average Rainfall <75mm	<55	15-30

Strength: Material for use in lower base course layer(layer immediately above the sub-base) shall have a minimum soaked CBR of 50. materials in upper base layer shall have a minimum CBR 80%

- Material shall have a minimum soaked CBR value of 20
- Wet Aggregate value shall not exceed 50



Sandy soil sub grade. Plight of WBM road covered with gravel cover done under NREGS. One layer of WBM and black topping is to be done on that stretch. Behaviour of the so called gravel when soaked is seen here.





## **Embankment Construction**

### **1. Embankment with natural earth**

### **2. Embankment with Coal Ash**

- a. Fly Ash
- b. Pond Ash
- c. Bottom Ash

## **Sub Grade Construction**

### **1. Sub Grade with natural earth**

### **2. Sub Grade with stabilised earth**

- a. Stabilisation with sand and lime
- b. Stabilisation with coal ash
- c. Stabilisation with soft aggregates
- d. Stabilisation with gravel / moorum
- e. Stabilisation with cement

### **MORD 301 Embankment Requirements**

- ❖ Liquid limit < 70%, Plasticity Index < 45%, FSI < 50%
- ❖ MDD(min): 1.44 g/cc up to 3m height and 1.52 g/cc for embankment subject ed to flooding and more than 3m height.
- ❖ In case of fly Ash minimum MDD is reduced to 0.9 g/cc as per IRC Special Publication No.58
- ❖ Breaking clods: 75mm maximum
- ❖ Moisture content: +1% or -2% of OMC for sandy / silty soils and OMC to OMC + 2% for clayey / BC soils
- ❖ Maximum layer thickness: 200mm (vibratory roller) or 150mm in case of smooth wheeled roller
- ❖ Trimming: additional width of 0.6m on either side
- ❖ Relative compaction: 98%
- ❖ Relative Compaction for expansive soils: 90-95%

### **MORD 303 Sub Grade Requirements**

#### **❖ Existing sub grade:**

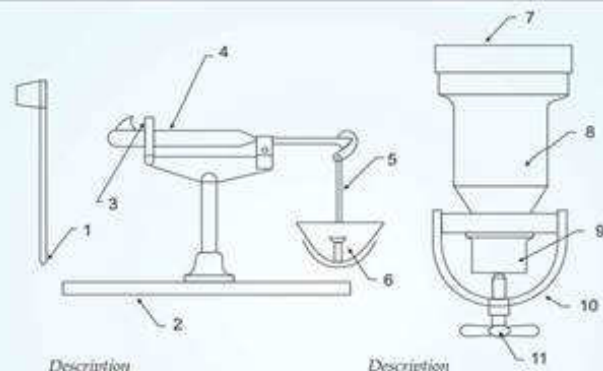
If sub grade CBR is less than 2%, a capping layer of 100mm thick with 10% CBR soil is to be provided and a CBR of 2% is to be taken for crust design

#### **❖ New sub grade and Shoulders:**

MDD (min) is 1.65 g/cc

Moisture content: +1% or -2% of OMC

Relative Compaction: 100%



- |   |  |
|---|--|
| <p>Description</p> <ol style="list-style-type: none"> <li>1. Scoop</li> <li>2. Balance Disc</li> <li>3. Index Mark</li> <li>4. Balance Arm</li> <li>5. Stirrup</li> <li>6. Cup</li> </ol> | <p>Description</p> <ol style="list-style-type: none"> <li>7. Gauge 0.50%</li> <li>8. Dial</li> <li>9. Cup</li> <li>10. U-clamp</li> <li>11. Clamp screw</li> </ol> |
|---|--|

**Rapid Determination of Moisture Content from Gas Pressure developed by the Reaction of Calcium Carbide with the Free Water of the Soil**

### MORD 1100 Pipe Culverts

*Pipes of less than 500mm diameter for irrigation water crossings/channels shall be considered as buried conduits and not culverts.*

*Fill above the top of the pipe to the finished road level shall not be less than 600mm. If it is not practicable, the pipe shall be encased in M10 concrete with 100mm cover. RC pipes for culverts shall be NP-3 or NP-4 pipes as per IS:458. Internal diameter of the RC pipes shall not be less than 900mm except in exceptional situations where it may be 600mm or 750mm. RC pipes for buried conduits also shall be NP-3 or NP-4.*

*Type A concrete (Min. M15) bedding shall be provided when the height of fill above the pipes is more than 4m.*

*Type B bedding (sand, moorum or granular material) shall be provided when the fill height is between 0.6m to 4m. Material passing 5.6mm sieve and minimum 75mm thick*

### MORD 1100 Pipe Culverts

In case of expansive soils, Sand or moorum or non-expansive material shall be provided under the bedding. Minimum thickness is 450mm.

Where two or more pipes are laid, they shall be separated by a distance of half the diameter of the pipes subject to a minimum of 450mm.

If the pipes are laid in layers, the minimum horizontal and diagonal distance between the pipes shall be same as the above and centers of the pipes shall form vertices of equivalent triangles.

Longitudinal slope of the pipe shall be not flatter than the bed slope subject to 1 in 1000 in plains. In hilly areas. It shall be according to the bed slope but not steeper than 1 in 30.

Invert of the pipe shall be minimum 150mm below the average bed level.

### CD works – Definitions

- a) Minor bridge: a bridge having a total length up to 60m  
A minor bridge up to 30m length is sometimes classified as small bridge.
- b) Major bridge: a bridge having a total length above 60m
- c) High Level Bridge: A bridge which carries the roadway highest flood level of the channel or drain
- d) Submersible bridge: A bridge designed to be overtopped during floods.
- e) Causeway: A paved submersible structure with or without openings(vents) which allows flood to pass through and/or over it.
- f) Ford: An unpaved shallow portion in a river or stream which can be used as a crossing during dry weather/normal flow.

### CD works – Definitions

- g) Culvert: a cross drainage work having a total length of 6m or less in between the inner faces of the dirt walls or extreme vent way boundaries measured at right angles there to.
- h) Afflux: It is the rise in flood level immediately on the upstream of a bridge as a result of obstruction caused by the construction of the bridge and its approaches.
- i) Highest Flood Level: is the highest flood ever recorded or calculated level for the design discharge, whichever is higher.
- j) Ordinary Flood Level: is the level of flood occurred every year. It can be determined by averaging the flood discharges of 7 consecutive years.
- k) Low water Level: is the level of water surface attained generally during dry season. It can be also determined by averaging the low water levels observed during 7 consecutive years

### Section 1800 of MORD Quality Control MORD 1802.2: Tolerance Limits for Horizontal Alignment

Horizontal alignment shall be reckoned with respect to the centerline of the carriageway as shown on the drawings. The permitted tolerances for the edges of the carriageway and for the edges of the roadway and lower layers of pavement in plain and rolling terrains and in hilly terrain are given below.

Location	Permitted tolerances	
	In plain and rolling terrain	In Hilly terrain
Edges of carriageway	±20mm	±30mm
Edges of roadway and lower layers of pavement	±30mm	±50mm

### MORD1802.3: Tolerances in Surface Levels table 1800.1

Sub-Grade	+20mm	-25mm
Sub-Base		
Flexible Pavement	+10mm	-20mm
Concrete Pavement (Dry Lean Concrete)	+6mm	-10mm
Base courses for flexible pavement		
Bituminous Course	+6mm	-6mm
Non-bituminous: Machine laid	+10mm	-10mm
Non-bituminous: Manually laid	+15mm	-15mm
Wearing Courses for flexible pavement: Machine laid	+6mm	-6mm
Wearing Courses for flexible pavement: Manually laid	+10mm	-10mm
Cement Concrete Pavement	+5mm	-6mm

### MORD 1802.4: Surface Regularity for Pavement layers

Type of Construction	Max. permissible undulation measured with 3M straight edge	
Sub-Grade	20mm	15mm
Granular Sub Base	12mm	10mm
Stabilized Soil Layer	12mm	10mm
WBM Grade I	15mm	12mm
WBM Grade II/ Grade III	12mm	8mm
Wet Mix Macadam Base	10mm	8mm
Surface Dressing	10mm	12mm
Built-up Spray Grout	12mm	8mm
20mm Bituminous pre-mix carpet	8mm	8mm
Bituminous Macadam	12mm	8mm
Mix Seal Surfacing	8mm	8mm
Cement Concrete	6mm	6mm



**MORD Table 1800.2, Frequency of Quality Control Tests for Earthwork**

Type of Test	Frequency
Placement moisture Content As per IS: 2720-part 2	1 in 250 cu.m for each layer subject to a maximum of 4 tests per day
Degree of Compaction As per IS: 2720-part 28	1 set of tests per 2000m <sup>2</sup> area comprising 5 to 6 measurements
CBR of Sub-Grade on remoulded samples As per IS:2720- part 16	As required

**MORD Table 1800. 2, Frequency of Quality Control Tests for Granular Sub-Bases/ Base/ Wearing Courses other than WBM**

Type of Test	Frequency
Gradation (IS: 2720-part 4)	2 tests per 500 cu.m subject to a minimum of 2 tests per day
Atterberg's Limits (IS: 2720-part 5)	2 tests per 500 cu.m subject to a minimum of 2 tests per day
Placement moisture content (IS: 2720-part 2)	2 tests per 500 cu.m subject to a minimum of 2 tests per day
Degree of Compaction (IS: 2720- part 28)	1 set of tests per 2000m <sup>2</sup> Area comprising 5 to 6 measurements
CBR (IS: 2720-part 16)	1 in 1000 cu.m

**MORD Table 1800.2, Frequency of Quality Control Tests for WBM courses**

Type of Test	Frequency
Aggregate Impact Value of Stone Aggregate (IS: 2386- part 4)	1 in 250 cu.m or source
Grading of Aggregates and screenings (IS: 2386-part 1)	2 tests per 250 cu.m or per day
Flakiness Index (IS:2386-part 1)	1 in 250 cu.m or per day
Atterberg's limits of binding material (IS: 2720-part 5)	1 in 50 cu.m or per day
Water Absorption (IS: 2386-part 3)	1 test per source

**MORD Table 1800.2, Frequency of Quality Control Tests for WMM courses**

Type of Test	Frequency
Aggregate Impact Value of Stone Aggregate (IS: 2386- part 4)	1 in 200 cu.m of aggregate
Grading of Aggregates and screenings (IS: 2386-part 1)	1 in 100 cu.m of aggregate
Flakiness Index (IS:2386-part 1)	1 in 200 cu.m of aggregate
Atterberg's limits of material passing 425 micron sieve (IS: 2720-part 5)	1 in 100 cu.m of aggregate
Density of compacted layer (IS: 2386-part 3)	1 test per 500 sq.m

**MORD Table 1800.3, Frequency of Quality Control Tests for Prime Coat and Tack Coat**

Test	Test Method	Frequency
Quality of binder	Viscosity, residue on 600 micron sieve and Storage Stability Tests for Emulsions and Flash Point Tests for Cutbacks (IS: 217)	1 test per lot or per 10 tonnes
Temperature of binder	Appendix – 10.6 of IRC: SP:20	Regularly
Rate of spread of binder	Appendix – 10.7 of IRC: SP:20	1 test per 500 sq.m. Not less than 2 tests per day

**MORD Table 1800.4, Frequency of Quality Control Tests for binder for bituminous courses**

Test	Test Method	Frequency
Quality of binder	Penetration, Softening Point and Ductility test for Paving Bitumen (IS: 73) additional test of Elastic recovery test for modified bitumen (IRC: SP: 73) Viscosity, residue on 600 micron sieve and Storage Stability Tests for Emulsions (IS: 8887) and Flash Point Tests for Cutbacks (IS: 217)	1 test per lot or per 10 tonnes
Temperature of binder	Appendix – 10.6 of IRC: SP:20	Regularly

**MORD Table 1800.4, Frequency of Quality Control Tests for Bituminous Macadam**

Test	Test Method	Frequency
AIV	IS: 2386-part 4	1 test per 250 cu.m per source
FIV	IS: 2386-part 1	1 test per 250 cu.m per source
Stripping	IS: 6241-1971	1 set of 3 representative specimens per source
Water Absorption	IS: 2386-part 3	1 set of 3 representative specimens per source
Grading	IS: 2386-part 1	1 test per 100 cu.m or per day
Binder Content	Appendix 10.8 of IRC: SP:20	2 tests per day per plant
Density of BM	Appendix 10.9 of IRC: SP:20	1 test per 1000 sq.m or per day
thickness	-	Regularly

**MORD Table 1800.5, Frequency of Quality Control Tests for Built Up Spray Grout/ Modified Penetration Macadam**

Test	Test Method	Frequency
AIV	IS: 2386-part 4	1 test per 250 cu.m per source
FIV	IS: 2386-part 1	1 test per 250 cu.m per source
Stripping	IS: 6241-1971	1 set of 3 representative specimens per source
Water Absorption	IS: 2386-part 3	1 set of 3 representative specimens per source
Soundness	IS: 2386-part 5	1 test per source
Binder spread rate	Appendix 10.7 of IRC: SP:20	1 test per 1000 sq.m or per day
Rate of spread of aggregates	Appendix 10.10 of IRC: SP:20	1 test per 1000 sq.m or per day
Grading	IS: 2386-part 1	1 test per 100 cu.m of aggregates

**MORD Table 1800.6, Frequency of Quality Control Tests for Surface Dressing/ seal Coat**

Test	Test Method	Frequency
AIV	IS: 2386-part 4	1 test per 250 cu.m per source
FIV	IS: 2386-part 1	1 test per 250 cu.m per source
Stripping	IS: 6241-1971	1 set of 3 representative specimens per source
Water Absorption	IS: 2386-part 3	1 set of 3 representative specimens per source
Soundness	IS: 2386-part 5	1 test per source
Binder spread rate	Appendix 10.7 of IRC: SP:20	1 test per 1000 sq.m and not less than 2 tests per day
Rate of spread of aggregates	Appendix 10.10 of IRC: SP:20	1 test per 1000 sq.m and not less than 2 tests per day
Grading	IS: 2386-part 1	1 test per 100 cu.m of aggregates

**MORD Table 1800.7, Frequency of Quality Control Tests for OGPC or Mix Seal Surfacing**

Test	Test Method	Frequency
AIV	IS: 2386-part 4	1 test per 250 cu.m per source
FIV	IS: 2386-part 1	1 test per 250 cu.m per source
Stripping	IS: 6241-1971	1 set of 3 representative specimens per source
Water Absorption	IS: 2386-part 3	1 set of 3 representative specimens per source
Soundness	IS: 2386-part 5	1 test per source
Grading	IS: 2386-part 1	1 test per 50 cu.m of aggregates
Binder Content	Appendix 10.6 of IRC: SP: 20	Regularly
Thickness	-	regularly

**MORD Table 1800.8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Levels and Alignment**

Level Tolerance	To be checked for each day's work (clause 1802.3)
Surface Regularity Longitudinal & Transverse	Regularly
Width of Pavement and position of paving edges	To be checked for each day's work (clause 1802.3)
Pavement Thickness	Regularly at grid points
Alignment of joints	To be checked for each day's work
Depth of Dowel bars	To be checked for each day's work

**MORD Table 1800.8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Cement and Water**

Item	Test method	frequency
Cement: Physical and Chemical tests	IS: 269, IS: 455, 1489, IS:8112 IS: 12269	One for each source of supply and occasionally when called for in case of long/ improper storage. Besides, the contractor shall also submit daily test data on cement released by the manufacturer.
Water Chemical Tests	IS: 456	Once for Approval of source of supply, subsequently in case of doubt



**MORD Table 1800.-8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Coarse and Fine Aggregates**

Test	Test Method	Frequency
AIV	IS: 2386-part 4	1 test per source
FIV	IS: 2386-part 1	1 test per source
Deleterious constituents	IS: 2386 part 2	1 test fo each day's work
Water Absorption/ Content	IS: 2386-part 3	Regularly as required subject to a minimum of 1 test a day for coarse aggregate and 2 tests a day for fine aggregates.
Soundness	IS: 2386-part 5	1 test per source
Gradation	IS: 2386-part 1	1 test per each day's work
Alkali Aggregate Reaction	IS: 2386-part 7	1 test per source

**MORD Table 1800-8, Frequency of Quality Control Tests for Paving Quality Cement Concrete Pavement**

**Concrete for pavement**

Strength of Concrete	IS:516	Minimum 6 cubes and 6 beams per day's work (3 each for 7 day 28 day strength).
Workability of fresh concrete Slump test	IS: 1199	1 test per 3 cubic meters of concrete at paving site or 1 test for each dumper laid at plant site

**MORD(2014)Table 1800.22, Frequency of Quality Control Tests for Semi Dense Bituminous Concrete Prior to Construction**

S.No	Type of test	Frequency
1	Quality of Binder (Paving Bitumen as per IS:73)	One Test per lot
	a) Absolute Viscosity and Penetration Test	
	b) R&B Softening Point Test	
2	c) Ductility Test	-do-
	Quality of Binder (Modified Bitumen) (IS:15462 and IRC:SP:53*)	One test on representative sample per Km length from each source identified by the contractor.
	a) Penetration Test	
	b) R&B Softening Point Test	
	c) Elastic Recovery Test	
	d) Seperation Test	
3	Aggregate Impact Value Test (IS:2386 Part 4)	
4	Flakiness Index of Stone Aggregates (IS:2386 Part 1)	Three tests per source
5	Bituminous Stripping of Aggregate Test(IS:6241)	One test per source
6	Water absorption (Is:2386 Part 3)	-do-
7	Soundness Test (Sodium or Magnesium sulphate test)(IS:2386 Part 3)	-do-
8	Sand equivalent test	-do-

\* Refer to Para 12 of IRC:SP:53

**MORD(2014)Table 1800.23, Frequency of Quality Control Tests for Semi Dense Bituminous Concrete During Construction**

S.No	Type of test	Frequency
1	Mix Grading (IS:2386 Part 1)	Individual constituent and mixed aggregate from dryer. At least two tests per day.
2	Stability and voids analysis of mix	At least two tests per day
3	Binder content	At least two tests per day
4	Temperature of Binder in boiler and aggregate in dryer	At regular intervals
5	** Temperature of mix during laying and compaction	At regular intervals
6	Rate of spread of mix and thickness of compacted layer	Regular, at close intervals
7	Density of compact Layer	One test per 700 Sqm area Minimum 3 test per day
8	Aggregate Impact Value Test (IS:2386 Part 4)	At random one test per Km

\*\* Temperature measurement will be done by using metallic contact thermometer with digital display

## A TECHNICAL PRESENTATION

D.V.Bhavanna Rao. M.Tech., F.I.E.,  
C.E. AP R&B Retired  
PM, TPQA, NCRMP  
for



Please visit  
<http://apnrcrmptpqa.wordpress.com>

## Important Aspects in Construction in concrete Structures

### ORDINARY PORTLAND CEMENT ( IS:456-2000) BLENDED CEMENTS

Grades:33,43 and 53

#### GRADES of CONCRETE

- i) Ordinary Concrete:M10, M15 and M20
- ii) Standard Concrete:M25, M30, M35, M40, M45, M50 and M55
- iii) High Strength Concrete: M60, M65, M70, M75and M80

## Ingredients of Cement Concrete

**Cement**  
**Water**  
**Coarse Aggregate**  
**Fine Aggregate**  
**Admixtures**

### Ordinary Portland Cement

It is composed of calcium silicates and aluminates. It is obtained by blending in predetermined proportions of lime stone and clays which are pulverised and fired at high temperatures to produce clinker. Clinker is ground with small quantities of gypsum to produce a fine powder.

#### Major compounds of cement

Tri-calcium silicates		$C_3S$	
Di-calcium silicates		$C_2S$	
Tri-calcium aluminates		$C_3A$	
Tetra-calcium Alumino-ferrite		$C_4AF$	
C =CaO	S=SiO <sub>2</sub>	A=Al <sub>2</sub> O <sub>3</sub>	F=Fe <sub>2</sub> O <sub>3</sub>
Lime stone	sand	clay	Hematite

**Hydration of cement:**  $C_3S$  and  $C_2S$  are the most important compounds and responsible for strength of cement paste. By selecting proper mixture of raw materials to change percentages of  $C_3S$  and  $C_2S$  and by grinding to required fineness necessary grade of cement is produced. Ratio of  $C_3S$  and  $C_2S$  is raised from 1.2 to 3 for 53 grade cement

- ❖  $C_3S + \text{water} = \text{CSH gel} + \text{Ca(OH)}_2$  (=lime 39%)
- ❖  $C_2S + \text{water} = \text{CSH gel} + \text{Ca(OH)}_2$  (=lime 18%)
- ❖  $\text{Ca(OH)}_2 + \text{CO}_2 \text{ Humidity} + \text{CaCO}_3$  (insoluble)
- ❖  $\text{CaCO}_3 + \text{CO}_2 \text{ Humidity} = \text{Calcium bi carbonate}$  (soluble).

It causes lime leaching and degradation of concrete. In blended cements reactive silica reacts with  $\text{Ca(OH)}_2$  and results in secondary CSH gel formation.

- ❖ 53 grade OPC give about 25% surplus lime
- ❖ 43 grade OPC give about 18% surplus lime

#### Physical characteristic requirement of cement

Characteristic	Requirements		
	33 grade IS: 269-1989	43 grade IS: 8112-1989	53 grade Is: 12269-1987
<b>Minimum compressive strength in <math>\text{N/mm}^2</math></b>			
3 days	16	23	27
7 days	22	33	37
28 days	33	43	53
Fineness (minimum) ( $\text{M}^2/\text{Kg}$ )	225	225	225
Setting time (minute)			
Initial – (minimum)	30	30	30
Final – (maximum)	600	600	600
Soundness, expansion			
Le Chatleier – (maximum) mm	10	10	10
Autoclave test – (maximum) %	0.80	0.80	0.80

**Cement Grade:** As per IS: 4032 part – 6, Mortar cube compressive Strength test is conducted on 70.6mm 1:3 cement mortar cubes to determine the grade of cement and sand used shall be as per IS:650. Grade number is 28 days' compressive strength in MPa or  $\text{N/mm}^2$   
 $1\text{MPa} = 10.21 \text{ Kg/cm}^2$

Assessment of Concrete compressive strength is done by conducting cube testing on 3 specimens of 150mm cubes from the same concrete and the average value is considered. Average value of 3 specimens represent a sample result. If the results of 3 specimens show more than 15% variation with average value, it be ignored.

#### Water for mixing and curing

Potable water (pH value 6 to 8 as per MORD802.5) is generally considered satisfactory for both mixing and curing. PH value shall not be less than 6%(IS:456)

In case of doubt, 28 days average compressive strength of at least three 150mm cubes prepared with water proposed to be used shall not be less than 90% of the average strength of 3 similar cubes prepared with distilled water.

Initial setting time of test block made with water proposed to be used shall not be less than 30 minutes and shall not differ by  $\pm 30$  minutes from the initial setting time of test block prepared with distilled water.

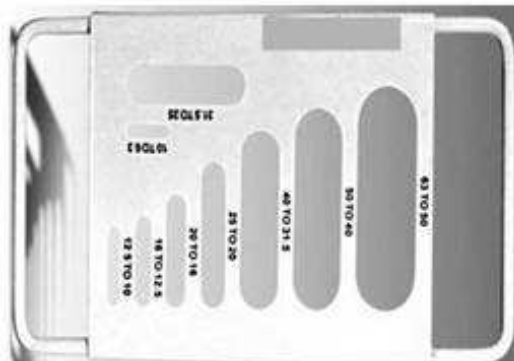


**Permissible limits for solids in Water**  
**Cl. 5.4 of IS: 456-2000 or IS:3025**

	Tested as per	Permissible limit maximum
Organic	IS 3025 part 18	200 mg/l
Inorganic	IS 3025 part 18	3000 mg/l
Sulphate as SO <sub>3</sub>	IS 3025 part 24	400 mg/l
Chloride as cl	IS 3025 part 32	2000 mg/l for PCC 500 mg/l for RCC
Suspended matter	IS 3025 part 18	2000 mg/l

**Physical Requirements of Coarse Aggregates IS: 383**

Properties	Limiting Values in percent	
	for wearing surfaces	other than wearing surfaces
Crushing Value	30	45
Aggregate impact value	30	45
Los Angeles abrasion value	30	50
Soundness	when tested with Na <sub>2</sub> SO <sub>4</sub>	when tested with MgSO <sub>4</sub>
Fine aggregates	10	15
Coarse aggregates	12	18



**IS sieves:**  
63,50,40,25,20,  
16,12.5,10 and  
6.3mm

**Flakiness Index Test**  
**IS: 2386 part 1**  
Thickness of flaky material is less than 0.6 times mean size



**Aggregate Impact test**  
**IS; 2386 part 4**

Material passing 12.5 mm sieve and retained on 10mm sieve is placed in mould in 3 layers by tamping 25 times for each layer. After 15 blows, material passing 2.36 mm sieve is weighed and compared with sample weight in %.



**Requirements of coarse (single size) aggregate as per table 2 of IS: 383**

IS Sieve Size	Percent by Weight Passing the Sieve		
	40 mm	20 mm	12.5 mm
63 mm	100	--	--
40 mm	85-100	100	--
20 mm	0-20	85-100	--
16 mm	--	--	100
12.5 mm	--	--	85-100
10 mm	0-5	0-20	0-45
4.75 mm	--	0-5	0-10

**Requirements of coarse (graded size) aggregate as per table 2 of IS: 383**

IS Sieve Size	Percent by Weight Passing the Sieve		
	40 mm	20 mm	12.5 mm
63 mm	100	--	--
40 mm	95-100	100	--
20 mm	30-70	95-100	100
12.5 mm	--	--	90-100
10 mm	10-35	25-55	40-85
4.75 mm	0-5	0-10	0-10

Maximum size of Coarse aggregate may be as large as possible within the limits specified, but in no case greater than  $\frac{1}{4}$ th of minimum thickness of member or 10mm less than the clear distance between individual reinforcement or 10mm less than clear cover to any reinforcement.

**40 mm HBG single size metal for concrete as per IS:383**



IS Sieve mm	Cumulative % passing	% passing
40	92	85-100
20	9	0-20
10	2	0-5

**40 mm HBG graded metal for concrete as per IS:383  
Mixture of 40, 20 and 12.5 single sizes**



IS Sieve mm	Cumulative % passing	% passing
40	95	95-100
20	50	30-70
10	26	10-35
4.75	2	0-5

**20 mm HBG single size metal for concrete  
as per IS:383**

IS Sieve mm	Cumulative % passing	% passing
40	100	100
20	92	85-100
10	9	0-20
4.75	2	0-5



**20 mm HBG graded metal for concrete  
as per IS: 383.**

Mixture of 20, 12.5 and 6.3mm single sizes

IS Sieve mm	Cumulative % passing	% passing
40	100	100
20	97	95-100
10	40	25-55
4.75	5	0-10



Properties	Limits of deleterious materials as per IS: 383-1970			
	Fine aggregates % by weight		Coarse aggregates % by weight	
	uncrushed	crushed	uncrushed	crushed
Coal and lignite	1.00	1.00	1.00	1.00
Clay lumps	1.00	1.00	1.00	1.00
Material finer than 75 micron	3.00	15.00	3.00	3.00
Shale	1.00	-	-	-
Total % of all Deleterious materials	5.00	2.00	5.00	5.00

**Fineness Modulus of fine aggregates: 2.0 to 3.5**  
**Zone-IV sand not suitable for RCC works (IS:456)**  
**MORD and MORTH specify Zone I to III for concrete**

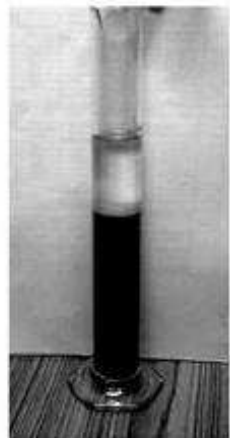


**In a 250 ml cylinder pour damp sand duly shaking up to 200 ml mark. Fill cylinder with water sufficient to submerge sand fully and stir the sand well. It can be seen that sand surface is below original level**



$$\text{Bulkage of sand} = 100(200-y)/y$$





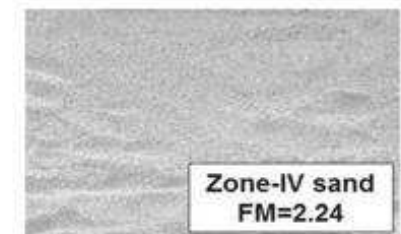
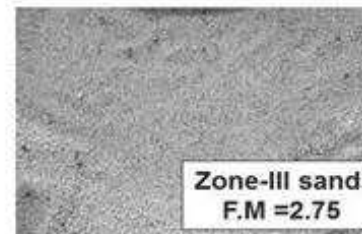
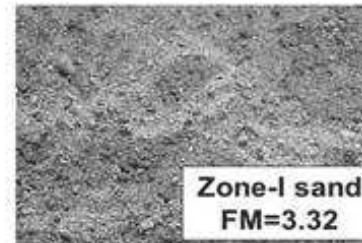
### Silt content test

Fill 200 ml jar up to 100 ml level with sand.

Pour water up to 150 ml level and shake vigorously. Allow it for 3 hours to settle.

$$\text{Silt content} = \frac{h}{H} \times 100$$

Total deleterious content shall not exceed 5%  
As per MORD, MORTH or IS:383



### Fine Aggregate as per Table 4 of IS: 383

IS Sieve Designation	Percent passing for			
	Grading Zone-I	Grading Zone-II	Grading Zone-III	Grading Zone-IV
10mm	100	100	100	100
4.75mm	90 – 100	90 – 100	90 – 100	95 – 100
2.36mm	60 – 95	75 – 100	85 – 100	95 – 100
1.18mm	30 – 70	55 – 90	75 – 100	90 – 100
600microns	15 – 34	35 – 59	60 – 79	80 – 100
300microns	5 – 20	8 – 30	12 – 40	15 – 50
150microns	0 – 10	0 – 10	0 – 10	0 – 15

### Mineral Admixtures

1. Fly Ash (up to 25% as per IS 1489)
2. Rice Husk Ash
3. Silica Fume
4. Slag (up to 65% as per IS 455)
5. Metakaoline

### **Advantages in using Blended Cements**

1. Low heat of hydration
2. Reduced permeability
3. Increased durability
4. Enhanced performance
5. Reduced Alkali Silicate Reaction
6. Continuous strength gain
7. Increased workability

### **Portland Pozzolana Cement**



- Increases CSH volume
- Denser CSH formed by secondary reaction
- Retards hydration in the early stages
- Accelerates during the middle stage
- Pore structure and composition

### **Portland Slag Cement**

- ❖ Reduced  $\text{C}_3\text{A}$  in PSC
- ❖ Lower content of free CH
- ❖ Lower basic nature of CSH
- ❖ Sulphate resistant
- ❖ Chloride and Sulphate are present together

### **What is GGBS ?**

Ground Granulated Blast furnace Slag (GGBS) is a Potential Hydraulic Material which is ground to very fine state under controlled conditions

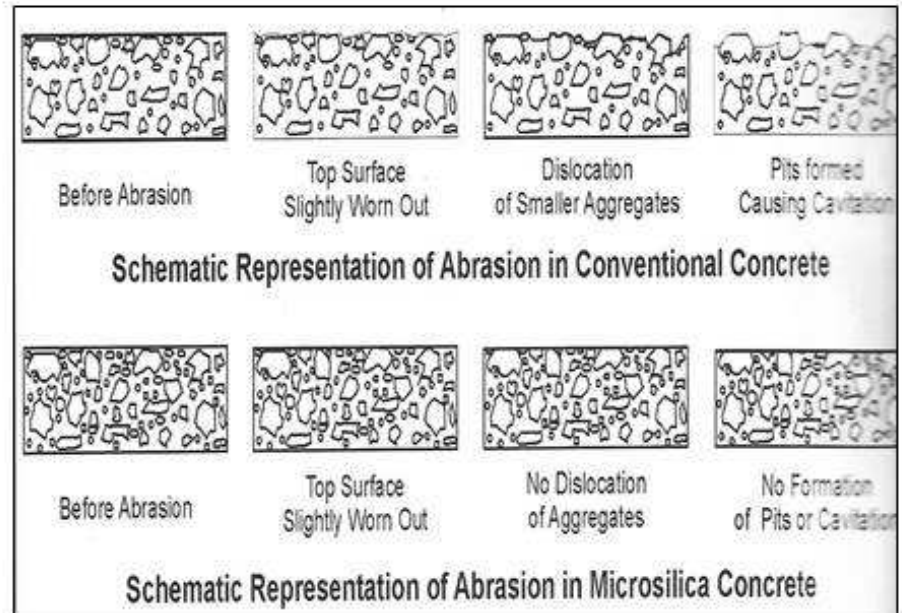
*The basic raw material for GGBS is Granulated Blast furnace Slag produced as a by-product in the manufacture of Pig Iron in the Blast furnace*

To improve the Durability of the Concrete, usage of GGBS along with OPC is recommended in IS 456 : 2000, BS 6699 : 1986 & ASTM C989 : 1982

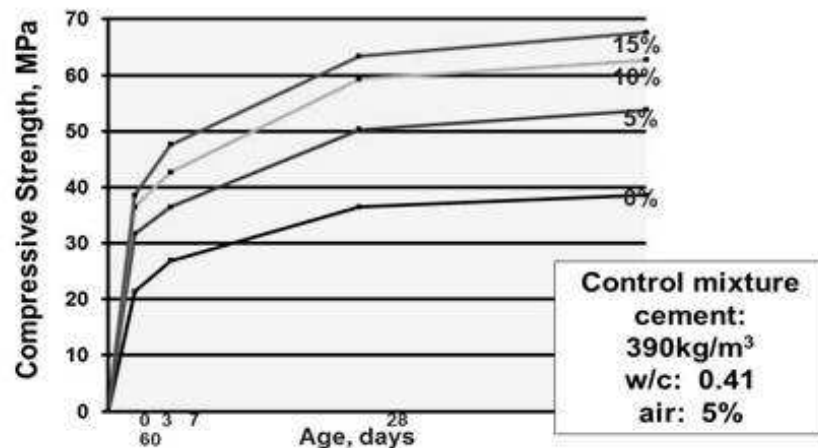
## Silica Fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys in an electric-arc furnace. This photo, taken before environmental regulations were put into effect, shows silica fume being discharged from a smelter. Today, no silica fume is discharged to the environment in the United States. It is also known as condensed silica fume or micro silica.

Micro Silica is an ultra fine material i.e., about 100 times finer than cement. It easily reacts with extra lime and blocks the finest of fine pores of concrete. It improves mechanical bonding of concrete. Silica Fume product forms as-produced powder, water-based slurry, densified, blended



Silica-Fume Concrete: Typical Strengths



## Problems with Blended Cements

1. Lower Early Strength Gain
2. Longer Duration of Shuttering
3. Continuous Curing
4. Improper Blending
5. Quality of Admixtures

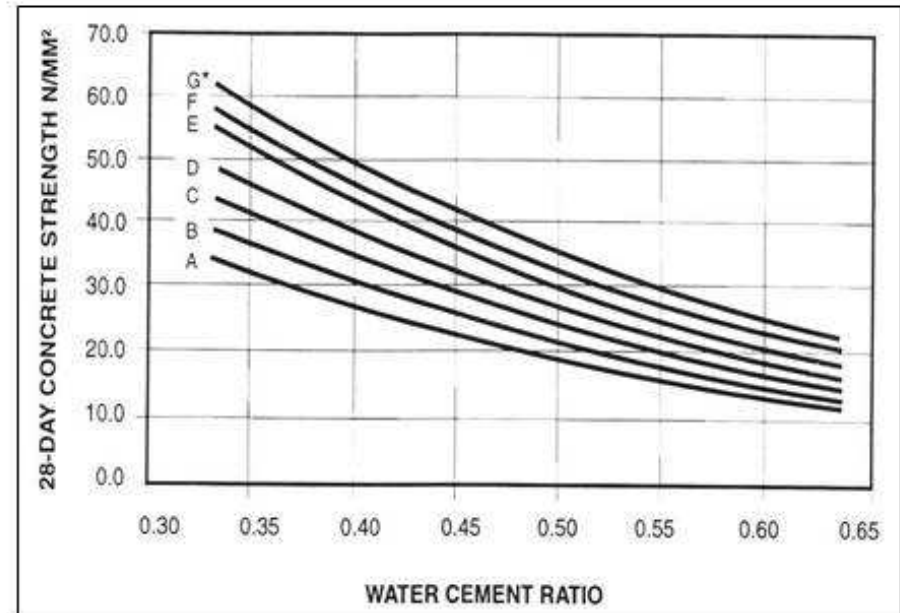


### Water - Cement ratio

Many feel that controlling W/C means reduction of water and there by production of stiff unworkable concrete mix. It is unfortunate that many in the field of concrete production have not realised that workability can be maintained at the desired level even while maintaining strict control over the low W/C. In simple words, if water is required to be increased, cement should also be increased such that specified W/C does not increase. Another simple way is to reduce the aggregate quantity or in other words to reduce the aggregate to cement ratio of the concrete mix.

It has been observed that cement water paste with more volume of water will also occupy greater total volume of space and after completion of hydration process will therefore end up with larger volume of capillary pores.

As the capillary pores in cement paste reduces the strength increases and permeability of the concrete or mortar prepared using the paste decreases.



### Coefficient of Permeability for different W/C ratios

S.No	W/C ratio	Coefficient of Permeability
1	0.35	$1.05 \times 10^{-3}$
2	0.50	$10.30 \times 10^{-3}$
3	0.65	$1000 \times 10^{-3}$

### Permeability for different W/C ratios at different curing periods

W/C	Curing period in days				
	1	3	7	28	90
0.32	5.60	0.30	0.12	0.00	0.00
0.40	18.70	0.59	0.07	0.07	0.00
0.50	214.00	14.70	2.35	0.19	0.00

### Porosity (%) for different W/C ratios at different curing periods

W/C	Curing period				
	1	3	7	28	90
0.32	20.80	19.17	14.40	9.80	5.90
0.40	33.30	28.60	20.90	16.80	11.10
0.50	43.50	37.80	32.20	20.80	14.50

### Function of Plasticizers

Fine cement particles being very small clump together and flocculate when water is added to concrete. This ionic attraction between the particles trap considerable volume of water and hence water required for workability of concrete mix is not fully utilised. Negative charges are induced on the fine cement particles causing flocs to disperse and release the entrapped water. Water reducing admixtures or plasticizers therefore help to increase the flow of the concrete mix considerably.

### Chemical Admixtures - Plasticizers

Plasticizers are also called water reducing admixtures. Ordinary water reducing plasticizers which enable upto 15% of water reduction. High range water reducing super plasticizers which enable up to 30% of water reduction

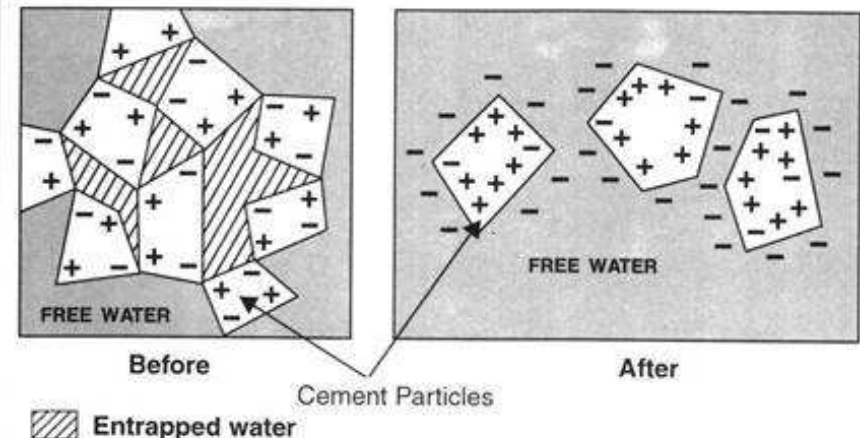
The plasticizers are generally used to achieve the following:

a) In fresh concrete:

1) Increase workability and / or pumpability without increasing the water/cement ratio. 2) Improve cohesiveness and thereby reducing segregation or bleeding 3) Improve to some extent set retardation

b) In Hardened concrete:

1) Increase strength by reducing the water/cement ratio, maintaining same workability. 2) Reduce permeability and improve durability by reducing water/cement ratio. 3) Reduce heat of hydration and drying shrinkage by reducing cement content



Dispersion of entrapped air with the addition of plasticizer

**Increase in Slump by adding plasticizer  
without changing cement content, water  
cement ratio**

Concrete Mix	Cement Content (Kg/M <sup>3</sup> )	W/C	Slump (mm)	Strength (Kg/cm <sup>2</sup> ) at	
				7 days	28 days
Reference mix without Plasticizer	440	0.37	25	390	540
Mix with Plasticizer	440	0.37	100	411	541

**Increase in Compressive strength by  
reducing W/C ratio without increasing  
cement content**

Concrete Mix	Cement Content (Kg/M <sup>3</sup> )	W/C	Slump (mm)	Strength (Kg/cm <sup>2</sup> ) at	
				7 days	28 days
Reference mix without Plasticizer	315	0.60	95	218	291
Mix with Plasticizer	315	0.53	90	285	375

## Durability of Concrete

Durability of concrete is its ability to resist weathering action, chemical attack, abrasion, and all other deterioration processes.

Weathering includes environmental effects such as exposure to cycles of wetting and drying, heating and cooling, as also freezing and thawing.

Chemical deterioration process includes acid attack, expansive chemical attack due to Sulphate reaction, alkali aggregate reaction, corrosion of steel in concrete due to moisture and chloride ingress

## Causes of deterioration of concrete

- 1) Porosity and permeability
- 2) Thermal and plastic cracking
- 3) Entry of chemicals (chlorides, sulfates, water, Carbon Dioxide)
- 4) Corrosion of reinforcement
- 5) Harmful effects of chloride
- 6) Carbonation:  $\text{Ca(OH)}_2 + \text{CO}_2 = \text{CaCO}_3 + \text{H}_2\text{O}$   
( reduction of alkalinity - ph. below 7)
- 7) Sulphate attack
- 8) Alkali aggregate reaction



## Lime Leaching

Water can decompose any of the hydrated compounds present in concrete. If concrete comes in continuous contact with water or moisture, the free lime occurring in hardened concrete being easily soluble is the first compound to be attacked and will leach out. This lime extraction to the concrete surface increases both porosity and permeability. The soluble calcium hydroxide leaches through the capillary pores of concrete and leaves a passage for other pollutants such as water, chlorides and Sulphates to enter. This also causes alkalinity of concrete to drop initiating corrosion of steel within concrete.

## Corrosion of Steel

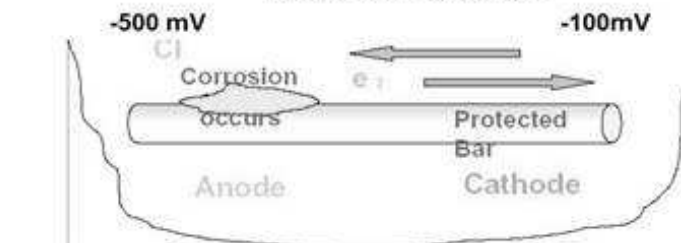
Mechanism of corrosion of steel is an electro-chemical process. The electro-chemical process starts when there is a potential difference caused due to difference in concentration of dissolved ions such as alkalis, chlorides and oxygen, in the vicinity of steel. Due to the potential difference some parts of the metal become anodic and the other parts become cathodic. Dissolution or pitting of iron takes place and rust appears on the anodic part as iron gets converted to ferrous oxide or ferrous hydroxide. For this chemical process presence of moisture and oxygen is necessary. The concrete acts as an electrolyte and the electro-chemical process takes place.

Depending on the state of oxidation, metal get converted to rust (corrosion product) which may occupy 6 to 8 times the original size of steel.

**Rate of Chloride diffusion in OPC and Blended Cements**

Type of Cement	Chloride Diffusion Sq.cm / S x 10
OPC	4.47
Pozzolana Cement (70% OPC & 30% fly ash)	1.47
Slag Cement (35% OPC & 65% slag )	0.41
Sulphate Resistant Cement	10.0

**Electrochemical reactions in a typical corrosion cell in reinforced Concrete**

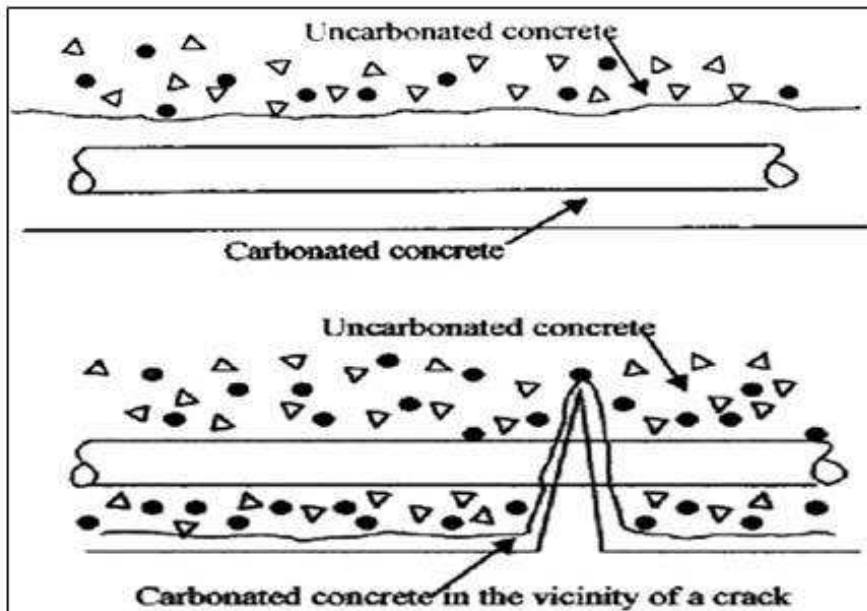
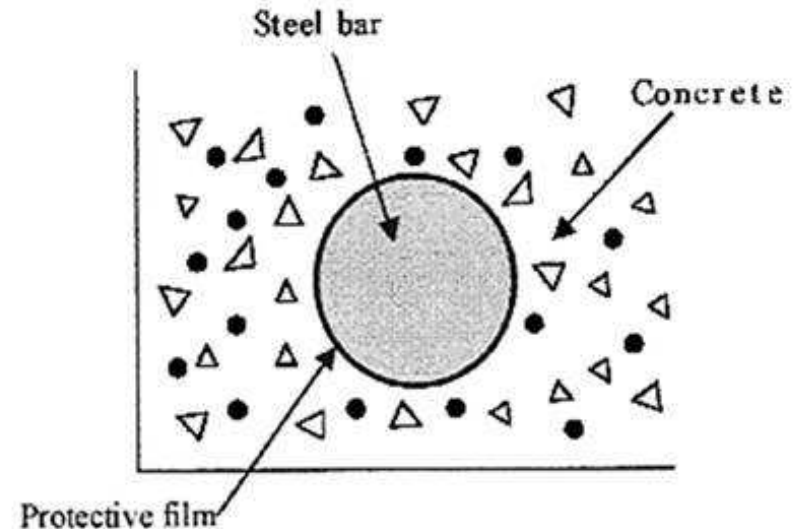


## Carbonation

The carbon dioxide in the atmosphere in presence of water reacts with the concrete surface and concrete gets carbonated or in other words turns acidic. This chemical reaction starts at the surface and gradually goes within the concrete mass and is generally measured as depth of carbonation.

Concrete is an alkaline substance and provides excellent protection to reinforcement embedded inside. The alkaline environment forms a protective oxide film which passivates the steel and protects it from corrosion. Concrete initially has a pH value of above 13.

Due to leaching, carbonation and defective construction practice the pH value drops rapidly. Once the pH value of concrete in the cover area drops below 10, corrosion of steel reinforcement is inevitable and therefore concrete durability is at stake.



Rate of Carbonation depends on:

- 1 Concrete Quality
- 2 Environmental conditions
- 3 Type of cement used

Estimated 20 years Carbonation depths for different grades of concrete

Sr. No.	Estimated 20 yrs. depth (mm)	28 days compressive strength (N/mm <sup>2</sup> )
1.	6mm	58.00
2.	14mm	41.50
3.	22mm	31.50
4.	33mm	21.00

## **Sulphate Reaction**

Sulphates are generally found in ground water and subsoil. Sea water also contains large quantity of Sulphates. Sulphates can be naturally occurring or could be as a consequence of industrial waste.

Blended cements have low  $C_3A$  content and also enable production of pastes containing small amount of calcium hydroxide. The Pozzolana cements have also shown great Sulphate resistance which is probably due to the composition and the structure of the pores in hydrated pastes.

## **Alkali Aggregate Reaction**

Several harmful chemical reactions between aggregates and ordinary Portland cements have been reported. The most common reaction is the one between certain types of silica occurring aggregates and alkalis present in cement. The type of silica which are alkali reactive are opal, chalcedony and tridymite.

Due to this reaction a gel made up of alkaline – earth silicate is formed. This gel has a tendency to absorb water and swell. The swelling causes internal stress and when this stress exceeds the tensile strength of the pastes cracking of concrete can occur.

This problem cannot be always solved by changing the aggregates. Therefore cement of appropriate chemical composition has to be used.

Using blast furnace slag cements and Pozzolanic cements is yet another solution.

## **Ingredients for Highly Durable Concrete**

1. Very low porosity through the development of a tight and refined pore structure of the cement paste
2. Very low permeability of the concrete
3. High resistance to chemical attack
4. Low heat of hydration
5. High early strength and continued strength development
6. Low water-binder ratio
7. High workability and control slump loss
8. Low bleeding and plastic shrinkage
9. Dimensional or volume stability
10. High elastic modulus
11. Low thermal stress
12. Low creep

## **Factors to be controlled for producing durable concrete**

1. Structural design,
2. Study of environment in which structure is located
3. Water cement ratio, cement content, concrete grade
4. Cover and cover block quality,
5. Materials quality and mix design
6. Workability and cohesiveness of concrete mix
7. Batching, mixing, transporting, compacting and curing
8. Maintenance and usage in service life



### **Durable Concrete Strategy**

1. A material strategy to develop a high-durability concrete, that is high strength through durability rather than high durability through strength.
2. A management strategy to develop efficient protective system to protect concrete and steel from aggressive environmental attack.
3. A design strategy to integrate material properties with structural performance that will ensure material stability and structural integrity.

**Emeritus Professor Narayana Swamy**

### **Environmental Exposure Conditions Table 3 of IS: 456-2000**

**Mild  
Moderate  
Severe  
Very Severe  
Extreme**

### **Mild Exposure Condition**

**Concrete surfaces protected  
against weather or aggressive  
conditions, except those in  
coastal area**

### **Moderate Exposure Condition**

**Concrete surfaces sheltered from  
severe rain or freezing of whilst wet.**

**Concrete exposed to condensation  
and rain.**

**Concrete continuously under water.  
Concrete in contact or buried under  
non aggressive soil/ground water.**

**Concrete surfaces sheltered from  
saturated salt air in coastal area**

## Severe Exposure Condition

Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation.

Concrete completely immersed in sea water

Concrete exposed to coastal environment

## Very Severe Exposure Condition

Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. Concrete in contact with or buried under aggressive sub-soil/ground water

## Extreme Exposure Condition

Surfaces of members in tidal zone.

Members in direct contact with liquid/solid aggressive chemicals

Exposure Conditions as per IRC: 21-2000  
Code of Practice for road bridges section III

**Severe:** Marine environment: alternative wetting and drying due to sea spray; alternative wetting and drying combined with freezing;

Buried in soil having corrosive effect;

Members in contact with water where the velocity of flow and the bed material are likely to cause erosion;

**Moderate:** Conditions other than severe

Minimum Cement content, Minimum Grade of Concrete and maximum water-cement ratio for different exposure conditions

Table 5 of IS: 456-2000

Exposure	Plain Concrete			Reinforced Concrete		
	Minimum cement content kg/CuM	Maximum free water cement ratio	Minimum Grade of concrete	Minimum cement content kg/CuM	Maximum free water cement ratio	Minimum Grade of concrete
Mild	220	0.60	-	300	0.55	M20
Moderate	240	0.60	M15	300	0.50	M25
Severe	250	0.50	M20	320	0.45	M30
Very severe	260	0.45	M20	340	0.45	M35
Extreme	280	0.40	M25	360	0.40	M40

Requirements of minimum concrete grade, minimum cement content and maximum water cement ratio as per IRC: 21-2000

structural member	min. grade of concrete conditions of exposure		min. cement content conditions of exposure		max. water cement ratio conditions of exposure	
	moderate	severe	moderate	severe	moderate	severe
PCC	M15	M20	250	310	0.5	0.45
RCC	M20	M25	310	360	0.45	0.4

Note: quantity of cement apply for 20mm aggregates. For larger aggregates reduction up to 10% and for smaller aggregates increase up to 10% is permitted

Development length factors of bars for limit state method as per IS: 456-2000

Concrete Grade	Mild steel bars		Deformed bars	
	Tension	Compression	Tension	Compression
M 20	46	37	47	38
M 25	39	32	41	33
M 30	37	29	38	31
M 35	32	26	34	27
M 40	30	24	30	24

Development length ( $l_d$ ) = factor  $\times$  bar dia  
 Lap length in flexural tension = greater of  $l_d$  or 30  $\phi$   
 Lap length in direct tension = greater of 2  $l_d$  or 30  $\phi$   
 Lap length in compression = greater of  $l_d$  or 24  $\phi$

Development length in multiples of dia as per IRC:21

Concrete grade		M20	M25	M30	M35	M40 & above
	bar gr.					
Bonding zone I favourable	Fe 500	66	56	48	42	42
	Fe 415	55	46	40	35	35
	Fe 240	65	60	55	50	50
Bonding Zone-II Un-favourable	Fe 500	1.4 times the values given for bonding zone-II				
	Fe 415					
	Fe 240					

## Detailing of Reinforcement

1. Layout of steel bars
2. Anchorages
3. Splices ( location and stagger )
4. Curtailment
5. Concrete Cover
6. Bar sizes
7. Lap lengths
8. Free spaces around bars



## Requirements of good detailing

1. Simple to fabricate and place
2. Control cracks (width as well as length)
3. Joints as strong as members
4. Along stress trajectories (deviation < 20°)
5. Bar sizes as few as possible
6. Spacing module (bars, stirrups, and ties)

**Table 9 Proportions for Nominal Mix Concrete**

(Clause 9.3 and 9.3.1 of IS:456)

Grade of Concrete	Total Quantity of Dry Aggregates by Mass per 50kg of Cement, to be taken as the sum of the Individual Masses of Fine and Coarse Aggregates, kg, Max	Proportion of Fine Aggregate to Coarse Aggregate (by Mass)	Quantity of Water per 50kg of Cement, Max
(1)	(2)	(3)	(4)
M5	800	Generally 1:2 but subjected to an upper limit of 1:1½ and a lower limit of 1:2½	60
M7.5	625		45
M10	480		34
M15	330		32
M20	250		30

**Some Controlled Concrete Mixes used in R&B works**

Concrete Grade	Proportion by Weight			W:C ratio	Cement Kg/cum
	Cement	Sand	Metal		
M 15	1	2.71	5.27	0.7	240
M 20	1	1.73	3.25	0.52	360
M 20	1	2.51	3.76	0.6	297
M 25	1	2.13	3.19	0.52	342
M 25	1	1.54	2.9	0.45	400
M 30	1	1.84	2.76	0.46	387
M 30	1	1.24	2.32	0.42	470
M 40	1	1.067	3.332	0.38	421
M 40	1	0.94	3.09	0.36	450

**Controlled Concrete Mixes of some NHA works**

Concrete Grade	Proportion by Weight			W:C ratio	Cement Kg/cum
	Cement	Sand	Metal		
M 15	1	2.09	4.5	0.5	300
M 20	1	2.19	3.61	0.45	370
M 20	1	1.87	3.97	0.45	340
M 25	1	1.35	3.23	0.40	342
M 25	1	1.41	3.24	0.45	410
M 35	1	1.25	2.99	0.40	430

**Material quantities per cum as per MORT&H  
standard data 2003**

Type & grade of concrete	Coarse aggregates			sand	cement
	40mm	20mm	12.5mm		
PCC M15	0.54	0.27	0.09	0.45	275
PCC M20	0.36	0.36	0.18	0.45	344
RCC M20		0.54	0.36	0.45	347
PCC M25	0.36	0.36	0.18	0.45	399
RCC M25		0.54	0.36	0.45	403
PCC M30	0.36	0.36	0.18	0.45	405
RCC M30		0.54	0.36	0.45	401
RCC M35		0.54	0.36	0.45	422

**CONCRETE MIX DESIGN with  
GGBS**

PARTICULARS	Grade M15
OPC 53 Grade	150 Kgs/M <sup>3</sup>
Ground Granulated Blast furnace Slag	150 Kgs/M <sup>3</sup>
Sand	360 Kgs/M <sup>3</sup>
Crusher Dust	360 Kgs/M <sup>3</sup>
Aggregates 10 mm	500 Kgs/M <sup>3</sup>
20 mm	650 Kgs/M <sup>3</sup>
Water/Binder Ratio	0.62
Slump	80 mm
Compressive Strength (N/mm <sup>2</sup> ) 28 Days	41.50

**Concrete Mix Design with GGBS**

PARTICULARS	Grade M 50	Grade M 50
OPC 53 Grade	250 Kgs/M <sup>3</sup>	350 Kgs/M <sup>3</sup>
Duncan GGBS	250 Kgs/M <sup>3</sup>	150 Kgs/M <sup>3</sup>
Sand	757 Kgs/M <sup>3</sup>	757 Kgs/M <sup>3</sup>
Aggregates 10 mm	421 Kgs/M <sup>3</sup>	421 Kgs/M <sup>3</sup>
20 mm	505 Kgs/M <sup>3</sup>	505 Kgs/M <sup>3</sup>
Water/Binder Ratio	0.33	0.33
Slump	80 mm	95 mm
Compressive Strength (N/mm <sup>2</sup> )		
7 Days	38.90	47.30
21 Days	51.90	59.0
28 Days	58.40	60.0

**Nominal Cover to Meet Durability Requirements as per IS:456-2000**

Exposure	Nominal Concrete Cover in mm not less than
Mild	20
Moderate	30
Severe	45
Very severe	50
Extreme	75



Notes: 1. For main reinforcement up to 12mm diameter bar for mild exposure the nominal cover may be reduced by 5mm. 2. Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by +10mm/0mm. 3. For exposure condition 'severe' and 'very severe', reduction of 5mm may be made, where concrete grade is M35 and above.

## Workability of Concrete

Placing conditions	Degree of workability	Slump (mm)
Blinding concrete, Shallow sections; Pavements using pavers	Very low	Compaction Factor: 0.75 to 0.80
Mass concrete; Lightly rein-forced sections in slabs, beams, walls, columns, Floors, Hand placed pavements; Canal lining; Strip footings	Low	25 to 75
Heavily reinforced sections in slabs, beams, walls, columns; Slip form work; Pumped concrete	Medium	50 to 100; 75 to 100
Trench fill; In-situ piling	High	100 to 150
Tremie concrete	Very high	Flow method

## FORMWORK FOR CONCRETE WORKS

❖ **Workmanship:** The formwork shall be robust and strong and joints are leak proof. Close watch shall be maintained to check for settlement of formwork during concreting. Any settlement of formwork during concreting shall be promptly rectified.

❖ **Reuse of formwork:** When formwork is dismantled and before reuse all components shall be cleaned of deposits of soil, concrete or other unwanted materials. All bent steel props shall be straightened before reuse and the maximum deviation from straightness is  $1/600$  of the length.

## Requirement of Formwork

1. To get required shape, size, finish, position and alignment of concrete members
2. To have load carrying capacity without distortion
3. To have design for quick erection and removal
4. To handle easily using available equipment and manpower
5. Joints between formwork must be tight enough to prevent leakage
6. To provide easy and safe access for concrete handling and placing
7. To avoid damage to concrete or formwork itself while stripping

## Stripping Time (11.3 of IS:456)

Type of Formwork	Minimum Period Before Striking Formwork
(a) Vertical formwork to columns, wells, beams	16 – 24 hrs
(b) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days
(c) Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days
(d) Props to slabs: 1) Spanning up to 4.5m 2) Spanning over 4.5m	7 days 14 days
(e) Props to beams and arches: 1) Spanning up to 6m 2) Spanning over 6m	14 days 21 days



## **Curing**

The chemical action between cement and water which results in the setting or hardening of concrete or mortar. Although there is normally adequate quantity of water for full hydration when the mortar or concrete mix is prepared, it is important to ensure that the water is either retained or replenished to enable the chemical reaction to be continued till such time the required strength is gained. In order to help the hydration process to continue, water in the capillaries should be prevented from evaporating.

Curing plays a very significant role in concrete and mortar performance and needs full attention of the persons involved in the construction. Since cement hydration is very rapid in the first few days, it is very important for enough water to be retained in the concrete or mortar

## **Curing methods**

1. By maintaining the presence of mixing water during the early hardening period. Methods generally deployed are Ponding or Immersion, Spraying, Sprinkling, fogging, wet covering using Hessian cloth or gunny bags etc.,
2. By preventing loss of mixing water by sealing the exposed surface of concrete. The exposed surfaces are generally covered by curing compound, impervious paper, plastic sheets or by leaving formwork in place.

## **Compaction of Concrete**

Compaction is necessary to remove entrapped air present in concrete after it is mixed, transported and placed. Compaction also eliminates stone pockets and remove all types of voids that may possibly left in the concrete, causing reduction in strength and durability.

### **Compaction by Vibration**

On vibration, concrete mix gets fluidized resulting in entrapped air raising to the surface and concrete denser

Internal Vibrators (Pin Vibrators) and External Vibrators (Form Vibrators, Vibration tables and Surface Vibrators) are available

### **Guidelines for compaction with Pin Vibrator**

- 1) Insert poker quickly and allow it to penetrate by its own weight to the bottom of layer so that the entrapped air is removed uniformly.
- 2) Leave the poker in concrete for 10 seconds. Compaction time depends on slump.
- 3) Poker must be inserted quickly, but withdrawal must be slow so that the hole left by the poker is filled up as it is being withdrawn.
- 4) Locations of poker insertion should be staggered.
- 5) Avoid touching the form work and reinforcement with poker.
- 6) Poker should extend upto 100mm into the previous layer.
- 7) It is safer to over vibrate than under vibrate.

## Sampling and Acceptance Criteria

Test result of a sample = average strength of 3 specimens  
Individual variation = not more than  $\pm 15\%$  of average

Sampling frequency		Acceptance criteria as per Table 11 of IS-456		
Quantity of concrete in cum	No. of samples	Grade	Mean of 4 non-overlapping consecutive test results in $\text{N/mm}^2$	Individual test results $\text{N/mm}^2$
1-5	1	M 15	$\geq f_{ck} + 0.825 \text{ SD}$ or $f_{ck} + 3 \text{ N/mm}^2$	$\geq f_{ck} - 3 \text{ N/mm}^2$
6-15	2			
16-30	3			
31-50	4	M 20 or above	$\geq f_{ck} + 0.825 \text{ SD}$ or $f_{ck} + 4 \text{ N/mm}^2$	$\geq f_{ck} - 4 \text{ N/mm}^2$
51 and above	4 + 1 per Additional $50\text{m}^3$			

Acceptance criteria as per IRC:21-2000 for bridges.

When both the following conditions are met, the concrete complies with the specified compressive strength

Mean strength determined from any group of 4 consecutive test results should exceed  $f_{ck}$  by  $3 \text{ N/mm}^2$

Strength of any individual test sample is not less than  $f_{ck} - 3 \text{ N/mm}^2$

Note: Sampling frequency is the same as per IS:456-2000

## Brick Work as per APPS 501

Bricks must have correct size, shape and sharp square edges. Bricks shall not break when dropped from 1m height, shall give ringing sound when struck with each other and leave no impression with finger nails.

1) Mortar joint thickness shall not exceed 10mm in 1st class bricks and 12mm in 2nd class bricks.

2) Crushing strength (shall not be less than 35  $\text{Kg/Sq.cm}$  for ordinary bricks) and water absorption (shall be less than 20%)

3) Bricks shall be soaked at least for 1 hour before use.

4) Brick work should be raised uniformly and height of work in a day shall be less than 1.5m. Difference in height between two different portions shall be less than 1m.

5) When the mortar is green, the face joints should be raked to a depth of 12 to 19 mm.

## Stone Masonry as per APSS 601

- 1) Bond: A stone in any course shall overlap the stone in the course below, i.e. Joints parallel to the pressure in two adjoining courses shall not lie too closely in the same vertical line.
- 2) Bond stones shall be built in the walls at intervals of 2m in length and 0.6m in height and shall run through the wall if the wall is not more than 600 mm in thickness. If the wall is more than 600 mm thick a line of headers shall be laid from face to back, each header overlapping the other by at least 150 mm. The bond stones shall be clearly marked on both the faces.

## A TECHNICAL PRESENTATION

D.V.Bhavanna Rao. M.Tech., F.I.E.,  
C.E. AP R&B Retired  
PM, TPQA, NCRMP  
for



Please visit  
<http://apncrmtpqa.wordpress.com>

## Quality Assurance in Reinforcement Steel

All the reinforcement shall be clean and free from rust, mild scales, dust, paint, oil, grease, adhering earth or any other material or coating that may impair the bond between the concrete and the reinforcement, or cause corrosion of the reinforcement or disintegration of concrete.

## Steel Reinforcement

The reinforcement shall be of mild steel and high yield strength deformed bars, hard drawn steel bars, deformed bars, cold twisted steel bars, hard drawn steel wire fabric or structural steel sections conforming to the respective Indian Standard specifications.

### Bridge Reinforcement requirements as per IRC:21-2000

Reinforcement shall consist of the following grades specified by their characteristic strength as the minimum value of 0.2% or yield stress

Grade designation	Bar type conforming to IS Specification	Characteristic strength $f_y$ MPa	Elastic modulus MPa
Fe 240	IS:432 part 1 Mild steel	240	200
Fe 415	IS:1786-2008 Deformed	415	200
Fe 500	IS:1786-2008 Deformed	500	200



Steel reinforcement is routinely used in reinforced concrete (RC) structures to augment the relatively low inherent tensile strength of concrete.

It is also used:

1. to carry shear, compressive and torsional forces in excess of concrete's capability without reinforcement.
2. to control cracking of concrete members under working loads or as a result of early thermal effects.
3. to minimise or prevent spalling of concrete in fire conditions, as a result of seismic effects, or in the highly stressed regions around anchorages in prestressed concrete construction.

Reinforcement, plays a vital role in ensuring the safety, integrity and durability of almost all concrete structures.

1. Reinforcement steel shall possess the required physical and metallurgical properties
2. It shall be of acceptable quality
3. It is stored, handled, cut and bent so as to avoid corrosion, damage and contamination
4. It is properly and accurately fixed.

## **Standard Code for steel reinforcement**

**Indian Standard IS 1786:2008**

**High Strength Deformed Steel Bars  
and Wires for**

**Reinforcement – specification**

**(Fourth Revision)**

### **Application of IS:1786-2008**

1. Deformed bars produced by re-rolling finished products such as plates and rails (virgin or used or scrap), or by rolling material for which the metallurgical history is not fully documented or not known, are not acceptable as per this standard.
2. It applies to reinforcing bars and wires which may be subsequently coated.
3. It applies to reinforcing bars and wires supplied in coil form but its requirements apply to the straightened product.
4. It applies to hot rolled steel with or without subsequent treatment.

## Chemical Requirements

Maximum Limits as per IS1786-2008

Constituent	Percent, Maximum						
	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 550	Fe 550D	Fe 600
Carbon	0.3	0.25	0.3	0.25	0.3	0.25	0.3
Sulphur	0.060	0.045	0.055	0.040	0.055	0.040	0.040
Phosphorus	0.060	0.045	0.055	0.040	0.050	0.040	0.040
Sulphur & Phosphorus	0.11	0.085	0.105	0.075	0.100	0.075	0.075

Note: The figures following Fe indicate the specified minimum 0.2% proof stress or yield stress in N/mm<sup>2</sup>

The letter D following the strength grade indicates the category with same specified minimum 0.2% proof stress/ yield stress but with enhanced specified minimum percentage elongation

## Important Terminology

Elongation	The increase in length of a tensile test piece under stress. The elongation at fracture is conventionally expressed as a percentage of the original gauge length of a standard test piece.
Nominal diameter/size	The diameter of a plain round bar/wire having the same mass per meter length as deformed bar/wire.
Nominal mass	The mass of bar/wire of nominal diameter and of a density 0.00785 kg/mm <sup>3</sup> per meter.
0.2% proof stress	The stress at which a non-proportional elongation equal to 0.2% of the original gauge length takes place.
Tensile strength/ Ultimate tensile stress	The maximum load reached in a tensile stress divided by cross-sectional area of the gauge length portion of the test piece.
Yield Stress	Stress at which elongation first occurs in the test piece without increasing the load during the tensile test. In the case of steels with no such definite yield point, proof stress shall be applicable.

## Nominal cross sectional Area and Mass as per IS:1786

Nominal size (mm)	Cross section Area mm <sup>2</sup>	Mass per Meter
4	12.6	0.099
5	19.6	0.154
6	28.3	0.222
8	50.3	0.395
10	78.6	0.617
12	113.1	0.888
16	201.2	1.58
20	314.3	2.47
25	491.1	3.85
28	615.8	4.83
32	804.6	6.31
36	1018.3	7.99
40	1257.2	9.86

## Tolerance on Nominal Mass as per IS:1786

Nominal size (mm)	% Tolerance on the nominal mass		
	Batch	Individual sample	Individual sample for coils only
Up to and including 10mm	±7%	- 8	±8
over 10 mm & upto 16mm	±5%	- 6	±6
Over 16 mm	±3%	- 4	±4

Note: For individual sample plus tolerance is not specified. For coils batch tolerance is not specified

#### Requirements of Bond (IS:2770 part 1)

For high strength deformed bars/ wires, the mean area of ribs (in mm<sup>2</sup>) per unit length (in mm) above the core of the bar/wire, projected in on a plane normal to the axis shall not be less than following values:

0.12 $\phi$	For $\phi \leq 10$ mm
0.15 $\phi$	For $\phi$ more than 10mm and $\leq 16$ mm
0.17 $\phi$	For $\phi > 16$ mm

The mean projected area of transverse rib alone shall be not less than one-third of the values given above.

When subjected to pullout testing in accordance with IS 2770 part1, the bond strength calculated from the load at measured slip of 0.025mm and 0.25mm for deformed bars/ wires shall exceed that of a plain round bar of the same size by 40% and 80 % respectively.

#### Rebend Test (IS:1786-2008)

The test piece shall be bent to an included angle of 135° using a mandrel diameter given below. The bent piece shall be aged by keeping in boiling water (100°C) for 30 minutes and then allowed to cool. The piece then shall be bent back to have an included angle of 157½°.

Nominal Size of specimen mm	Mandrel diameter for different grades			
	Fe 415	Fe 500	Fe 550	Fe 600
Up to and including 10mm	5 $\phi$	5 $\phi$	7 $\phi$	7 $\phi$
Over 10mm	7 $\phi$	7 $\phi$	8 $\phi$	8 $\phi$

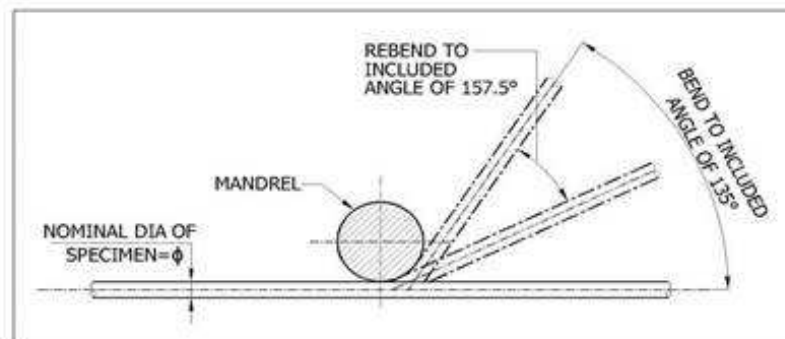
The specimen shall be considered to have passed the test if there is no rupture or cracks visible to a person of normal or corrected vision on the rebent portion

#### Bend Test (IS:1599-1985)

The bend test shall be performed in accordance with the requirements of IS 1599 and the mandrel diameter as given below.

Nominal Size mm	Mandrel diameter for different grades			
	Fe 415	Fe 500	Fe 550	Fe 600
Up to and including 20	3 $\phi$	4 $\phi$	5 $\phi$	5 $\phi$
Over 20	4 $\phi$	5 $\phi$	6 $\phi$	6 $\phi$

The test piece, when cold, shall be doubled over the mandrel by continuous pressure until the sides are parallel. The specimen shall be considered to have passed the test if there is no rupture or cracks visible to a person of normal or corrected vision on the re-bent portion.



Ø represents the nominal size of the test piece

Rebend Test



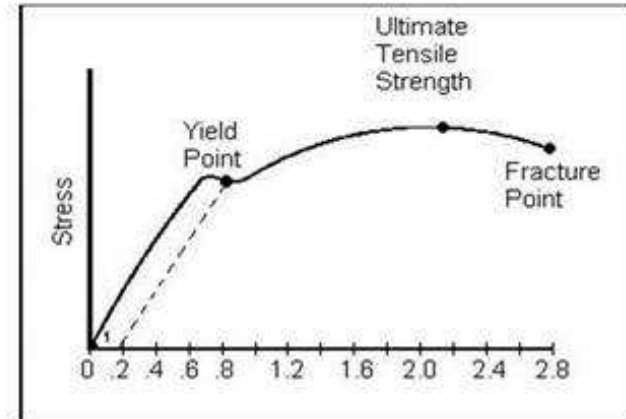
### How do you do a tensile test?

The ductility of a sample is determined by conducting a tensile strength test on a Universal Testing Machine. Samples of the material are placed in a Universal Testing Machine, gripped by the ends, and a vertical force is applied until they break; they are pulled apart. During the stretching process, the machine measures the load ( $p$ ), or the force applied to the sample, and the displacement of the sample ( $s$ ); along with the original cross sectional area of the sample ( $A_0$ ) and the original length ( $L_0$ ), an engineering stress-strain curve can be created. Stress ( $\delta$ ), computed by dividing the load by the cross sectional area, is plotted against strain ( $\epsilon$ ), derived by dividing the displacement ( $s$ ) by the length:

$$\delta = p/A_0, \epsilon = s/L_0$$

When the graph is analyzed, it is found that the strain hardening of the material increases up to a certain maximum point, after which the strain begins to deform the material, softening it until it breaks. Graphically, it is the highest point on the engineering stress-strain curve. The maximum point is known as the Ultimate Tensile Strength, or UTS, and is used in measuring the ductility of metals.

### Stress Strain curve for Structural Steel



### Tensile Test Values:

#### Young's Modules:

This is the slope of the linear portion of the stress-strain curve, it is usually specific to each material; a constant, known value.

#### Yield Strength:

This is the value of stress at the yield point, which is calculated by plotting young's modules at a specified per cent of offset (usually offset = 0.2%).

#### Ultimate Tensile Strength:

This is the highest value of stress on the stress-strain curve.

#### Percent Elongation:

This is the change in gauge length divided by the original gauge length.

### Elastic Limit

The elastic limit is the limit beyond which the material will no longer go back to its original shape when the load is removed, or it is the maximum stress that may be developed such that there is no permanent or residual deformation when the load is entirely removed.

### Elastic and Plastic Ranges

The region in stress-strain diagram from O to P is called the elastic range. The region from P to R is called the plastic range.

### Yield Point

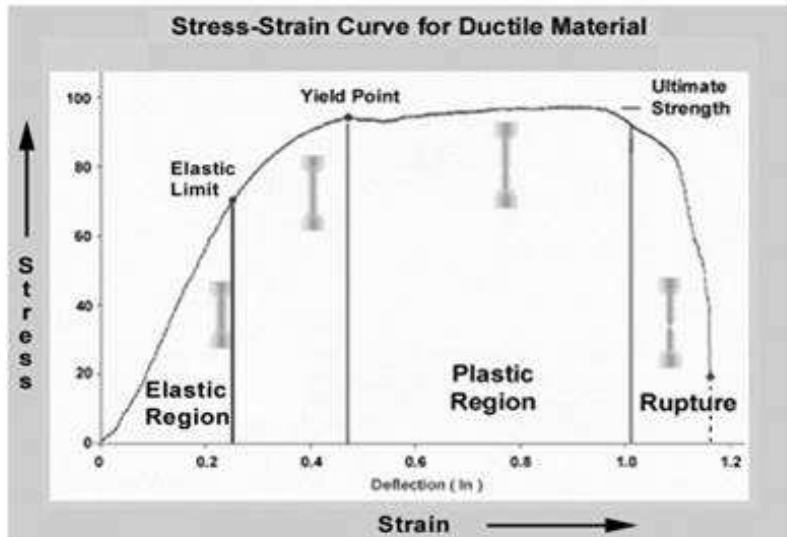
Yield point is the point at which the material will have an appreciable elongation or yielding without any increase in load.

### Ultimate Strength

The maximum ordinate in the stress-strain diagram is the ultimate strength or tensile strength.

### Rupture Strength

Rupture strength is the strength of the material at rupture. This is also known as the breaking strength.



**Mechanical properties of HYSD bars and wires  
as per IS 1608 read in conjunction with IS 2062**

Property	Grade of Steel			
	Fe 415	Fe 500	Fe 550	Fe 600
0.2% proof stress/yield stress, minimum in MPa	415	500	550	600
Elongation, % minimum on a gauge length of 5.65 $\sqrt{A}$ , where A is cross section area of test piece	14.5	12	10	10
Tensile strength, minimum, MPa	10% more than actual 0.2% p.s. and not less than 485 MPa	8% more than actual 0.2% p.s. and not less than 545 MPa	6% more than actual 0.2% p.s. and not less than 585 MPa	6% more than actual 0.2% p.s. and not less than 660 MPa

**Mechanical properties of HYSD bars and wires with enhanced elongation as per IS 1608 read in conjunction with IS 2062**

Property	Grade of Steel		
	Fe 415D	Fe 500D	Fe 550D
0.2% proof stress/yield stress, minimum in MPa	415	500	550
Elongation, % minimum on a gauge length of 5.65 $\sqrt{A}$ , where A is cross section area of test piece	18.0	16.0	14.5
Tensile strength, minimum, MPa	12% more than actual 0.2% p.s. and not less than 500 MPa	10% more than actual 0.2% p.s. and not less than 565 MPa	8% more than actual 0.2% p.s. and not less than 600 MPa

### Frequency of Testing

Nominal size	For Casts/ heats below 100 tonnes	For casts/ Heats of 100 tonnes or more
For all sizes	2	3

For checking nominal mass, mechanical properties, bend test and rebend test, test specimen of sufficient length shall be cut from each size of the finished bar/ wire at random at a frequency not less than the specified above.

## **Re-test**

Should any one of the test pieces first selected fail to pass any of the tests specified in the standard, two further samples shall be selected for testing in respect of each failure. Should the test pieces from both these additional samples pass, the material represented by the test sample shall be deemed to comply with the requirements of that particular test. Should the test piece of either of these additional samples fail, the material represented by the samples shall be considered as not having complied with this standard, IS 1786-2008

## **Manufacturer's Certificate**

- 1) Place of Manufacture of the reinforcing steel**
- 2) Nominal diameter of the steel**
- 3) Grade of the steel**
- 4) Rolled-in marking of the steel**
- 5) Cast/ heat number**
- 6) Date of testing**
- 7) Mass of the testing lot**
- 8) Individual test results for all the properties**

## **Quality Control Checklist for Steel Manufacturer**

- 1) Tolerances on diameter and sections**
- 2) Geometrical dimensions of the section with minimum values or guaranteed tolerance limits (height, longitudinal spacing and length of ribs)**
- 3) Guaranteed yield point**
- 4) Tensile strength**
- 5) Elongation at fracture**
- 6) Bending, rebending capacity**

Checklist for initial scrutiny of drawings and schedules.

- Can the reinforcement as detailed be fixed?
- Does the detailing permit sensible location of construction joints?
- Is the reinforcement congested?
- Would alternative detailing provide greater flexibility or ease of fixing?
- Is there scope for prefabrication?
- What is the best sequence?
- Is the reinforcement detailed to provide sufficient rigidity and stability of cages during fixing?
- Are set-up bars, bracing bars, chairs, spacers etc. required?
- Do schedule agree with drawings?
- Does reinforcement in one member clash with that in an adjacent member?
- Are scheduled bending dimensions compatible with member dimensions and specified concrete cover?
- Are starter bars detailed?



### **Delivery checklist**

1. Ensure adequate offloading space
2. Check weights given on delivery ticket (by calculation and bar count)
3. Ensure correct handling during unloading
4. Check reinforcement is of correct type
5. Check bundles are correctly labelled
6. Check reinforcement is of correct grade
7. Check bar size (for example, by gauge or tape)
8. Check extent of scale and pitting.

### **Storage checklist**

- 1) Ensure storage area is spacious and well organised
- 2) Ensure reinforcement is stored clear of the ground
- 3) Keep reinforcement free of mud, oil, grease
- 4) Provide a loose protective cover over the reinforcement
- 5) Ensure good air circulation around the steel
- 6) Store materials according to construction program
- 7) Avoid long term storage of reinforcement on site.

### **Bending checklist**

- 1) Use a steel tape when marking bars for bending
- 2) A site bending yard must be properly planned and set up
- 3) Reinforcement should be bent cold on a proper powered bending machine
- 4) Do not permit high yield steel to be heated on site before bending
- 5) Check the bent shape for dimensional accuracy (for example, against a full size template), bend radii and for signs of fracture.

### **Pre-concreting checklist**

1. Ensure correct number of bars have been fixed check that all laps are of the correct length
2. Ensure correct use of cover blocks, spacers etc. check cover to reinforcement is correct at all locations
3. Ensure that all twisted ends of ties are bent inwards away from concrete faces
4. Ensure adequate access for concrete compaction

### **Site actions necessary to avoid wasteful costs**

- 1) Ordering in good time in economic loads
- 2) Minimising damage by careful handling and storage
- 3) Minimising wastage by intelligent cutting and accurate bending
- 4) Minimising loss by providing secure storage
- 5) Accuracy in cutting and bending
- 6) Slings of reinforcement must be done carefully,
- 7) Prefabrication, either on or off site
- 8) Storing reinforcement in reverse sequence to use to avoid double handling
- 9) Avoidance of site welding reduces costs.

### **Field test for Checking TMT bars**

1. Concrete and Rebars are the two vital components in any reinforced concrete construction.
2. Safety and durability of such constructions is directly dependent on the quality of Concrete and / or Rebars.
3. The main problem in India today, is defective, substandard and fake rebars in the market.

The two major types of rebars in Indian Market are:

- ❖ Thermo-processed (TMT) rebars; and
- ❖ Cold Twisted Deformed (CTD) rebars

### **Identification and Marking**

The manufacturer or supplier shall have ingots, billets and bars or bundles of bars/wires marked in such a way that all finished bars/ wires can be traced to the cast from which they were made. Every facility shall be given to the purchaser or his authorised representative for tracing the bars/ wires to the cast from which they were made.

For each bundle/ coil of bars/wires a tag shall be attached indicating the cast/lot number, grade and size.

All bars/wires should be identified by marks/brands introduced during rolling which indicate the name of manufacturer or their brand name.

Each bundle containing the bars/wires may also be suitably marked with the Standard Mark in which case the concerned test certificate shall also bear the Standard Mark.

1. Thermo-processing technique is essentially 'Controlled water quenching of rebars' by passing Rebars through 'specially designed quenching tubes'.
2. The quenching is controlled by appropriate adjustments in temperature, pressure and volume of water in the tube.
3. The strength of Rebars after quenching, increases to about 450 N/sq.mm.



**CTD Bar before and after twisting**



**TMT Bar before and after processing**

1. In CTD rebars, bars are twisted to predetermined pitch, when the strength level gets enhanced to about 450 N/sq.mm.
2. In case of CTD bars, it is fairly easy to visually identify twisted rebars from untwisted or inappropriately twisted rebars.
3. Whereas, in case of TMT rebars, it is difficult to identify 'Controlled water quenched rebar' from a 'non-quenched rebar' or 'inappropriately quenched rebar'.

### **Fake and substandard (TMT) rebars**

1. While producing TMT rebars, if the prescribed methods of production are not appropriately adopted, whatever the reasons may be, it results in fake or substandard TMT rebars.
2. It is generally not possible to make out the fake and the substandard rebars by mere physical observations.
3. Standard, Fake and Substandard rebars look alike, misleading the users.



**Fake & Substandard (TMT) rebars can be classified into 3 specific categories:**

1. TMT rebars (?) with no quenching at all (Fake rebars),
2. TMT rebars with abrupt quenching in water tanks (Fake rebars); and
3. TMT rebars with inadequate / improper quenching in quenching tubes (Substandard rebars)./

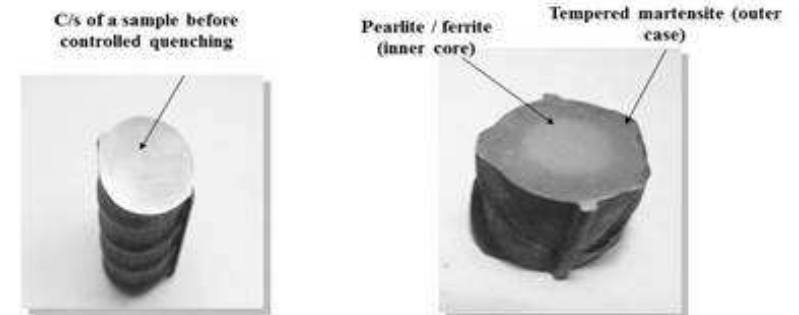
1. There has been a continuous search for a simple 'Cursory Field Test' to identify easily these fake or substandard TMT rebars in worksites.
2. Although well-defined laboratory tests are available, they are involved and time consuming.
3. Whereas in case of CTD rebars, physical observation of rebars is good enough to identify substandard rebars.

### **The cursory test – outline of test**

Whenever a rebar under a high temp is quenched under controlled conditions and cooled in air subsequently, due to metallurgical transformation, two distinct phases (shades) show out.

Tempered martensite in the form of a ring with definite width forms the outer case (ring), whereas the inner core remains pearlite / ferrite.

The outer case (ring) and inner core are distinctly visible, when the cross-section of rebar is etched.



**Rebar before and after Thermo-Processing**

### **The Cursory Field Test - test procedure**

Following are the steps for carrying out the test;

1. Cut 'small length samples' from a few randomly selected TMT rebars of any lot, preferably in a cutting machine, if not, by hack-saw cutting.
2. Cross-sections of test samples shall be mirror finished with any suitable polishing device.

An ideal polishing device is a unit with rpm of about 3000, wherein an emery sheet can be mounted on the rotating circular disc.

Polishing of cross-sections shall be done for atleast about 10 minutes.

Contd/....

The cursory field test - Test procedure (Contd/.....)

3. The c/s shall be smeared (etched) with drops of 'Nitrol Solution'.

It is nothing but a synthesis of '10 % of Conc. Nitric Acid' and '90 % of Ethyl Alcohol'.

Soon after etching, two distinct phases (Shades) with uniform thickness are clearly visible on the c/s, if the rebars are 'Genuine TMT Rebars'.

If the two phases are not distinct, the rebars are either 'Substandard' or 'Fake' TMT rebars.

**Note:** It is essential that the c/s be examined soon after etching. In case of delay, etching to be redone.



**Appearance of Genuine Thermo-processed (TMT) rebars after etching with Nitrol**



**Appearance of Fake Thermo-processed (TMT) rebars after etching with Nitrol**



**Appearance of (inadequately / inappropriately quenched) Thermo-processed (TMT) rebars after etching with Nitrol**

#### **Chemical properties of Genuine Thermo-Processed (TMT) Rebars**

Diameter (mm)	% Carbon	0.2% Proof Stress (N/sq.mm)	Ultimate Tensile Strength (N/sq.mm)	Elongation over a gauge length of '5 dia' (%)
12	0.174	602	696	20
16	0.152	567	685	24
25	0.160	513	629	23

**Note: The test results satisfy the requirements of IS:1786-2008 for rebars.**

#### **Chemical Properties of Fake Thermo-Processed (TMT) Rebars**

Diameter (mm)	% Carbon	0.2% Proof Stress (N/sq.mm)	Ultimate Tensile Strength (N/sq.mm)	Elongation over a gauge length of '5 dia' (%)
12	0.204	353	552	32
16	0.186	314	520	35
20	0.198	390	556	29

**Note: The test results do not satisfy the requirements of rebars as per IS:1786-2008**

#### **Chemical properties of Thermo-Processed (TMT) Rebars**

Diameter (mm)	% Carbon	0.2% Proof Stress (N/sq.mm)	Ultimate Tensile Strength (N/sq.mm)	Elongation over a gauge length of '5 dia' (%)
12	0.230	388	630	30
16	0.221	375	538	29
20	0.233	359	539	25
25	0.204	363	516	30

**Note: The test results do not satisfy the requirements of rebars as per IS:1786-2008**





## DO'S AND DONT'S



IN DETAILING OF  
REINFORCED CONCRETE

WRONG DETAILING OF REINFORCING IS  
MAINLY ATTRIBUTED DUE TO .....

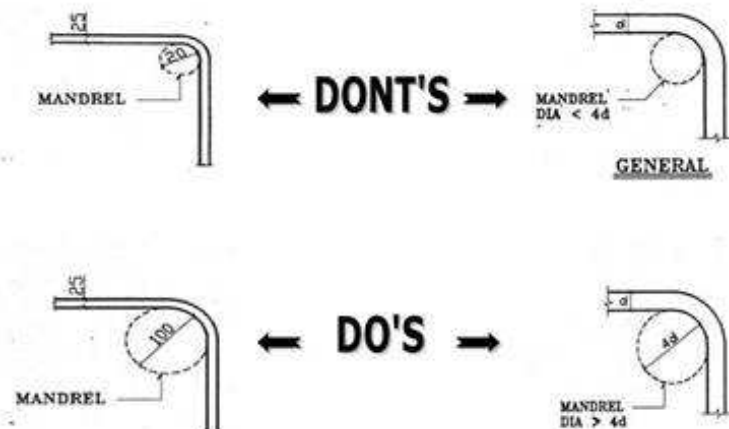
- ☞ Inadequate details in structural drawings.
- ☞ Improper translation of the details in drawings.
- ☞ Inadequate care exercised in study of drawings, prior to actual fabrication.

TO ACHIEVE EFFICIENT PERFORMANCE OF  
REINFORCING BARS,

IT IS ESSENTIAL TO .....

- ☞ Position the reinforcing bars appropriately.
- ☞ Provide proper anchorage and development length.
- ☞ Provide adequate concrete cover for protective of bars.

### CHOICE OF MANDREL FOR BAR BENDING





# DO'S AND DONT'S



**IN DETAILING OF  
REINFORCED CONCRETE**  
By Sri S.Jaswant Kumar,  
Chief Engineer R&B Retired

**WRONG DETAILING OF REINFORCING IS  
MAINLY ATTRIBUTED DUE TO .....**

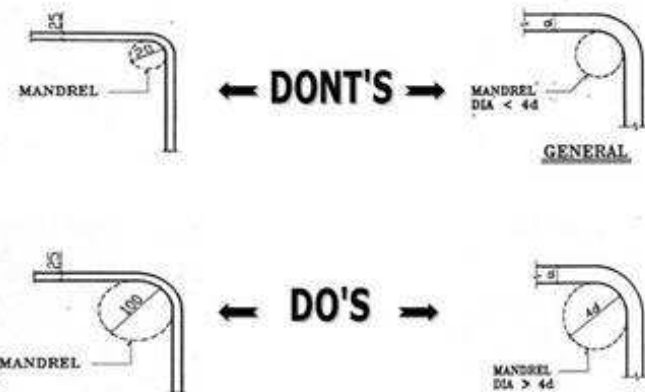
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**TO ACHIEVE EFFICIENT PERFORMANCE OF  
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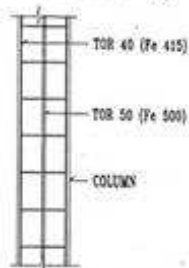
- ☞ Position the reinforcing bars appropriately.
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## CHOICE OF MANDREL FOR BAR BENDING

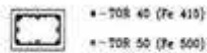


### MIX UP OF BARS

**DON'T** ↘

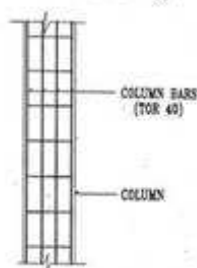


ELEVATION



PLAN

**DO** ↘



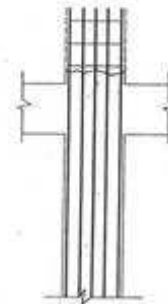
ELEVATION



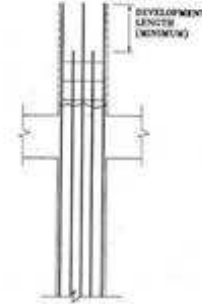
PLAN

### STAGGERING BARS FOR CONTINUITY IN COLUMNS

**DON'T** ↘



**DO** ↘



**NOTE:**

ALTERNATIVELY IF STAGGERING IS NOT DONE, SPACING OF TIES SHALL BE REDUCED TO HALF THE NORMAL SPACING IN THE LAPPING REGION.

### BAR LAPPING AT COLUMN - BEAM JUNCTION

**DON'T** ↘

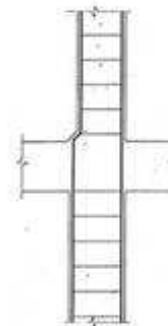


**DO** ↘

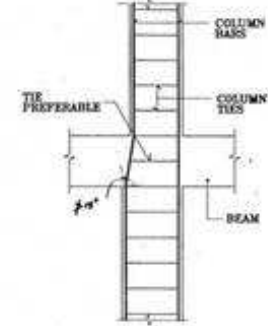


### ABRUPT KINKING OF BARS IN COLUMNS

**DON'T** ↘



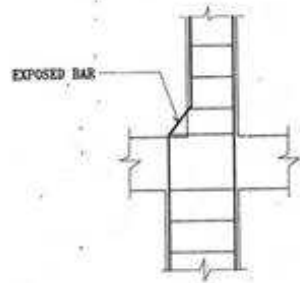
**DO** ↘



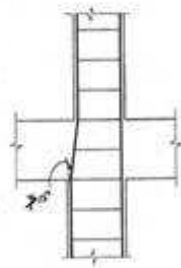


### ABRUPT KINKING OF BARS OUTSIDE THE COLUMNS

**DON'T** ↘

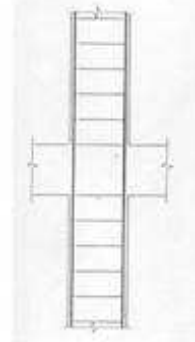


**DO** ↘

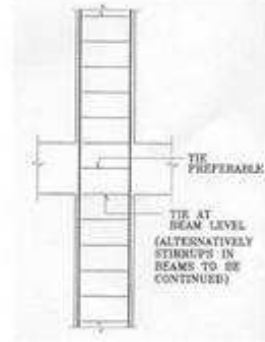


### DEFECTIVE PROVISION OF TIES IN COLUMN

**DON'T** ↘

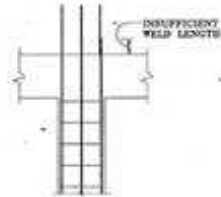
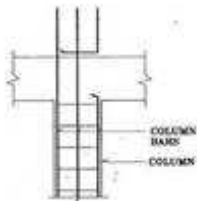


**DO** ↘

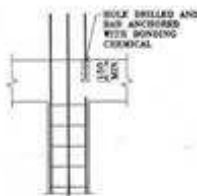


### DISCONTINUITY OF BARS IN COLUMNS

**DONT'S** →

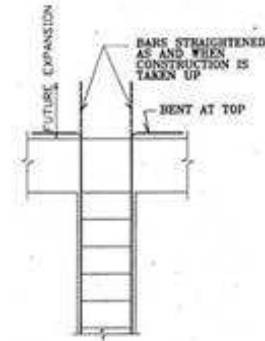


**DO'S** →

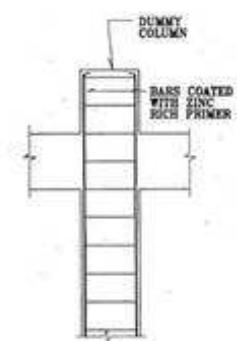


### LEAVING THE BARS FOR FUTURE EXPANSION

**DON'T** ↘



**DO** ↘

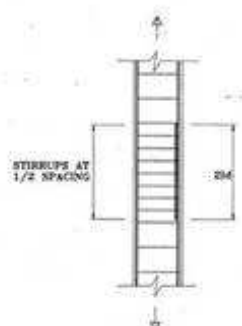


### LAPPING OF BARS IN TENSION MEMBERS

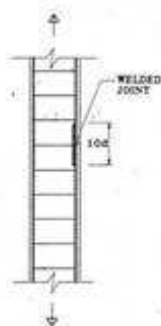
**DON'T** →



**DO** →

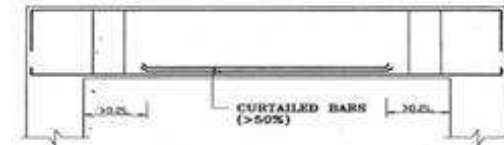


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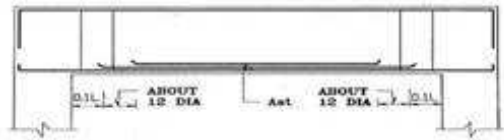


### CURTAILMENT OF BARS IN BEAMS

**DON'T** →

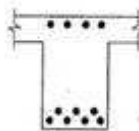
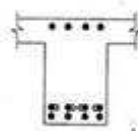
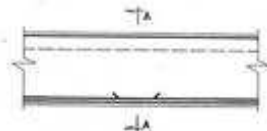


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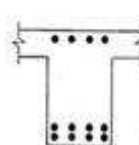
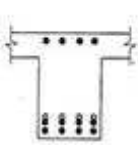
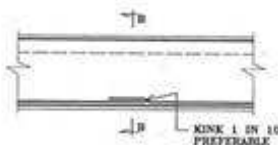


### LAPPING / PLACEMENT OF BARS IN BEAMS

**DONT'S** →



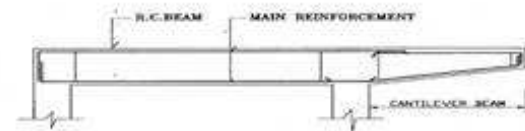
**DO'S** →



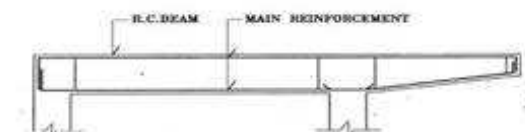
KINK 1 IN 10 PREFERABLE

### LAPPING OF BARS IN CANTILEVER BEAMS

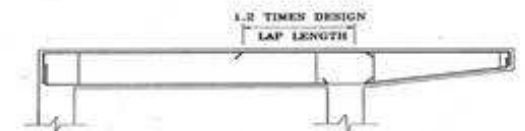
**DON'T** →



**DO** →

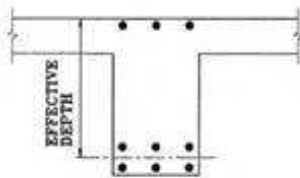


**DO** →

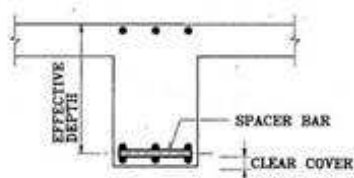


### DEFECTIVE POSITION OF BARS IN BEAMS

DON'T ↴

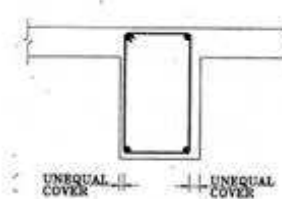


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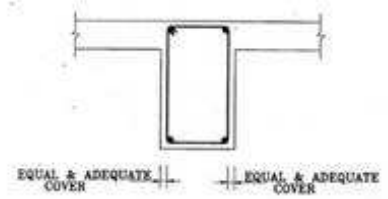


### UNEQUAL COVERS IN BEAMS

DON'T ↴



DO ↴



### PLACEMENT OF BARS AT SLAB SUPPORT

DON'T ↴



DO ↴



### BAR PLACEMENT IN CANTILEVERED SLAB

DON'T ↴

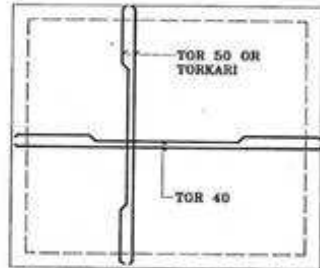


DO ↴

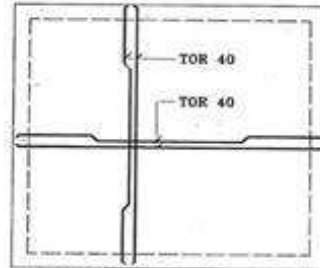


### MIXING UP OF BARS IN TWO-WAY SLABS

**DON'T ↴**

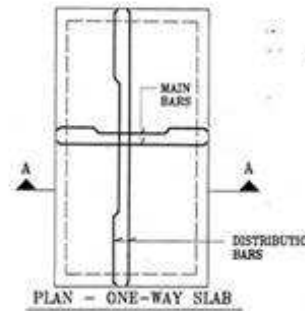


**DO ↴**

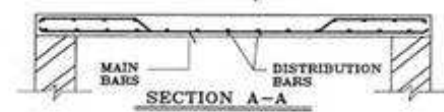


### ARRANGEMENT OF BARS IN ONE-WAY SLAB

**DON'T ↴**

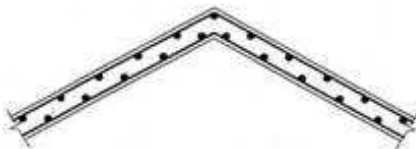


**DO ↴**

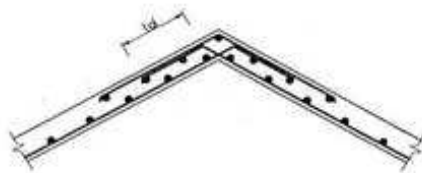


### REINFORCEMENT DETAILING IN GABLES

**← DON'T**

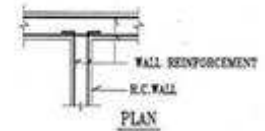
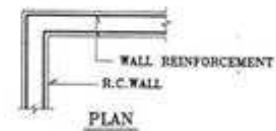


**DO →**

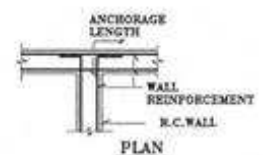
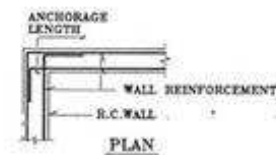


### REINFORCEMENT AT WALL INTERSECTIONS

**DONT'S ↴**

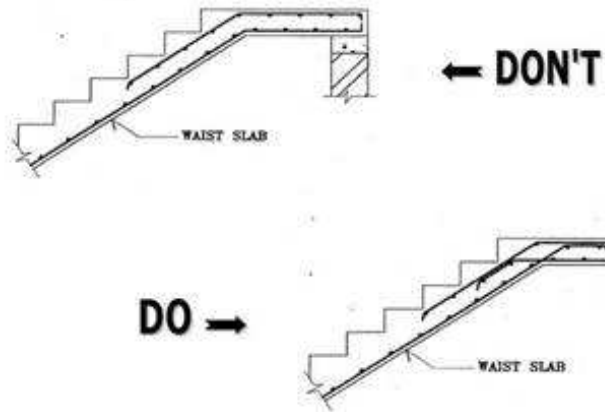


**DO'S ↴**

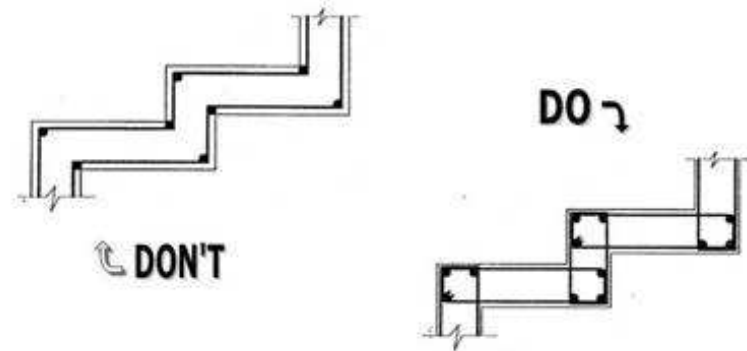




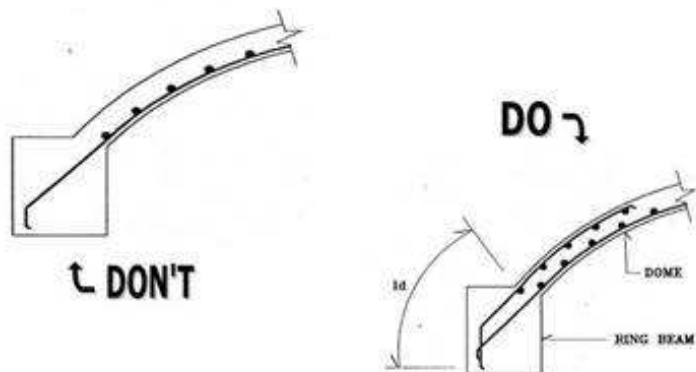
### PLACEMENT OF BARS IN WAIST SLAB



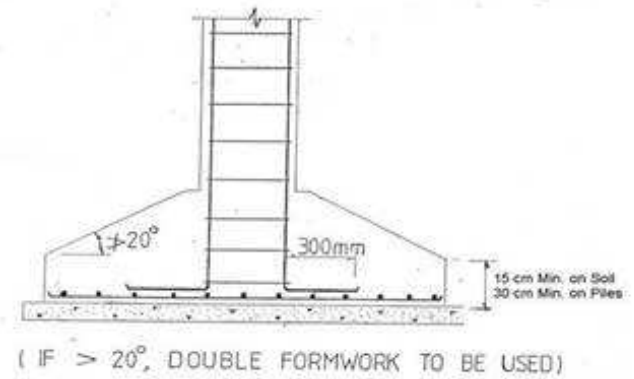
### REINFORCEMENT IN FOLDED STAIRCASE



### REINFORCEMENT DETAILING IN LARGE DOMES

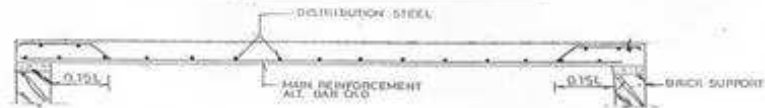


### DETAILING OF FOOTINGS



## ONE-WAY SLABS – PLACEMENT OF REINFORCEMENT

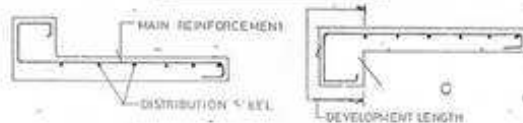
### SIMPLY SUPPORTED SLAB :



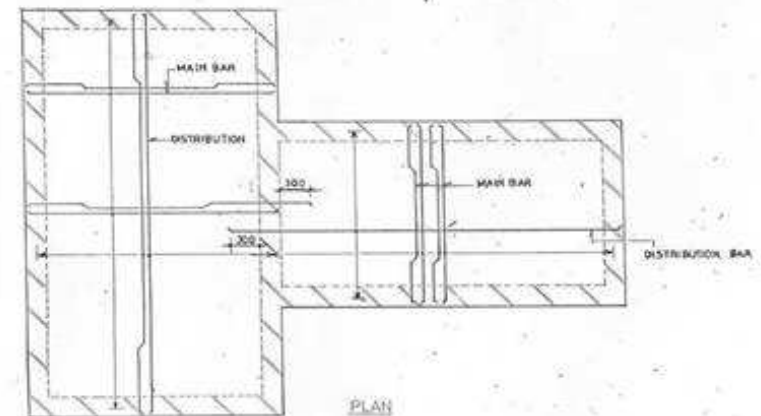
### CONTINUOUS SLAB :



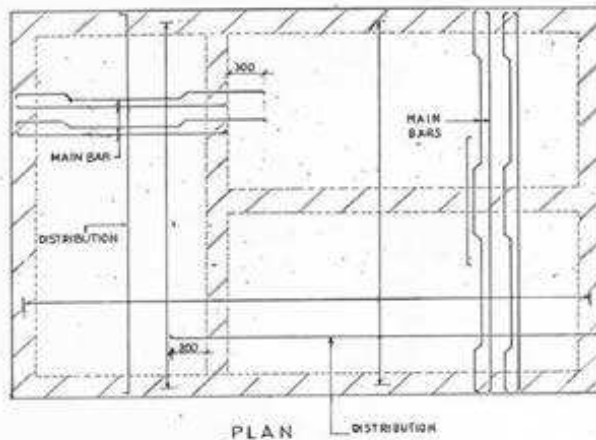
### CANTILEVER SLAB :



## DETAILING ASPECTS IN SLABS SPANNING IN DIFFERENT DIRECTIONS

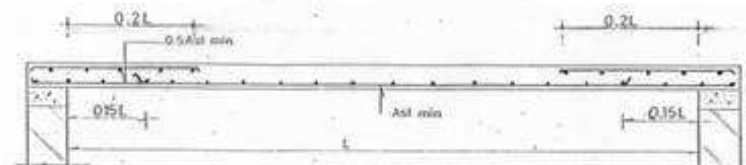


## DETAILING ASPECTS IN SLABS SPANNING IN DIFFERENT DIRECTIONS

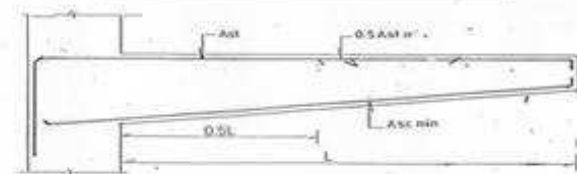


## CURTAILMENT OF BARS

### CURTAILMENT IN SLAB



### CURTAILMENT IN CANTILEVER BEAM

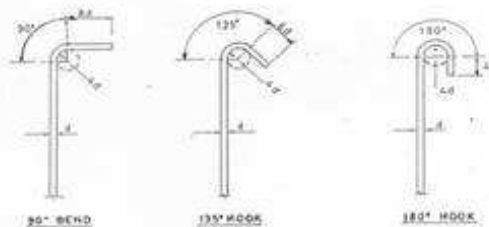


## BENDS, HOOKS AND LINKS

VARIOUS FORMS  
OF LINKS

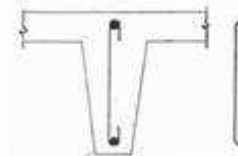


STANDARD BENDS  
AND HOOKS

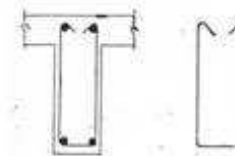


## BEAM STIRRUPS

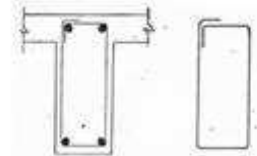
SINGLE LEG



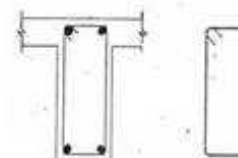
DOUBLE LEG  
OPEN TYPE



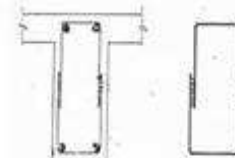
DOUBLE LEG  
PARTIALLY OPEN  
TYPE



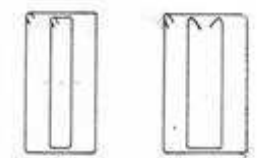
DOUBLE LEG  
CLOSED TYPE



DOUBLE LEG  
WELDED TYPE



MULTIPLE TYPE



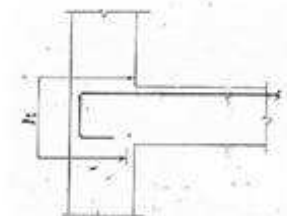
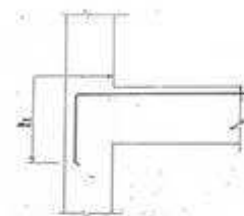
## ANCHORAGE FOR BEAM BARS

ANCHORAGE LENGTH			
	M 15	M 20	M 25
TENSION	50 x d	45 x d	40 x d
COMPRESSION	45 x d	40 x d	35 x d

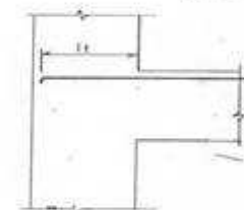
Contd.....

Contd.....

## ANCHORAGE FOR BEAM BARS

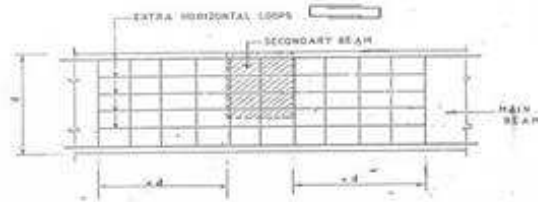


$l_t$  = ANCHORAGE LENGTH

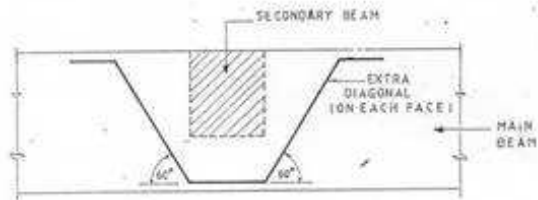


### REINFORCEMENT AT BEAM TO BEAM SUPPORT

HORIZONTAL  
LOOPS

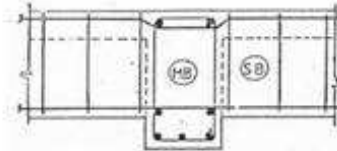


EXTRA DIAGONAL  
OPEN STIRRUPS

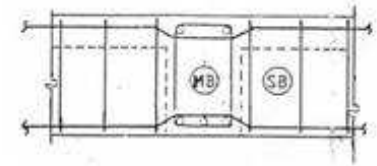


### TYPICAL DETAILS OF BEAM INTERSECTIONS

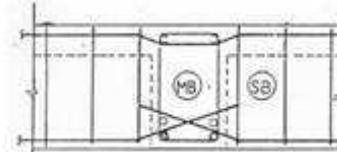
1. SECONDARY BEAM SHALLOWER  
THAN MAIN BEAM



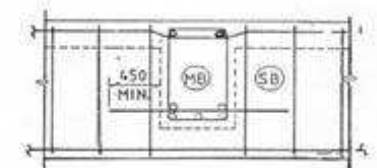
2. BOTH MAIN AND SECONDARY  
BEAMS OF SAME DEPTH



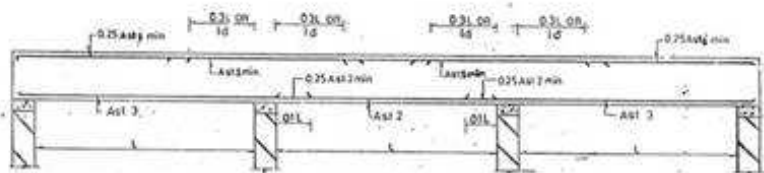
3. BOTH MAIN AND SECONDARY  
BEAMS OF SAME DEPTH



4. SECONDARY BEAM DEEPER  
THAN MAIN BEAM



### CURTAILMENT OF BARS



### CURTAILMENT IN CONTINUOUS BEAM

### DIFFERENT TYPES OF TIES

SINGLE TIE



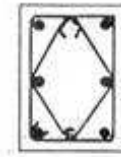
SINGLE TIE +  
SINGLE LINK



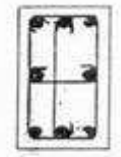
DOUBLE TIE



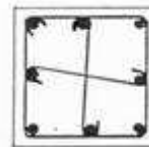
DIAMOND TIE +  
SINGLE LINK



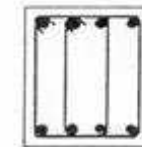
SINGLE TIE +  
DOUBLE LINKS



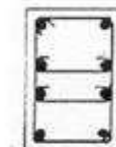
SINGLE TIE +  
DOUBLE LINKS



DOUBLE TIES



SINGLE TIE +  
DOUBLE LINKS



**NOTE:**

1. TIE DIA :

≥ 1/4 BAR DIA

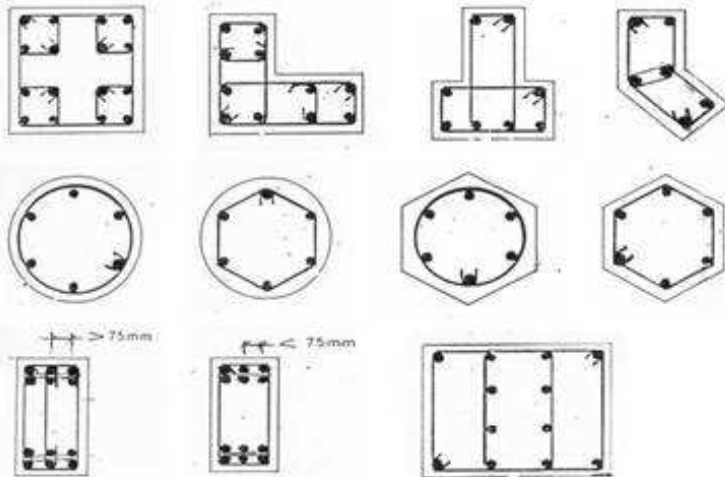
2. TIE SPACING :

≥ 16 x BAR DIA

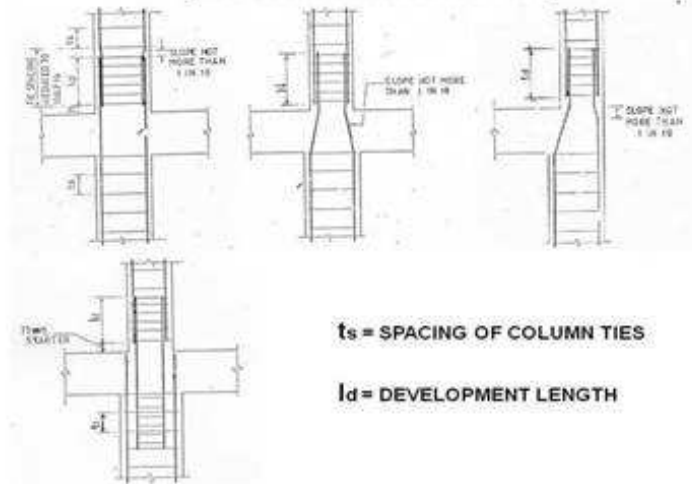
≥ 48 x TIE DIA



### DIFFERENT TYPES OF TIES

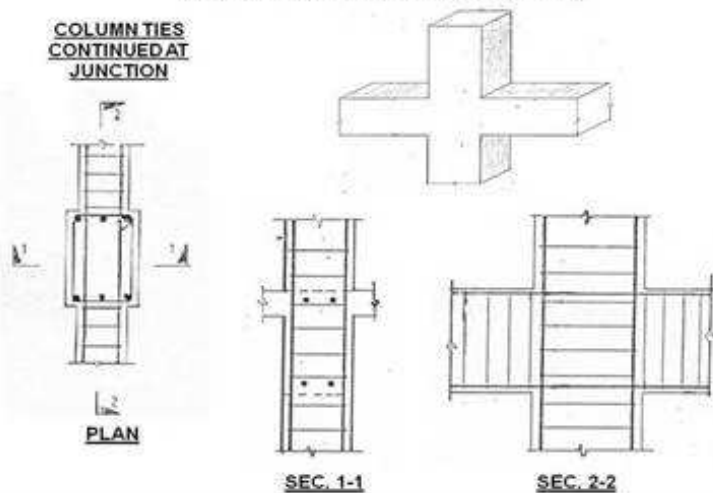


### COLUMN TRANSITIONS



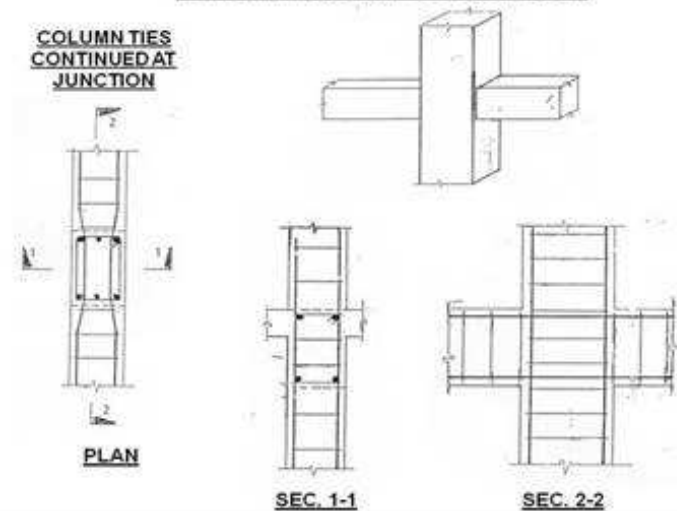
### DETAILING AT JUNCTION

COLUMN TIES  
CONTINUED AT  
JUNCTION



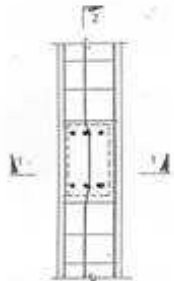
### DETAILING AT JUNCTION

COLUMN TIES  
CONTINUED AT  
JUNCTION



### DETAILING AT JUNCTION

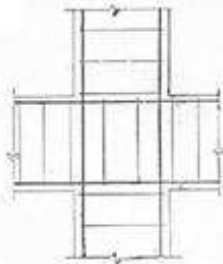
BEAM STIRRUPS  
CONTINUED AT  
JUNCTION



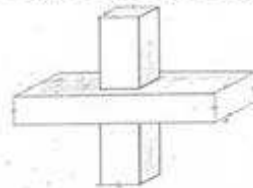
PLAN



SEC. 1-1

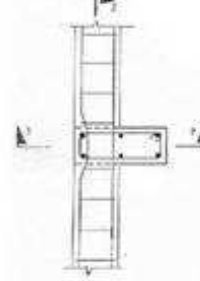


SEC. 2-2



### DETAILING AT JUNCTION

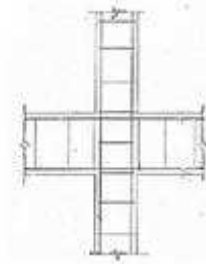
BEAM STIRRUPS  
CONTINUED AT  
JUNCTION



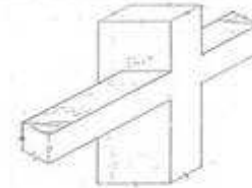
PLAN



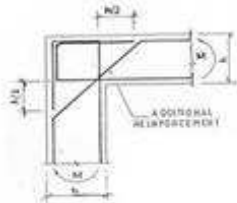
SEC. 1-1



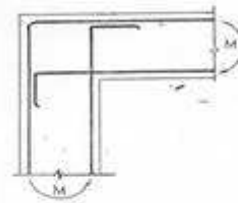
SEC. 2-2



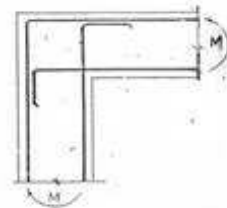
### DETAILING AT OPENING AND CLOSING CORNERS



OPENING  
CORNER

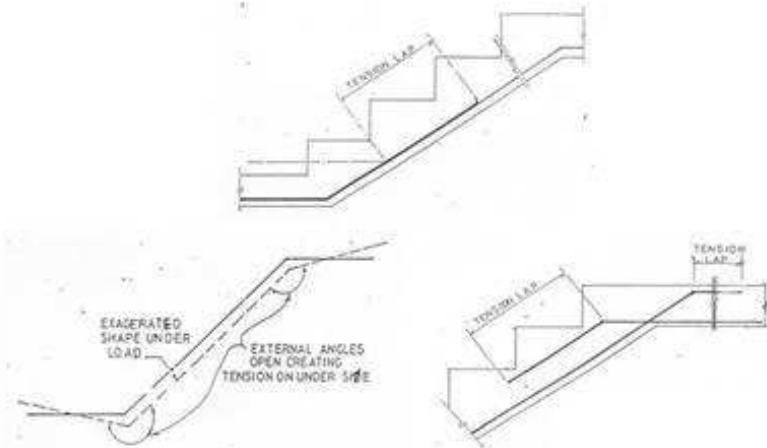


CLOSING  
CORNER

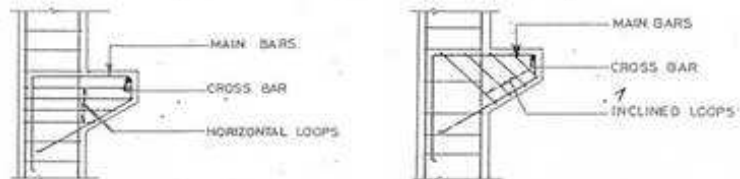


NOTE: STIRRUPS & OTHER  
REINFORCEMENT NOT SHOWN

### DETAILING IN STAIRCASE

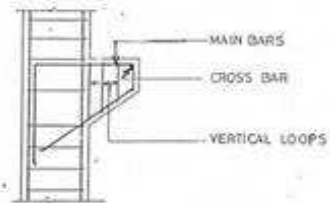


### DETAILING IN BRACKETS



**HORIZONTAL LOOPS**

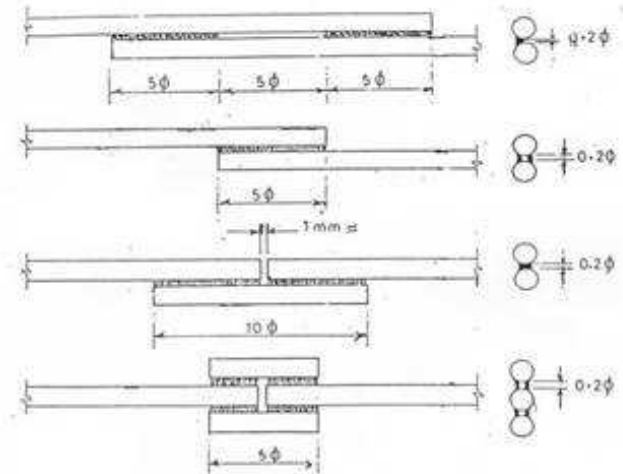
**INCLINED LOOPS**



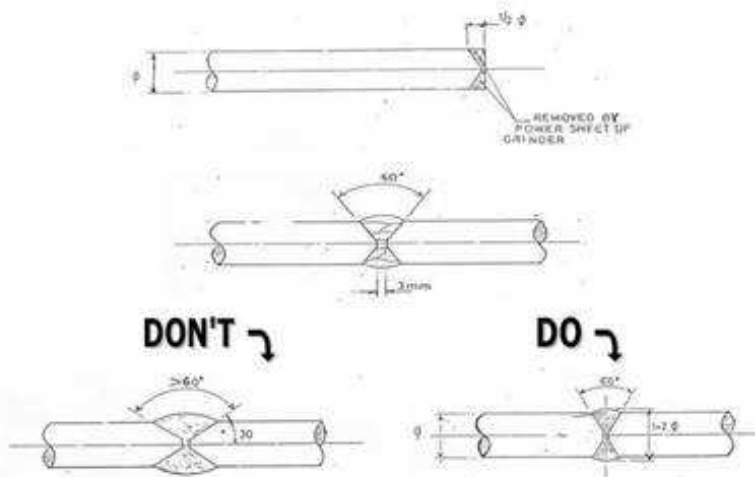
**VERTICAL LOOPS**

**NOTE : HORIZONTAL LOOPS PREFERRED**

### TYPICAL LAP WELD IN REBAR

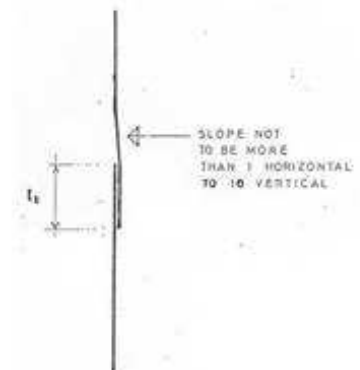


### TYPICAL BUTT WELD JOINT IN REBAR



### BAR KINKS

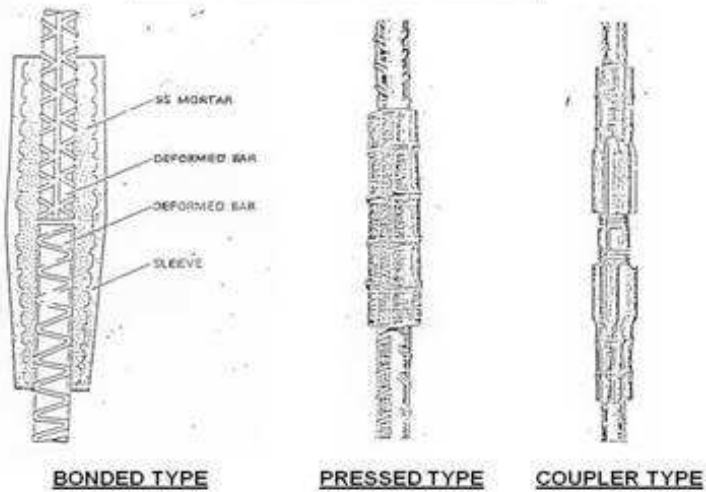
**BAR KINK IN COLUMN**



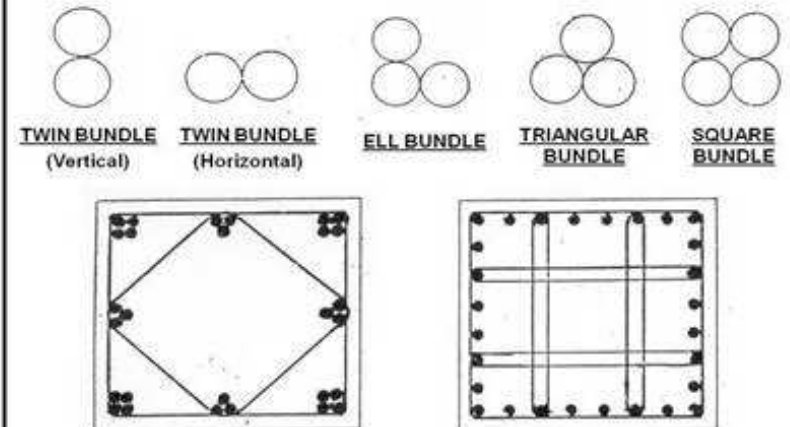
**BAR KINK IN BEAM**



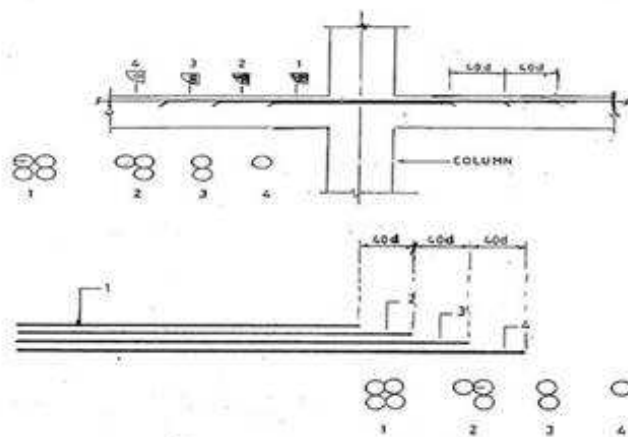
### TYPICAL SPLICE DETAILS



### BUNDLING OF BARS

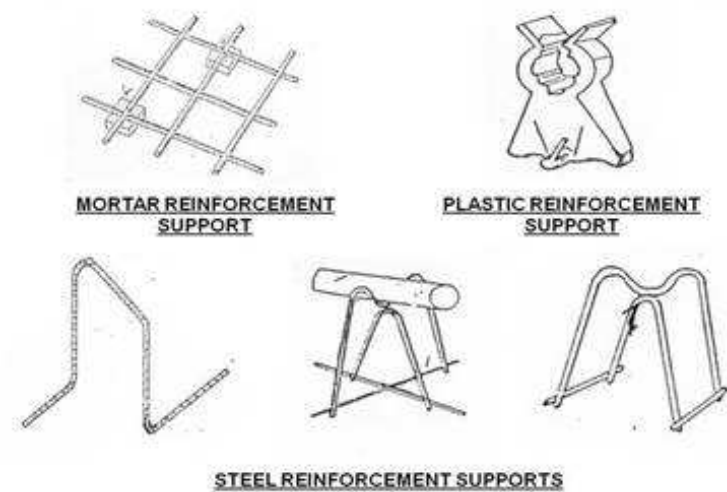


### CURTAILMENT OF BARS IN BUNDLES



**NOTE:** ONLY BUNDLED BARS SHOWN

### TYPICAL SUPPORTS TO REINFORCEMENT

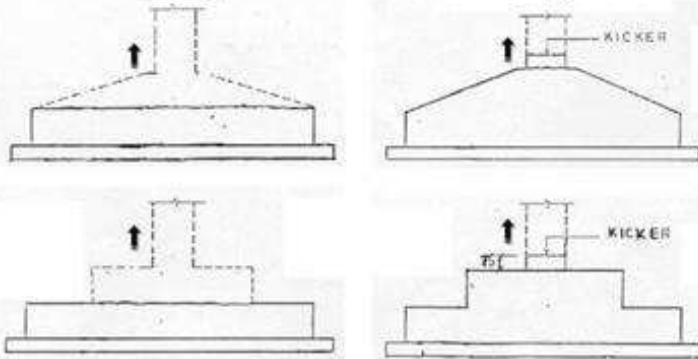




### CONSTRUCTION JOINT IN FOOTING

**DONT'S** ↘

**DO'S** ↘

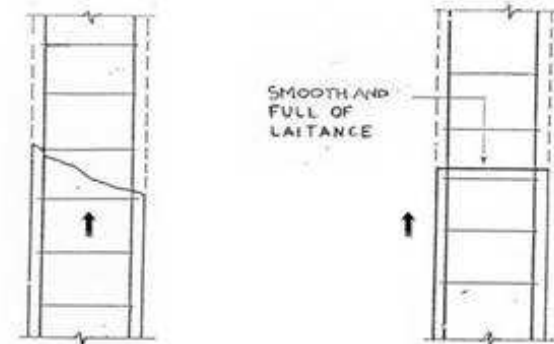


↑ - INDICATES DIRECTION OF CONCRETING  
PROVISION OF KICKER IS OPTIONAL

### CONSTRUCTION JOINT IN COLUMN

**DONT** ↘

**DONT** ↘



↑ - INDICATES DIRECTION OF CONCRETING

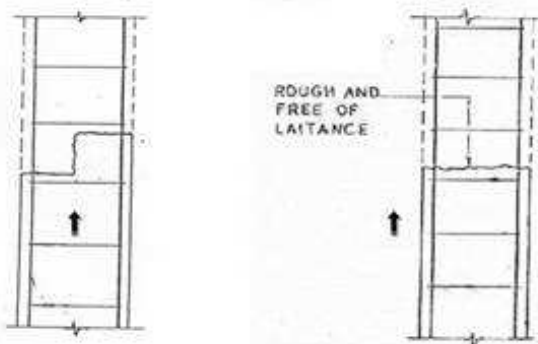
Contd.....

Contd...

### CONSTRUCTION JOINT IN COLUMN

**DONT** ↘

**DO** ↘

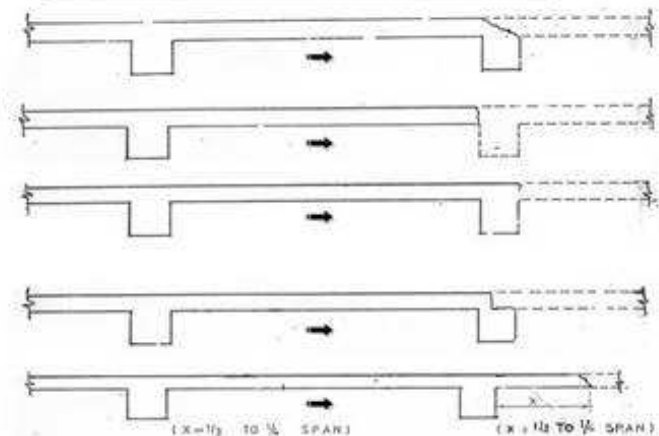


↑ - INDICATES DIRECTION OF CONCRETING

### CONSTRUCTION JOINT IN SLAB

**DONT'S**  
↙

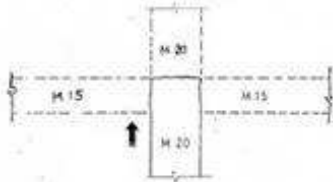
**DO'S**  
↙



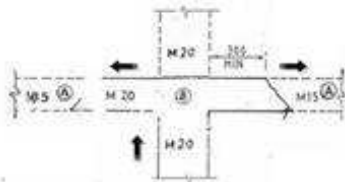
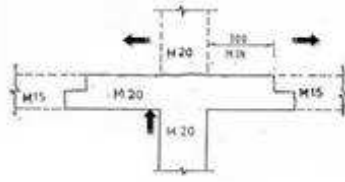
↑ - INDICATES DIRECTION OF CONCRETING

### CONSTRUCTION JOINT AT BEAM - COLUMN JUNCTION

**DON'T**



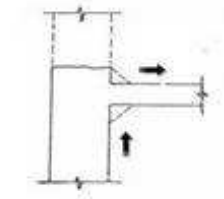
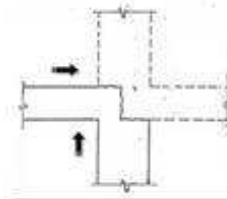
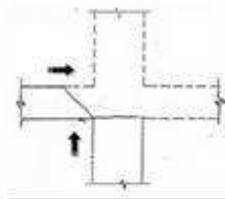
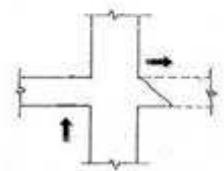
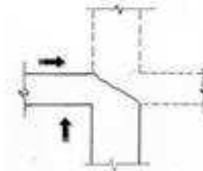
**DO**



- ← - PERMITTED ONLY WHEN  
CONCRETING OF (A)  
TAKEN UP IMMEDIATELY  
AFTER CONCRETING (B)
- ↑ - INDICATES DIRECTION  
OF CONCRETING

### CONSTRUCTION JOINT AT BEAM - COLUMN JUNCTION

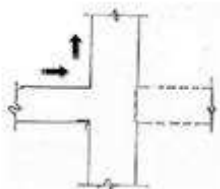
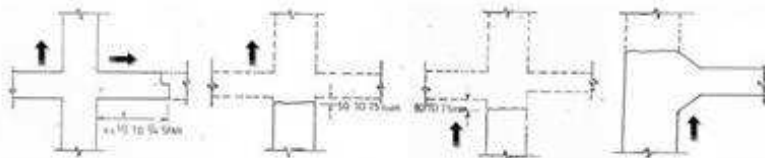
**DONT'S**



↑ - INDICATES DIRECTION OF CONCRETING

### CONSTRUCTION JOINT AT BEAM - COLUMN JUNCTION

**DO'S**

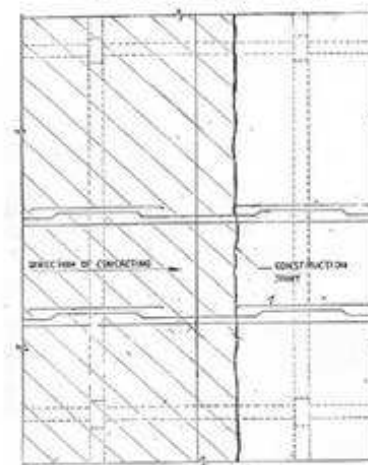


- PERMITTED ONLY WHEN
1. SHEAR RESISTANCE OF CONCRETE IS NEGLECTED.
  2. INTERFACE TREATED AS HIGH IN THE DESIGNS AND
  3. ADEQUATE DEVELOPMENT LENGTH OF PROTRUDING REINFORCING BARS ENSURED.

↑ - INDICATES DIRECTION OF CONCRETING

### TYPICAL CONSTRUCTION JOINT IN ONE-WAY SLAB

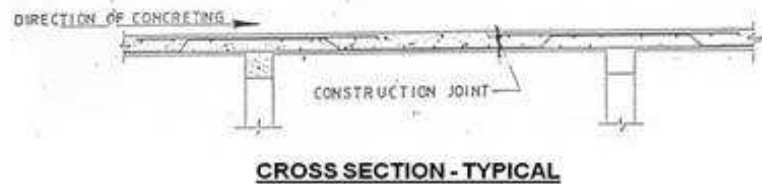
**PLAN**



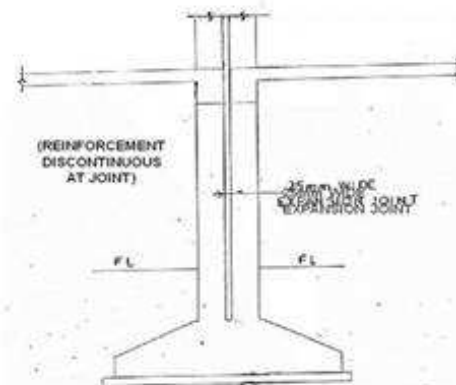
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### **TYPICAL CONSTRUCTION JOINT IN ONE-WAY SLAB**



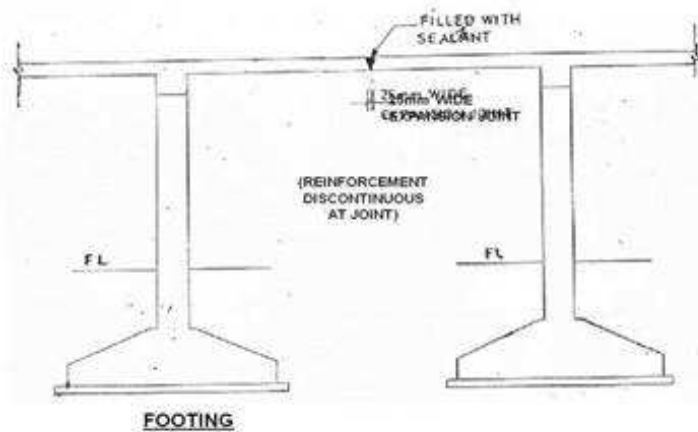
### **TYPICAL EXPANSION JOINT**



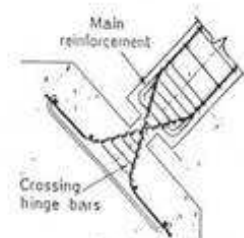
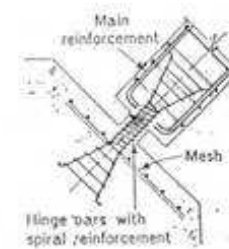
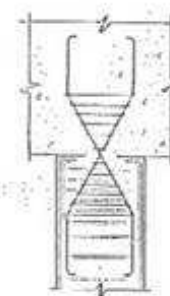
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### **TYPICAL EXPANSION JOINT**



### **R. C. HINGES**

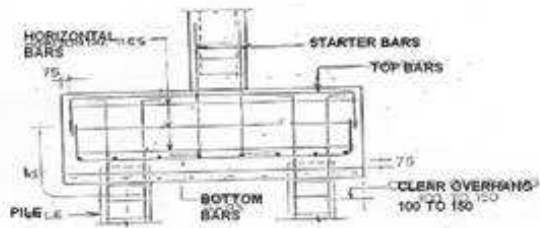


### PILE CAP

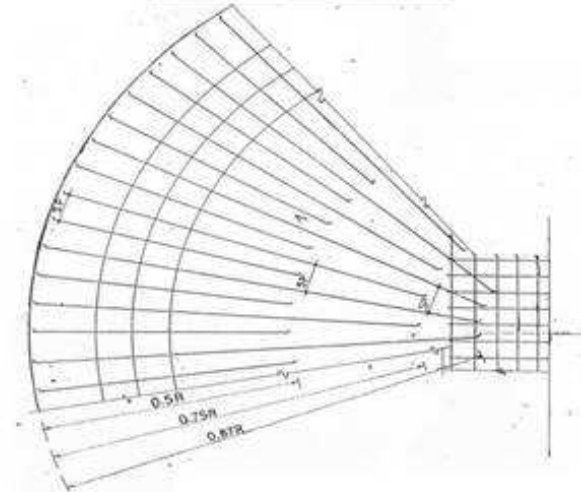
PLAN



SECTION 1-1



### CIRCULAR FLOORS



### DETAILING AT SHRINKAGE STRIPS IN THIN WALLS & LARGE SLABS

PLAN "TYPE - 1"



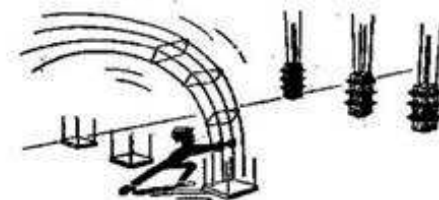
SHRINKAGE STRIP (600-900mm)

PLAN "TYPE - 2"



SHRINKAGE STRIP (600-900mm)

### MORE LAPS - FEWER FLAPS



**ECONOMISING ON LAPS DOES NOT ALWAYS SAVE MONEY.  
REMEMBER - Long bars need support.**

**Where possible relate bar lengths to the height of concrete lifts,  
so that bars are supported by the forms.**

**COURTESY: Please be practical for easier construction - reinforcement.**



## LAPPED BARS CAN CREATE PROBLEMS



**WHERE BARS ARE LAPPED,  
CHECK WHETHER CONCRETE CAN GO IN**

COURTESY: Please be practical for easier construction - reinforcement.

## THINK TO SCALE - LEAVE ROOM



**BARS ARE A LOT THICKER THAN  
THE CONVENTIONAL LINE ON THE DRAWING.**

**When reinforcement is heavy or complicated - THINK!  
CAN IT REALLY ALL BE GOT IN?**

COURTESY: Please be practical for easier construction - reinforcement.

## LEAVE ROOM FOR VIBRATOR..!



COURTESY: Please be practical for easier construction - reinforcement.

## CHAIR ME UP...!



COURTESY: Please be practical for easier construction - reinforcement.

## A TECHNICAL PRESENTATION

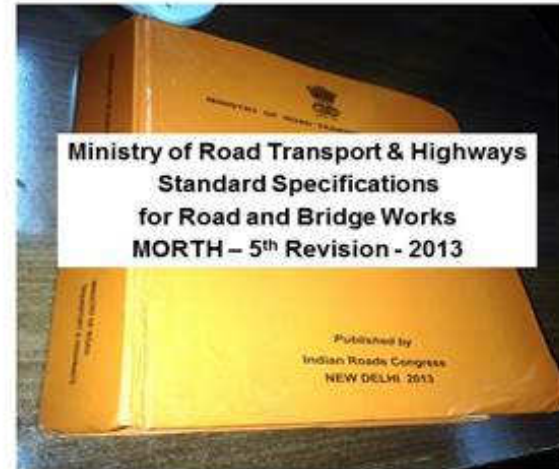
D.V.Bhavanna Rao. M.Tech., F.I.E.,  
Retired R&B Chief Engineer  
Ph:9494440202



**Construction and QC in flexible pavements  
as per 5<sup>th</sup> Revision of MORT&H Specifications**

### **MORTH(5<sup>th</sup> revision)300 Earthwork, Erosion control and Drainage**

- 301 Excavation for roadway and drains
- 302 Blasting operations
- 303 presplitting rock excavation slopes
- 304 Excavation for structures
- 305 Embankment construction
- 306 Soil erosion and sedimentation control
- 307 Turfing with sods
- 308 Seeding and mulching
- 309 Surface/ sub surface drains
- 310 Preparation and surface treatment of formation
- 311 works to be kept free of water
- 312 water course at culverts
- 313 Rockfill embankment
- 314 Ground improvement for weak embankment foundation using geosynthetics and stone columns



### **400 Sub-bases, Bases (non bituminous) and Shoulders (5<sup>th</sup> Revision)**

- 401 Granular Sub Base
- 402 Lime treated soil for improved sub grade/ sub base
- 403 Cement treated soil and cement fly ash treated soil for sub-base/ base
- 404 Water Bound macadam sub-base/ base
- 405 Crushed cement Concrete sub-base/ base
- 406 Wet Mix Macadam sub-base/ base
- 407 Crusher Run Macadam base
- 408 Shoulders, Islands and median
- 409 Cement concrete kerb and kerb with channel
- 410 Footpaths and Separators

## **500 Bases and Surface courses (Bituminous) (5<sup>th</sup> Revision)**

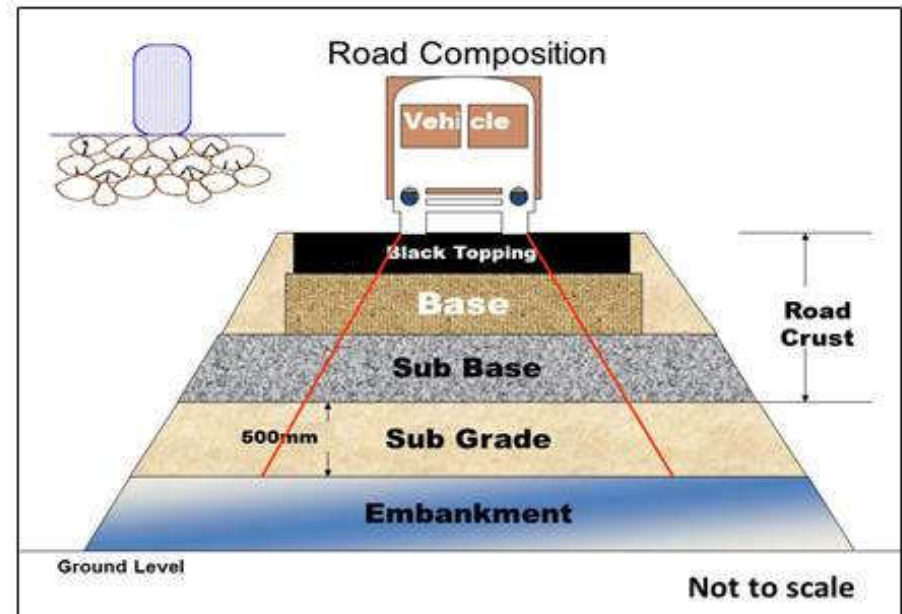
- 501 General requirements for Bituminous pavement layers.
- 502 Prime coat over Granular Base
- 503 Tack coat
- 504 Bituminous Macadam
- 505 Dense Bituminous Macadam
- 506 Sand Asphalt base course
- 507 Bituminous Concrete
- 508 Close-Graded premix surfacing/ Mixed seal surfacing
- 509 Surface Dressing
- 510 Open-Graded premix surfacing

## **500 Bases and Surface courses (Bituminous) continued (5<sup>th</sup> Revision)**

- 511 Seal coat
- 512 Slurry seal
- 513 Fog spray
- 514 Micro Surfacing
- 515 Stone Mastic Asphalt
- 516 Mastic Asphalt
- 517 Crack prevention Courses
- 517 Recycling of Bituminous pavement
- 518 Bituminous Cold Mix (Including Gravel Emulsion)
- 519 Recycling of Bituminous Pavement
- 520 Supply of stone Aggregates for pavement courses

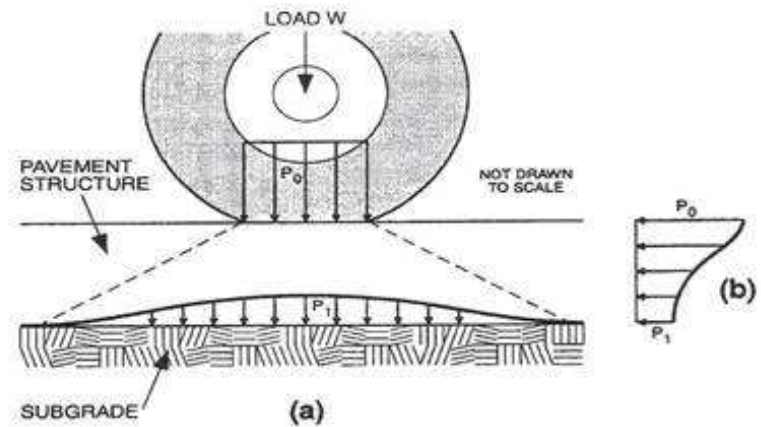
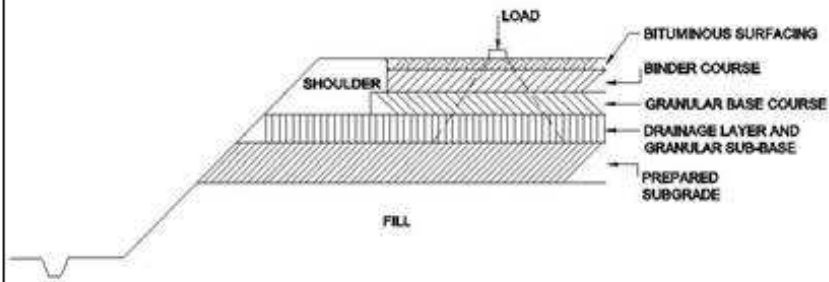
## **Other Important Sections (5<sup>th</sup> Revision)**

- 600 Concrete Pavement
- 601 Dry Lean Concrete sub Base
- 602 Cement Concrete Pavement
- 700 Geosynthetics
- 800 Traffic signs, markings & other road appurtenances
- 900 Quality control for road works
- 1000 Materials for structures
- 1100 Pile foundations
- 1200 Well foundations
- 1600 Steel Reinforcement
- 1700 Structural concrete
- 2000 Bearings
- 2100 Open foundations
- 2600 Expansion joints
- 2700 Wearing coat and appurtenances
- 3100 Reinforced Earth
- 3200 Soil nailing





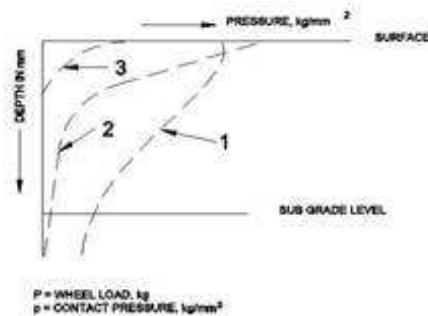
## Typical cross section of flexible pavement



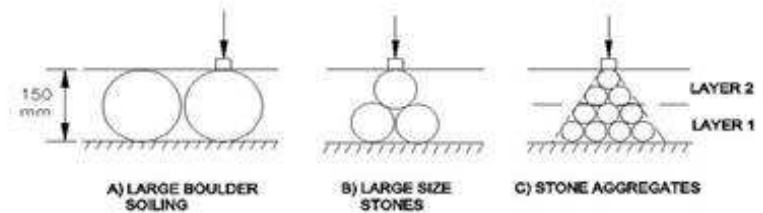
Spread of wheel load distribution through pavement structure

Maximum legal permissible loads IRC: 58 2002

Single axle	10.2 T
Tandem axle	19 T
Tridem axle	24 T



Effect Of Magnitude Of Load ( $P$ ) And Contact Pressure ( $P$ ) On Stress Distribution Through Flexible Pavement



pressure distribution through typical granular materials



**Earthwork excavation for  
embankment, sub-grade and  
shoulders shall be carried out as  
per Clause 305 of MORT&H  
Standard Specifications for road  
and bridge works  
(5<sup>th</sup> revision)**

**305. Soils unsuitable for embankment,  
sub grade and shoulders**

- (i) Material from swamps, marshes and bogs.
- (ii) Peat, log, stump and perishable material; soil classified as OL, OI, OH or Pt as per IS:1498.
- (iii) Materials susceptible to spontaneous combustion.
- (iv) Clay having liquid limit exceeding 50% and plasticity index exceeding 25%. (tests conducted on material passing 0.425 mm IS Sieve as per IS:2720 part 5).
- (v) Material with salts resulting in leaching action e.g. Soils of pH > 8.5).
- (vi) Expansive clay with free swelling index (test conducted on material passing 0.425 mm IS Sieve as per IS:2720 part 40) exceeding 50%

**305. Soils unsuitable for embankment,  
sub grade and shoulders continued**

(vii) Materials in a frozen condition.

(viii) Fill materials with a soluble sulphate content exceeding 1.9 gm of sulphate, (expressed as SO<sub>3</sub>) per litre when tested in accordance with BS:1377 test 10, but using a 2:1 water-soil ratio shall not be deposited within 500 mm or other distance described in the Contract, of concrete, cement bound materials or other cementitious materials forming part of permanent works.

(ix) Material with a total sulphate content (expressed as SO<sub>3</sub>) exceeding 0.5 per cent by mass when tested in accordance BS: 1377 test 9, shall not be deposited within 500 mm or other distance described in the Contract, of metallic items forming part of permanent works

**Important Quality Control Tests in Selecting soil or  
earth for embankment, sub-grade and shoulders**

**Liquid Limit in% (water absorbing nature)**

**Plasticity Index in% = L.L - P.L (Softening Nature)**

**Free Swell Index in% (expansive nature)**

**Maximum Dry Density (indirect strength indicator)**

**Optimum Moisture Content in% (enables effective  
compaction at site)**

**Standard Procter's Compaction for low traffic roads**

**Modified Procter's Compaction for high traffic roads**

**California Bearing Ratio (CBR in%) indicates bearing  
capacity**

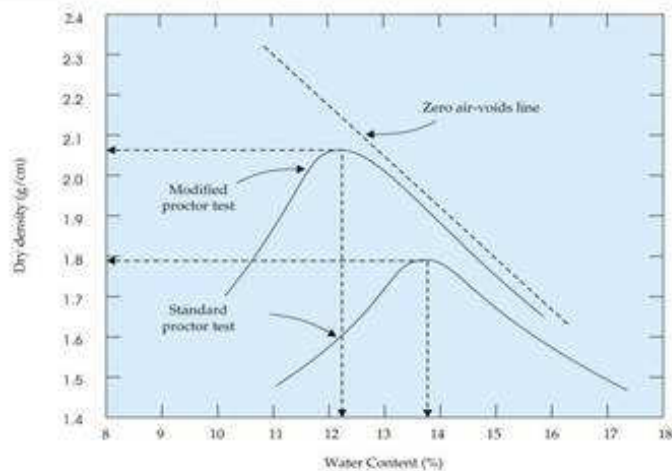
**MORT&H Table 300-1, Density Requirements of Embankment and subgrade materials**

S.No	Type of work	Maximum laboratory dry unit weight when tested as per IS:2720 (part 8)
1	Embankment up to 3m height, not subject to extensive flooding	Not less than 15.2kN/cu.m 14.4 as per MORD
2	Embankments exceeding 3M height or embankments of any height subject to long periods of inundation	Not less than 16.0kN/cu.m 15.2 as per MORD
3	Subgrade and earthen shoulders/ verges/ backfill	Not less than 17.5kN/cu.m 16,5 as per MORD

Notes: 1) This table is not applicable for lightweight fill material e.g. for cinder, fly ash etc. 2) The engineer may relax these requirements at his discretion taking into account the availability of materials for construction and other relevant factors. 3) The material to be used shall satisfy design at CBR at the dry unit weight as applicable in table 300-2

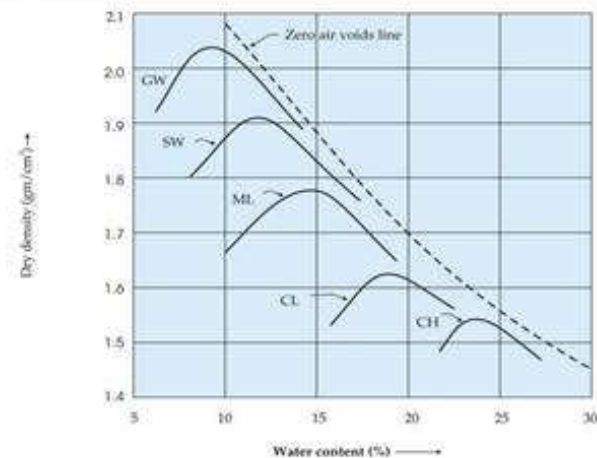
**MORT&H Table 300-2, Compaction requirements for subgrade and shoulders**

S.No	Type of work/ material	Relative compaction as % of laboratory MDD as per IS:2720 (part 8)
1	Subgrade and shoulders	Not less than 97%(100% as per MORD)
2	Embankments	Not less than 95%( 97%as per MORD)
3	Expansive clays a) Subgrade and 500mm portion just below the subgrade	Not allowed
	Expansive clays b) Remaining portion of embankment	90% to 95%



Note :  $1 \text{ g/cm}^3 = 9.81 \text{ kN/m}^3$

**Proctor Test Curve (Dry Density vs Moisture Content)**

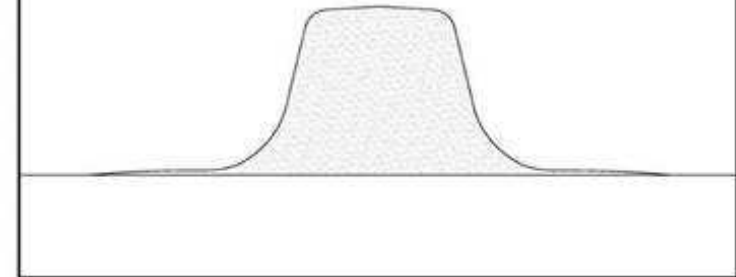


**Compaction Curve for a Range of Soil Types**

Some Test Results on Soils done at STC Vijayawada

District	classification	LL %	PI %	OMC %	MDD g/cc	FSI %	CBR %
Guntur	CH	66	33	21.3	1.6	65	3
Krishna	CI	48	24	19.2	1.63	46	3
Prakasam	SM	-	NP	13.7	1.90	-	10
E G	CH	61	32	24.5	1.4	86	3
W G	CI	39	21	26	1.45	65	4
Kurnool	SC	24	12	8.29	1.75	-	9
W G	CL	31	13	15.7	1.84	33	6
E G	CI	48	24	14.3	1.82	33	7
Prakasam	CH	61	32	24.5	1.4	95	3
W G	CI	49	29	16.7	1.68	200	5

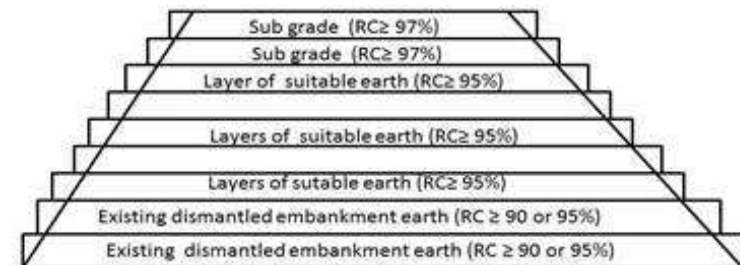
### Widening and strengthening the existing embankment

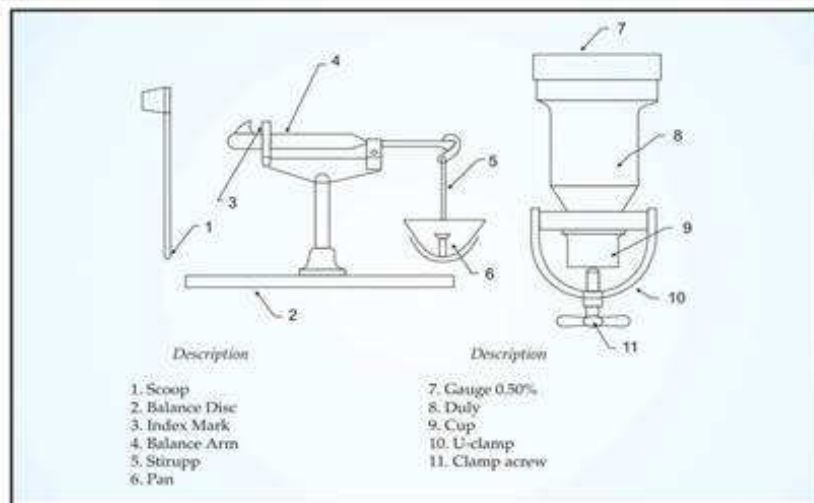


Existing Embankment Cross section  
After It is dismantled, lumps broken, spread to the required bottom width  $+2 \times 0.6\text{m}$  sectioned to longitudinal and cross profile, adding water to reach OMC and compaction to achieve required relative Compaction. Max. loose thickness of a layer is 300mm



### Stepwise Embankment strengthening



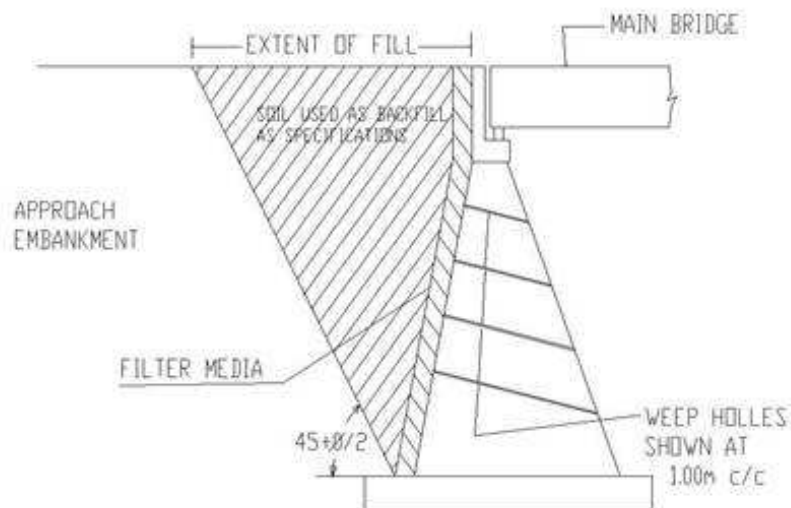


**Rapid Determination of Moisture Content from Gas Pressure developed by the Reaction of Calcium Carbide with the Free Water of the Soil**

#### 305.4.4: Embankment and Sub Grade Requirements around structures

The filling around culverts, bridges and other structures upto a distance of twice the height of the road from the back of the abutment shall be carried out independent of the work on the main embankment.

**Material with LL more than 40% and PI more than 20% shall not be allowed as backfill for all earth retaining structures. Backfill material shall conform to the general requirements given in appendix 6 of IRC: 78 (Standard Specifications and Code of practice for road bridges-section VII)**



**Filling behind abutments, retaining walls and return walls**  
**General guide to the selection of soils on basis of anticipated embankment performance – appendix - 6, IRC: 78**

Soil group to IS: 1498-1970		Visual description	MDD Kg/ m <sup>3</sup>	OMC % range	Anticipat ed performance
Most probable	possible				
GW,GP,G M, SW, HP	-	Granular materials	1850 to 2280	7 - 15	Good to Excellent
SB, SM, GM, GC, SM, SC	-	Granular materials With soils	1760 to 2160	9 - 18	Fair to excellent
SP	-	sand	1760 to 1850	19 - 25	Fair to good
MI, MH, DL	CL, SM,SB, SC	Sandy soils & silts	1760 to 2080	10 - 20	Fair to good



Weep holes with 100 mm dia AC/PVC/HDPE pipes at 1 M spacing in either direction. They extend through full width of concrete with slope of 1V : 20 H. Lowest shall be 150mm above low water level (2706) or ground level whichever is higher.



### **MORTH 2702 : Wearing Coat over Bridges**

- 1 Bituminous Concrete 50mm thick laid in one layer**
- 2 Bituminous Concrete 40mm overlaid with 25mm thick Mastic Asphalt layer**
- 3 Stone Matrix Asphalt 50mm thick laid in one layer**
- 4 Mastic Asphalt 50mm thick laid in one layer**

Before laying wearing coat deck surface shall be thoroughly cleaned and tack coat applied.

Profile making course of the same material shall be provided before laying the wearing coat. Thickness of wearing coat shall not be less than the thickness specified above at any point. Cross slope of deck shall be kept as 2.5%

### **MORTH 2702 : Wearing Coat over Bridges Cement Concrete Wearing Coat**

75mm thick CC minimum M30 grade Wearing Coat shall be laid separately over the bridge deck. Cross slope of deck shall be kept as 2.5%.

Steel reinforcement of 8mm dia at 150mm C/C shall be provided in both directions at mid depth of wearing coat. In a length of 1m near the expansion joint, additional reinforcement shall be provided to make the spacing as 75mm. Curing of wearing coat shall start as early as possible.

Profile corrective course along with wearing coat shall be laid in a single layer.

Overlay on the existing wearing coat shall not be permitted. Dismantling of damaged wearing coat shall be as per MORTH 2800.

### **MORTH 2704: Approach Slab**

Reinforced concrete approach slab with 12mm dia bars at 150mm C/C in both directions at top and bottom in M30 concrete covering the entire roadway width, shall be provided as per the details given in the drawings or as approved by the engineer.

Minimum length of approach slab shall be 3.5m and minimum thickness shall be 300mm. The approach slab shall rest on 150mm thick M15 concrete base or as given in the drawing or as directed by the engineer

### MORTH 2705: Drainage Spouts

Drainage along longitudinal direction shall be ensured by sufficient number of drainage fixtures embedded in the deck slab. The spouts shall be of not less than 100mm in diameter and shall be of corrosive resistant material such as galvanised steel with suitable cleanout fixtures. Spacing shall not exceed 10m. Down pipes shall be provided up to 500mm above HFL. In case of viaducts in urban areas, drainage pipes should be connected with suitably located runners and down pipes to discharge the run-off into drains provided at ground level

### Typical road cross section as per MORT&H specifications along with requirements



### Typical road cross section as per MORD(2014) specifications along with requirements



typical cross section of road (with single GSB layer) showing the required pavement composition as per IRC guidelines





typical cross section of road (with 2 layer GSB) showing the required pavement composition as per IRC guidelines



Most of the existing pavements in India have been constructed as a boxed section. The water, entering the sub grade is trapped and has no outlet. This is also known as the 'Bath tub' condition.

MORT&H(5<sup>th</sup> revision) TABLE 400-1, GSB grading requirements

IS Sieve size	Percent by weight passing through the IS sieve					
	Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
75.0mm	100	--	--	-	100	-
53.0mm	80-100	100	100	100	80-100	100
26.5mm	55-90	70-100	55-75	50-80	55-90	75-100
9.50mm	35-65	50-80	-	-	35-65	55-75
4.75mm	25-55	40-65	10-30	15-35	25-50	30-55
2.36mm	20-40	30-50	-	-	10-20	10-25
0.85mm	-	-	-	-	2-10	-
0.425mm	10-15	10-15	-	-	0-5	0-8
0.075 mm	< 5	< 5	< 5	< 5	-	0-3

MORT&H (5<sup>th</sup> revision) TABLE 400-2, Physical Requirements of GSB materials

Aggregate Impact Value (AIV)	IS:2386-part 4 or IS:5640	40 Maximum
Liquid Limit	IS:2720-part 5	25 Maximum
Plasticity Index	IS:2720-part 5	6 maximum
CBR at 98% dry density (IS:2720-part 8)	IS:2720-part 16	Minimum 30 unless otherwise specified

If water absorption is greater than 2%, Wet Aggregate Impact test shall be done. Grading III and IV are preferable for LSB. Gradings V and VI are for USB and drainage layer.

(4<sup>th</sup> Rev)TABLE 400-1, Grading for Close Graded Granular Sub-Base

	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

(4<sup>th</sup> Rev)TABLE 400-2. GRADING FOR COARSE GRADED GRANGULAR SUB-BASE MATERIALS

IS Sieve Designation	Percent by weight passing through 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
0.075 mm	< 10	< 10	< 10
CBR Value (Minimum)	30	25	20

Base Courses:

Wet Mix Macadam

Crusher Run Macadam (MORT &H)

Water Bound Macadam

Requirements of Base Courses:

Densely Compacted layers with hard, durable, angular and non-plastic materials capable of resisting heavy loads, resistance to lateral movement and transmission of reduced uniform load distribution to sub base layers

## 404 Water Bound Macadam

**Coarse Aggregates:** Gr-I to Gr-III , 40mm & 65 mm

**Screenings:** Type-A :6mm and 10mm,

**Type-B: Stone Dust**

**Binder: Stone Dust**

✦ **Process of WBM**

**Spreading Metal > Sectioning and Dry Rolling > Light Sprinkling of Water > rolling > Application of Screenings > Broo ming > Rolling > Watering & Sweeping > Rolling > Application of Binder > Sprinkling of Water & Sweeping > Rolling > Setting and Drying**



**Table 400-9, WBM gradation Requirements**

IS Sieve size	Cumulative percent passing	
	Grade I	Grade II
75mm	100	-
63mm	90-100	100
53mm	25-75	95-100
45mm	0-15	65-90
22.4mm	0-5	0-10
11.2mm	-	0-5

Aggregate Impact Value (IS:2386: part-4) :30% (max)  
 Combined flakiness and elongation index (IS:2386: part-1):  
 30% (max)

404.2.6. Screenings: Screenings to fill voids in the coarse aggregate shall generally consist of the same material as the coarse aggregate. However, where permitted, predominantly non-plastic material such as moorum or gravel (other than rounded river borne material) may be used for this purpose provided liquid limit and plasticity index of such material are below 20 and 6 respectively and fraction passing 75 cron sieve does not exceed 10 per cent.

**Table 400 - 10**

Type of screenings	IS Sieve	% passing
Type A 13.2mm (6mm & 10mm chips)	13.2mm	100
	11.2mm	95-100
	5.6mm	15-35
	180 micron	0-5
Type B 11.2mm (stone dust and 6mm chips)	11.2mm	100
	9.5	80-00
	5.6mm	50-70
	180 micron	5-25

**DO's**

1. Check aggregates for Soundness test when water absorption is more than 2%
2. Soft aggregate should be tested for wet aggregate impact value.
3. Construct shoulders simultaneously along with WBM layers.
4. Use inverted choke over fine grained soil sub-grade.
5. Remove BT surface before WBM is laid on an existing black top road.
6. Remove defective macadam to full depth and replace by fresh material and re-compact.

**Don'ts**

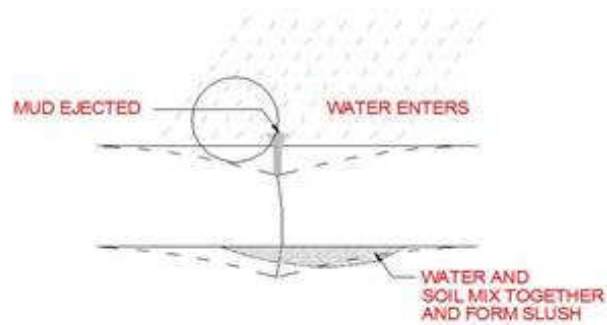
1. Do not use any material derived from rocks e.g. phyllites, shales or slates.
2. Do not use local soil and clayey material as screenings or binding material unless it meets the requirements of PI mentioned
3. Do not use binding material if screenings are of crushable type.
4. Do not spread coarse aggregate more than 3 days in advance of any subsequent operations.
5. Do not roll if sub-grade is soft or yielding or causes a wave like motion while rolling.
6. Do not lay WBM layer on lime treated sub-base until it has attained its strength.
7. Do not use screenings to make up depressions.
8. Do not allow traffic till WBM is fully set.

**405 Crushed cement concrete sub-base/base**

Broken cement slabs shall be crushed to a size not exceeding 75 mm and as far as possible, confirming to one of the gradings given in table 400-9 (WBM). It shall be constructed as WBM using crushed CC as coarse aggregate except that no screenings or binder need be applied.

Layer thickness shall be 100 mm in sub base and 75 mm in base. The top layer may be coated with penetration coat of bitumen at 25 Kg per 10 sqm and 0.13 cum per 10 sq.m of 11.2 mm key chips passing 13.2 mm and retained on 5.6 mm sieve shall be applied and rolled.

## Mud pumping in CC roads



## Damaged CC road being repaired as per MORT &H 405



Condition after spraying 25 kg/10 Sq.m, applying 0.13 cum of 12mm chips and rolling.



Road condition after laying BM 50mm and SDBC 25mm.





Table 400-13. Grading Requirements of Aggregates for the Wet Mix Macadam

IS Sieve Designation	Per cent by weight passing the IS Sieve
53.00 mm	100
45.00 mm	95-100
22.4 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600 micron	8-22
75 micron	0-5

### WET MIX MACADAM



Materials : 40mm, 20mm, 12mm, 6mm & Stone Dust, Mixing at Pug Mill with Water, Conveyed to Site, Spreading by Paver and Rolling. Relative Compaction = 98 %

Aggregate Impact Value (IS:2386: part-4) : 30% (max). Combined flakiness and elongation index (IS:2386: part-1) : 35% (max)

### DO's

1. Ensure compliance of all material and plant requirements.
2. Check aggregate for soundness test when water absorption is more than 2 %.
3. Build shoulders simultaneously along with WMM layers.
4. Remove BT surface before WMM is laid on an existing road.

### Don'ts

1. Do not use material other than crushed stone.
2. Do not allow segregation or pockets of coarse/fine material on the layer.
3. Do not allow any traffic on the WMM surface without covering it with a wearing course.

### 407 Crusher Run Macadam (MORT&H) 53 mm maximum size

Aggregate gradation requirement for Crusher Run Macadam 53mm max size

IS Sieve, mm	Per cent passing by weight 53 mm max size
63	100
45	87 - 100
22.4	50 - 85
5.6	25 - 45
0.710	10 - 25
0.090	2 - 5



### 407 Crusher Run Macadam (MORT&H) 37.5mm maximum size

Aggregate gradation requirement for Crusher Run Macadam 37.5mm max size

IS Sieve, mm	Per cent passing by weight 37.5 mm max size
63	--
45	100
22.4	90 - 100
5.6	35 - 55
0.710	10 - 30
0.090	2 - 5



## **BLACK TOPPED SURFACINGS**

**Strengthening layer: BM and DBM (HMP)**

**Wearing Courses: Surface Dressing and Open Graded Pre-mix Carpet**

**By Hot Mix Process:  
Mix Seal Surfacing, Semi Dense Bituminous Concrete and Bituminous Concrete**

## **Bitumen and Tar**

**Bitumen – Mixture of Hydrocarbons**

*Bitumen is a petroleum byproduct obtained by fractional distillation of petroleum crude.*

*Tar is obtained by destructive distillation of coal or wood in the absence of air*

## **Cutback Bitumen**

**Cutbacks:-** Cutbacks are obtained by adding volatile diluents to the Bitumen in order to reduce the viscosity

**After evaporation of diluents the Bitumen gets its binding properties**

**Volatile diluents:-** Naphthalene, gasoline, kerosene, light diesel oil etc.

**Emulsions:** *Bitumen is being suspended with water in finely divided particles in emulsifiers.*

**Emulsifiers:-** Soap water, surface active agents and colloidal powders, etc.

**Advantage:** *Emulsions can be easily spread over the surface of WMM/ WBM uniformly and after getting evaporation of emulsifier binding action of Bitumen starts.*



### Laboratory tests on bitumen

- Viscosity as per IS: 1206
- Penetration as per IS: 1203
- Softening point as per IS: 1205
- Fraass breaking point as per IS: 9381
- Temperature susceptibility
- Ductility as per IS: 1208
- Heat stability as per IS: 1209
- Solubility as per IS: 1216
- Specific gravity as per IS: 1202
- Loss on heating, thin film oven test as per IS: 1212
- Retained penetration after thin film oven test as per IS: 9382

### Elastic Recovery Test as per Appendix – 1 of IRC: 53

Prepare 3 test specimens for 1 sample as prescribed in IS: 1208 at 15 °C. Elongate the test specimen to 10cm at the rate of 5cm ± 0.25 cm per minute. Immediately cut the test specimen into 2 halves at the mid point using scissors. Keep the test specimen in water bath in an undisturbed condition for 1 hour at specified temperature. Move the elongated half of the test specimen back into position near the fixed half to just touch. Record combined length as X

$$\text{Elastic recovery (\%)} = (10 - X)/10 \times 100$$

### Recommended use of Cationic Emulsions as per IS 8887: 2004

Type	Recommended uses
Rapid Setting RS 1	Quick setting for Tack Coat
Rapid Setting RS 2	Surface treatment, Surface Dressing, Penetration macadam, Grouting
Medium Setting MS	Pre mixes and plant mixes
Slow Setting SS 1	Fog seal, Crack Seal, Prime Coat
Slow Setting SS 2	Slurry Seal and mixes with higher fine aggregate %
Modified Emulsion	Micro Surfacing

**Table 500-2, Mixing, laying and rolling temperatures for VG grade paving bitumen and modified binder**

Bitumen grade	Bitumen Temp. °C	Aggregate Temp. °C	Mix Temp. °C	Laying Temp. °C	Rolling Temp. °C
VG - 40	160 - 170	160 - 170	160 - 170	150 min.	100 min.
VG - 30	150 - 165	150 - 165	150 - 165	140 min.	90 min.
VG - 20	145 - 165	145 - 165	145 - 165	135 min.	85 min.
VG - 10	140 - 160	140 - 160	140 - 160	130 min.	80 min.

502 of MORTH Prime Coat over granular base  
Application of single coat of low viscosity liquid bituminous material (SS 1 Emulsion) to an absorbent granular surface for any superimposed bituminous treatment

Table 500-3, Quantity of bituminous primer for various granular surfaces

Type of surface	Quantity /Sq.m (Kgs)
WMM or WBM	0.7 to 1,0
Stabilised soil bases/ Crusher Run Macadam	0.9 to 1.2

### Prime Coat with Cutback Bitumen

Table 500-4, Type and Quantity of Cutback Bitumen over Granular Surfaces

Type of surface	Type of cutback	Quantity per Sq.m (Kgs)
WMM/WBM	MC 30	0.7 to 1,0
Stabilised soil bases/ Crusher Run Macadam	MC 70	0.9 to 1.2



Primed WMM surface with sand flushing. Electrical pole needs shifting.



### Methodology for Prime Coat

1. Bituminous primer should be slow setting bitumen emulsion, use of cutback being restricted to areas having sub zero temperature or for emergency operations.

2. The prime coat should be applied only on the top most granular base layer, over which bituminous treatment is to be applied. The granular base surface should be swept clean of dust and loose particles and where required, lightly and uniformly sprinkled with water to moist the surface.

3. The primer should be sprayed uniformly over the dry surface of absorbent granular base, using suitable bitumen pressure distributor or sprayer capable of spraying primer at specified rates and temperature so as to provide a uniformly unbroken spread of primer. Normal temperature range of spraying emulsion should be 20°C to 60°C. The rate of application depends upon the porosity characteristics of the surface to be primed and is given in above table.

### DO's

1. Use slow setting emulsion and restrict the use of cutback to subzero temperature conditions or emergency operations.
2. Use only pressure sprayers.
3. Preferably lay a trial section.
4. The Contractor to demonstrate at a spraying trial to ensure that the equipment is capable of producing a uniform spray.

### Don'ts

1. Do not apply primer when the atmospheric temperature in shade is less than 10°C or when the weather is foggy, rainy or windy.
2. Do not allow pouring of primer using perforated cans.
3. Do not allow traffic on primed surface.
4. Do not apply bituminous material to a wet surface.

### 503 Tack Coat ( MORT & H )

503.4.3: The application of tack coat shall be at the rate specified in the contract and shall be applied uniformly. If rate of application of tack coat is not specified in the contract then it shall be at the rate specified in table 500-2

Table 500-2, rate of application of tack coat

Type of Surface	Bituminous material Emulsion or cutback in Kg/10 Sq.M
Normal bituminous surfaces	2.0 to 2.5
Dry and hungry bituminous surfaces	2.5 to 3.0
Granular surfaces treated with primer	2.5 to 3.0
Non- bituminous surfaces:	
Granular base (not primed)	3.5 to 4.0
Cement concrete pavement	3.0 to 3.5

### Methodology for Tack Coat


1. Use a rapid setting bitumen emulsion for applying a tack coat, the use of cutback being restricted to areas having sub-zero temperature or for emergency applications.
2. The surface on which tack coat is to be applied should be clean, free from dust, dirt and any extraneous materials and dry.
3. The surface should be prepared as per sub-section 501.
4. The binder should be sprayed uniformly over the surface using suitable bitumen pressure sprayer capable of spraying bitumen and emulsion at specified rates and temperature so as to provide a uniformly unbroken spread of bitumen emulsion. For smaller jobs, a pressure hand sprayer may be used. Normal range of spraying temperature should be 20°C-60°C in case of emulsion and 50°C-80°C in case of cutback. The rate of application depends upon the type of surface and is given in above Table .
5. The surface should be allowed to cure until all the volatiles have evaporated.



DO's	Don'ts
1. Plan the work so that no more than the necessary tack coat for the day's operation is placed on surface.	1. Do not apply tack coat when atmospheric temperature is less than 10°C or when weather is foggy, rainy or windy.
2. Handle bituminous cutback carefully to avoid fire mishap.	2. Do not apply tack coat on a wet surface.
	3. Do not allow any equipment or vehicles on Tack Coat.

Physical Requirements of Coarse Aggregates for BM/DBM/SDBC/BC			
Table 500-6 for BM, table 500-8 for DBM & 500-17 for BC of 5 <sup>th</sup> Revision. Table 500-14(4 <sup>th</sup> revision) for SDBC			
Property	Test	Specification	Code Reference
Cleanliness	Grain size analysis	Max. 5% passing 0.075mm sieve	IS: 2386 part 1
Particle shape	Flakiness and Elongation Index	Max. 35%	IS: 2386 part 1
Strength	Los Angeles Abrasion Value or	Max. 40% for BM, 35% for DBM & SDBC & 30% for BC	IS: 2386 part 4
	Aggregate Impact Value	Max 30% for BM, 27% for DBM & SDBC, 24% for BC	IS: 2386 part 4

Physical requirements continued			
Durability	Soundness: Sodium Sulphate Magnesium Sulphate	12% 18%	IS: 2386 part 5
Absorption	Water Absorption	2%	IS: 2386 part 3
Stripping	Coating and Stripping of Aggregate bitumen	95%	IS: 6241
Water Sensitivity	Retained Tensile Strength	Min. 80%	to be done if stripping fails
Polishing	Polished Stone Value for SDBC and BC	Min. 55	Bs: 812 part 114

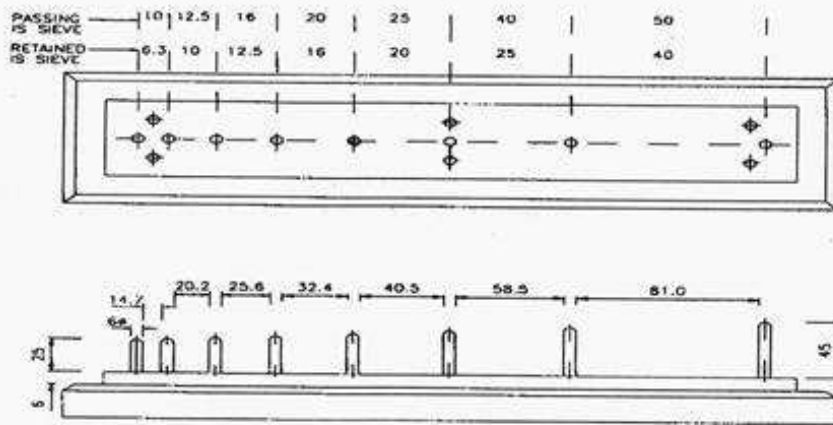


**Flakiness Index Test**  
IS: 2386 part 1  
Thickness of flaky material is less than 0.6 times mean size

IS sieves:  
63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3mm

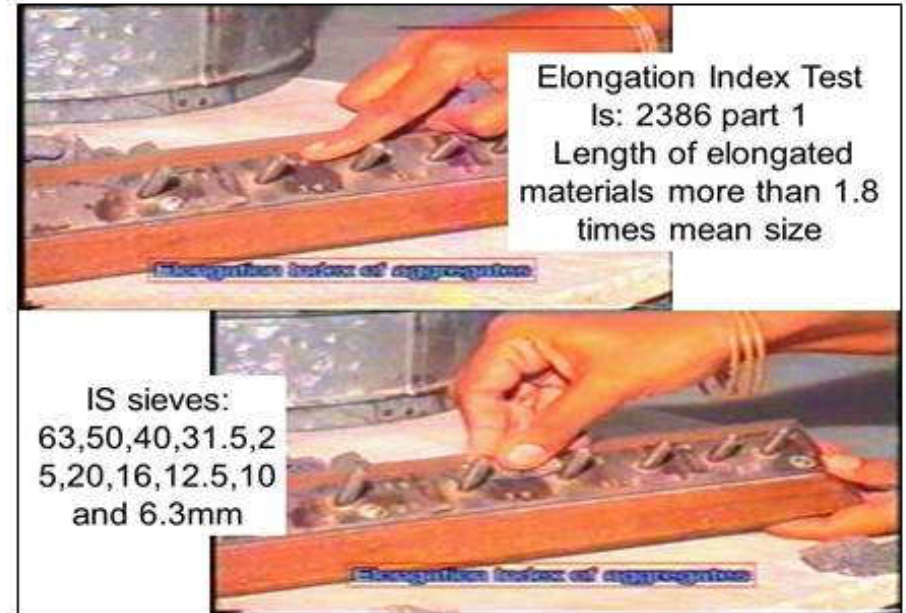


### Elongation gauge



(b) Elongation Gauge

Elongation Index Test  
IS: 2386 part 1  
Length of elongated materials more than 1.8 times mean size



IS sieves:  
63,50,40,31.5,2  
5,20,16,12.5,10  
and 6.3mm

Aggregate Impact test  
IS; 2386 part 4  
material passing 12.5 mm sieve and retained on 10 mm sieve is placed in mould in 3 layers by tamping 25 times for each layer.  
After 15 blows, material passing 2.36 mm sieve is weighed and compared with sample weight in %.



Aggregate Crushing test  
IS 2386 part – 4:  
material passing 12.5 mm sieve and retained on 10mm sieve is placed in mould in 3 layers by tamping 25 times for each layer.  
After application of 40 tons in 10 minutes, material passing 2.36 mm sieve is weighed and compared with sample weight in %.





Los Angeles Abrasion Test IS: 2386 part 4  
Charge is given after metal and balls are placed. Later it is sieved on 1.7mm sieve

Table 500-22, Surface Dressing 509 of MORT&H 5 <sup>th</sup> revision				
Nominal Size	Bitumen per 10sq.m			Chips per 10sq.m
	Uncoated aggregates		Coated aggregates	
	Bitumen	Emulsion	Bitumen	Aggregates in cum/10sq.m
19mm	12	18	10	0.14 to 0.15cum
13mm	10	15	8	0.9 to 0.11cum
10mm	9	13	7	0.7 to 0.8 cum
6mm	7.5	11	9	0.3 to 0.4 cum



Aggregate Polishing test is carried out on aggregates to be used in the wearing course of a pavement; the details of the test are given in BS812 (Part 114), there being no Indian Standard for this test. The standard method is to embed the aggregates in a mould in cement-sand mortar and subject the sample to accelerated polishing caused by a rotating pneumatic wheel, at an RPM of 320-325 for 3 hours 15 minutes. The specimens are thereafter tested for their polishing value in a British Portable Tester. This machine consists of a rubber sliding shoe which is mounted at the end of a pendulum. The slider when released brushes past the specimen and comes to a halt. The PSV is measured on a graduated scale.

The bitumen stripping test as per IS 6241 is basically a static immersion test, wherein aggregates coated with 5% bitumen at the specified temperature are immersed in water for 24 hours. The extent of stripping is only visually assessed at the end of the test. This test is rather subjective in nature.



**The Water Sensitivity Test as per AASHTO T283 requires that Marshall specimens are prepared at the desired bitumen content and one subset of these specimens are tested in dry condition for indirect tensile strength while the other subset are tested under “saturated” conditions for indirect tensile strength. A minimum retained tensile strength of 80% is normally specified. These tests are also carried out to determine the dosage of anti-stripping agent required to ensure the desired retentively of bituminous coating over the aggregates**

Table 500-7, COMPOSITION OF BITUMINOUS MACADAM (5 <sup>th</sup> Revision) 504		
Mix Designation	Grading I	Grading II
Nominal Aggregate Size	40 mm	19 mm
Layer Thickness	80 – 100 mm	50 – 75 mm
IS Sieve (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
0.30	2 -10	2 -10
0.075	0 -8	0 -8
Bitumen content, %	3.3	3.4
Bitumen Grade	35 to 90	35 to 90
Bitumen content shall be within a tolerance of $\pm 0.3\%$ for individual specimens for quality control tests		

#### Methodology for Bituminous Macadam

1. Prepare the base on which bituminous macadam course is to be laid and shape to the specified lines, grade and cross-section.
2. Apply tack coat over the base preparatory to laying of the bituminous macadam.
3. Bituminous Macadam should be prepared in a Hot Mix Plant of adequate capacity Ensure manufacturing and rolling temperatures for Bituminous Macadam as specified.
4. Transfer the mixed material quickly to site of work and lay by means of an approved self-propelled mechanical paver.
5. Commence initial rolling with 80-100 kN rollers (three-wheel or tandem type), beginning from the edge and progressing towards the centre longitudinally. On super elevated portions, rolling should progress from lower to upper edge parallel to centre line of pavement. Thereafter, do intermediate rolling with vibratory or pneumatic tyred road rollers. This should be followed by final rolling while the material is still workable.

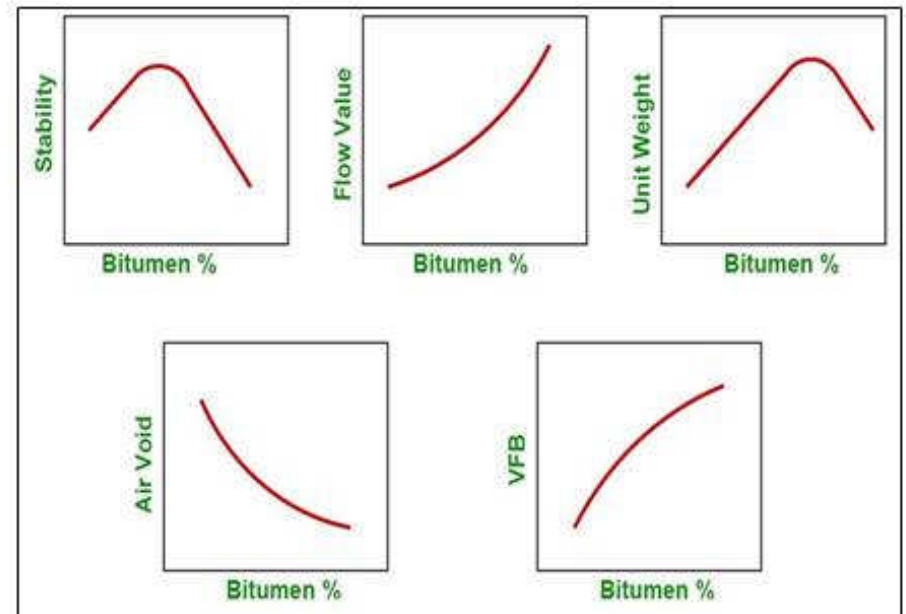
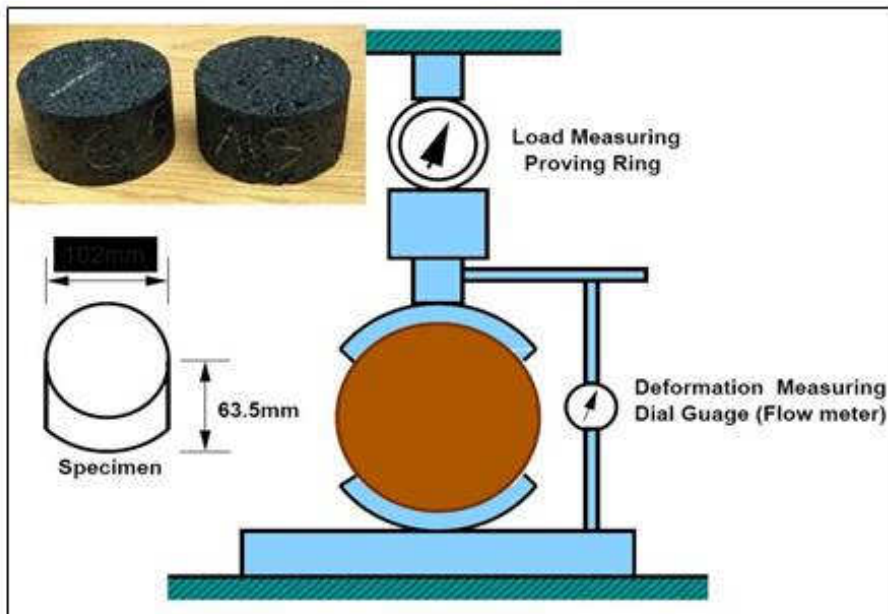
DO's	Don'ts
1.Ensure that stone aggregate conforms to the physical requirements and grading requirements and are dry and clean.	1. Do not undertake the work in foggy, rainy or windy weather or when the atmospheric temperature in the shade is less than 10°C.
2. In case the aggregate has poor affinity to bitumen use anti stripping agent with the approval of Engineer.	2. Do not allow the difference in temperature of binder and aggregate to increase beyond 14OC at any time.
3. While transporting the mixture it should be suitably covered by tarpaulin.	3. Do not allow the premix material to adhere to the roller wheels. (Do not use excess water for the purpose. Light sprinkling should do.)
4. Rolling operations should be completed before the mix becomes unworkable	4. Do not use lubricating oil on the wheels of the roller to prevent mix from adhering.
5. Maintain strict control on temperature while mixing and rolling.	5. Do not allow traffic until the mix has been covered with a wearing course.
6. Regulate the rate of delivery of material to paver to enable it to operate continuously.	6. Do not move roller at a speed more than 5 km/h.

## Mix Design of DBM, SDBC or BC

1 Proportioning of Coarse aggregate and Fine aggregate to satisfy the specified gradation.

2 Optimum Bitumen Content to satisfy the specified values of:

- Marshall Stability Value
- Flow Value
- Voids in Mineral Aggregate (VMA)
- Voids Filled by Bitumen (VFB)
- Air Voids in Mix





**MORTH 505 Table 500-10 Composition of Dense Bituminous Macadam**

Grading	1	2
Nominal aggregate size	40 mm	25 mm
Layer Thickness	80-100mm	50-75 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	95-100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
4.75	38-54	38-54
2.36	28-42	28-42
0.3	7-21	7-21
0.075	2-8	2-8
Bitumen content % by mass of total mix <sup>2</sup>	Min 4.0	in 4.5

**Table 500-9, Grading Requirements of mineral filler**

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

The filler shall be free from organic impurities and have a Plasticity Index not greater than 4. *The Plasticity Index requirement shall not apply if filler is cement or lime. When the coarse aggregate is gravel, 2 per cent by weight of total aggregate, shall be Portland cement or hydrated lime and the percentage of fine aggregate reduced accordingly. Cement or hydrated lime is not required when the limestone aggregate is used. Where the aggregates fail to meet the requirements of the water sensitivity test in Table 500-8, then 2 per cent by total weight of aggregate, of hydrated lime shall be added without additional cost.*

**Table 500-11, Requirements of DBM and BC**

Description	Requirements
Minimum stability (KN at 60°C)	9.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each face of the specimen
Percent air voids	3-5
Marshal Quotient (Stability/flow)	2-5
Percent voids in mineral aggregate (VMA)	See table 500-12
Percent voids filled with bitumen (VFB)	65-75

**Table 500-12, Minimum per cent voids in mineral aggregate (VMA)**

Nominal Maximum particle size	Minimum VMA, per cent related to design air voids, per cent		
	3.0	4.0	5.0
26.5	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Note: Interpolate minimum voids in the mineral (VMA) for design air voids values between those listed

Table 500-13, Permissible variations from job mix formula for DBM

Description	Permissible variation
	Base/binder course
Aggregate passing 19mm sieve or larger	± 8%
Aggregate passing 13.2mm, 9.5mm	± 7%
Aggregate passing 4.75mm	± 6%
Aggregate passing 2.36mm, 1.18mm, 0.6mm	± 5%
Aggregate passing 0.3mm, 0.15mm	± 4%
Aggregate passing 0.075mm	± 2%
Binder content	± 0.3%
Mixing temperature	± 10°C

Table 500-15 Composition Of Semi Dense Bituminous Concrete (4<sup>th</sup> Revision 508)

Grading	1	2
Nominal aggregate size	13 mm	10 mm
Layer Thickness	35-40mm	25-30 mm
IS Sieve (mm)	Cumulative %by weight of total aggregate passing	
19	100	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
0.3	9-19	9-19
0.075	3-8	3-8
Bitumen content % by mass of total mix <sup>2</sup>	Min 4.5	Min 5.0
Bitumen grade (pen)	65*	65*

\* Only in exceptional circumstances, 80/100 penetration grade bitumen may be used

**MORTH 508(4<sup>th</sup> revision)Table 500-16,  
Requirements of SDBC layer**

Description	Requirements
Minimum stability (KN at 60°C)	8.2
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each face of the specimen
Percent air voids	3-5
Percent voids in mineral aggregate (VMA)	See table 500-12
Percent voids filled with bitumen (VFB)	65-78

SDBC mix temperature being checked.



SDBC rolling is in progress. 2 plain passes, 1 vibratory pass and 1 plain pass are necessary. Low amplitude and high frequency are to be set in vibratory settings of roller as it is a thin layer



SDBC rolling is in progress. 2 plain passes, 1 vibratory pass and 1 plain pass are necessary. Low amplitude and high frequency are to be set in vibratory settings of roller as it is a thin layer

#### MORTH 507

**Table 500-17 Composition of Bituminous Concrete**

Grading	1	2
Nominal aggregate size	19 mm	13.2 mm
Layer Thickness	50mm	30-40 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
26.5	100	
19	79-100	100
13.2	59-79	90-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content % by mass of total mix <sup>1</sup>	5.2	5.4

**Table 500-18, Permissible variations from job mix formula for Bituminous Concrete**

Description	Permissible variation
	Wearing course
Aggregate passing 19mm sieve or larger	± 7%
Aggregate passing 13.2mm, 9.5mm	± 6%
Aggregate passing 4.75mm	± 5%
Aggregate passing 2.36mm, 1.18mm, 0.6mm	± 4%
Aggregate passing 0.3mm, 0.15mm	± 3%
Aggregate passing 0.075mm	± 1.5%
Binder content	± 0.3%
Mixing temperature	±10°C

#### Reasons for Poor performance of Asphalt mixes

**1 Inadequate initial compaction making the mix vulnerable to high secondary compaction under traffic.**

**2 Relatively high asphalt contents that permit the reduction of air voids to less than 3 per cent under secondary compaction, leading to rutting under heavy axle loads when pavement temperatures rise in summer.**

**3 Low asphalt contents and high air voids in the mix leading to top- down cracking, ravelling and stripping making the mix less durable.**



### 508 Mix Seal surfacing

Table 500-19, aggregate gradation

IS sieve designation (mm)	Cumulative per cent by weight of total aggregate passing	
	Type A	Type B
13.2 mm	-	100
11.2 mm	100	88 - 100
5.6 mm	52 - 88	31 - 52
2.8 mm	14 - 38	5 - 25
0.090 mm	0 - 5	0 - 5
Bitumen	22 kg / 10 sqm	19 kg / 10 sqm

As per Manual for construction and supervision of bituminous works Type A grading may be used for 25mm thick MSS also, by proportionately increasing bitumen content

Full width Dense Bituminous Macadam paving  
Screed unit has a self leveling floating mechanism to lay the material to the specified thickness, striking off the material deposited by screw, tamping and vibrating. Likely degree of compaction by tamping and vibrating screed varies from 80 to 90%.



### Bump integrator towed by a jeep

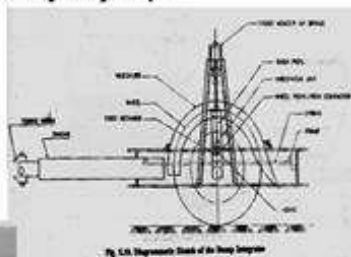


Fig. 5.1. Diagrammatic sketch of the Bump Integrator

### Recommended Roughness Values for roads In India in mm/km as per IRC:SP:30-2009

Surface type	good	average	poor	Very poor
Bituminous Concrete	< 2000	2000 to 3000	3000 to 6000	Over 6000
Surface Dressing	<3500	3500 to 4500	4500 to 7000	Over 7000
Premix Bituminous carpet/(Open Graded)	<3000	3000 to 4000	4000 to 6000	Over 6000
Water Bound Macadam/Gravel	<8000	8000 to 9000	9000 to 10000	Over 10000
Cement Concrete	<2200	2200-3000	3000-4000	Over 4000



### Factors Influencing Compaction of Asphalt mixes

- 1) Type of Aggregates
- 2) Shape of Aggregates
- 3) Grading of mix
- 4) Residual moisture content in aggregates
- 5) Binder content
- 6) Viscosity of binder
- 7) Temperature of mix during compaction

**Note:** The first six requirements are taken care in the mix design, leaving temperature of compaction as the single most important affecting the final result.

### 515.Stone Matrix Asphalt 500-35, Physical Requirements of Coarse Aggregates

Property	Test	Specification	Code Reference
Cleanliness	Grain size analysis	% passing 0.075mm sieve < 2%	IS: 2386 part 1
Particle shape	Combined Flakiness and Elongation Index	< 30%	IS: 2386 part 1
Strength	Los Angeles Abrasion Value	< 25%	IS: 2386 part 4
	Aggregate Impact Value	< 18%	
*Polishing	Polished Stone Value	IS: 2386 part 114	> 55%
durability	Soundness (either Sodium or Magnesium) – 5 cycles		
	Sodium Sulphate	IS: 2386 part 5	< 12%
	Magnesium Sulphate		< 18%
Water Absorption	Water Absorption	IS: 2386 part 3	< 2%

### 500-37, Composition of Stone Matrix Asphalt

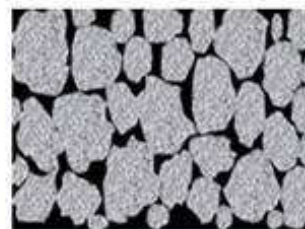
SMA Designation	13mm SMA	19mm SMA
Nominal Aggregate size	13mm	19mm
Course where used	Wearing Course	Binder (intermediate) course
Nominal layer thickness	40 – 50mm	45 – 75mm
IS sieve	Cumulative % passing by weight of total aggregates	
26.5	-	100
19 mm	100	90 - 100
13.2 mm	90 - 100	45 - 70
9.5 mm	50 - 75	25 - 60
4.75 mm	20 - 28	20 - 28
2.36 mm	16 - 24	16 - 24
1.18 mm	13 - 21	13 - 21
0.6 mm	12 - 18	12 - 18
0.3 mm	10 - 20	10 - 20
0.075 mm	8 - 12	8 - 12

### Causes of superior performance of SMA

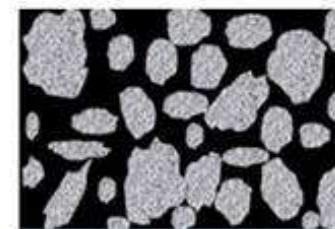
- 1) Higher amount of coarse aggregate provides better stone-to-stone contact, which provides highly rut resistant bituminous course.
- 2) Higher binder content adds durability
- 3) Stabilising additive reduces drain down of binder

### MORTH table 500-38, SMA mix requirements

Air voids content, percent	4.0
Bitumen content, percent	5.8 minimum
Celluloid fibers, percent	0.3 by weight of total mix
Voids in Mineral Agregate(VMA) %	17 min
Voids in Coarse Aggregate (VCA) %	Less than VCA (dry rodded)
Asphalt drain down,% ASTM D 6390 Annexe C of IRC:SP:79	0.3 max
Tensile Strength Ratio (TSR) % AASHTO T283, Annexe E of IRC:SP:79	85 min



Cross section of SMA and its stone skeleton



Cross section of Conventional dense bituminous mix and its stone skeleton

### 516. Mastic Asphalt

Mastic Asphalt is used as a wearing course for bridge decks and heavily stressed intersections in urban areas. This is a homogeneous mixture of well graded aggregates, limestone powder filler and a hard grade bitumen (10 to 20 pen) to yield a plastic and void less mass, which when applied hot can be trowelled and floated to form a very dense impermeable surfacing.

Binder content is 14 to 17%.

Normal thickness is 25 to 50mm.

Hardness number (IS: 1195-19780: Mastic Asphalt shall have a hardness number at the time of manufacture of 60 to 80 at 25°C prior to the addition of coarse aggregate and 10 to 20 at 25°C at the time of laying after the addition of coarse aggregate.

Table 500 – 39, Requirements for physical properties of binder

Property	Test method	Requirements
Penetration at 25°C	IS:1203	15 ± 5
Softening Pont, °C	IS:1205	65 ± 10
Loss of heating for 5 hours at 163 °C Max	IS:1212	2.0
Solubility in trichloroethylene, % by mass Min	IS:1216	95
Ash, (mineral matter) by mass Max	IS:1217	1.0

In cold climatic regions (temperature less than 10°C) VG40 grade bitumen may be used

**Table 500 – 40, Grade and thickness of Mastic Asphalt Paving and Grading of Coarse aggregate**

Application	Thickness range (mm)	Nominal size of coarse aggregate (mm)	Coarse aggregate, % by mass of total mass
Roads and Carriageway	25 - 50	13	40 ± 10
Heavily stressed areas i.e. junctions and toll plazas	40 - 50	13	45 ± 10

Nominal size of coarse aggregate	13mm
IS Sieve (mm)	Cumulative % passing by weight
19	100
13.2	88 - 100
2.36	0 - 5

**Table 500 – 41, Grading of fine aggregate (inclusive of Filler)**

IS Sieve	Percentage by weight of aggregate
Passing 2.36mm but retained on 0.600mm	0 - 25
Passing 0.600mm but retained on 0.212mm	10 - 30
Passing 0.212mm but retained on 0.075mm	10 - 30
Passing 0.075mm	30 - 55

Filler shall be limestone powder passing 0.075mm sieve and shall have a calcium carbonate content of not less than 80% by weight when determined in accordance with IS: 1514

**Table 500 – 32, Composition of Mastic Asphalt blocks without coarse aggregates**

IS Sieve	Percentage by weight of Mastic Asphalt	
	Minimum	Maximum
Passing 2.36mm but retained on 0.600mm	0	22
Passing 0.600mm but retained on 0.212mm	4	30
Passing 0.212mm but retained on 0.075mm	8	18
Passing 0.075mm	25	45
Bitumen Content	14	17

**Mastic Asphalt wearing Coat for bridge**



## 514 Micro Surfacing

Micro surfacing is a thin layer of a mixture of a modified bitumen based emulsion, aggregate, water and additives like cement and lime in desired proportions. It is generally applied over a hungry, baked flexible pavement surface and also in case of fretting of aggregate over already laid surface, shallow depressions and fine to moderate cracks. It can be applied with machine up to a thickness of 5mm in one application. Where the situation demands there can be two applications of the same thickness.

**Table 500-27, Aggregate grading for Micro Surfacing (514)**  
Grading II and III are same for slurry seal

IS Sieve size	Cumulative percent passing	
	Type II (4 to 6mm)	Type III (6 to 8mm)
9.5mm	-	100
6.3mm	100	90 – 100
4.75mm	90 - 100	70 – 90
2.36mm	65 - 90	45 – 70
1.18mm	45 - 70	28 - 45
600 micron	30 - 50	19 – 34
300 micron	18 - 30	12 – 15
150 micron	10 - 21	7 – 18
75 micron	5 - 15	5 – 15

**500-31, Types of Micro Surfacing and rate of Application**

items	Type II (4 to 6mm)	Type III (6 to 8mm)
application	Preventive and renewal treatment for roads carrying less than 1500CVPD	Preventive and renewal treatment for roads carrying 1500 to 4500 CVPD
Quantity of Mix of dry aggregates Kg/sq.m	8.4 to 10.8	11.1 to 16.3
Residual binder % by weight of dry aggregates	6.5 to 10.5	5.5 to 10.5

**Extra width of pavement and roadway**

Radius of curve	extra width
Up to 40m	1.5m
41 to 60m	1.2m
61 to 100m	0.9m
101 to 300m	0.6m

Super elevation shall be provided in curves as per IRC: 73 and shall be limited to 7%. It shall not be less than the minimum specified cross fall/ camber



Minimum radii of horizontal curves		
Nature of terrain	Desirable minimum	Absolute minimum
plain	360m	230m
Rolling	230m	155m
Mountainous	90m	60m
Steep	60m	30m

Recommended Vertical Gradients		
Nature of terrain	Ruling gradient	Limiting gradient
Plain and rolling	3.3%	5.0%
Mountainous	5.0%	6.0%
Steep	6.0%	7.0%

The vertical alignment should provide for a smooth longitudinal profile.

Gradients up to ruling gradients shall be adopted as far as possible.

Limiting gradients shall be adopted only in very difficult situations and for short lengths

Design service volume of two-lane highway in PCUs per day

Nature of terrain	Design Service volume in PCUs per day	
	Without paved shoulder	With 1.5m paved shoulder
Plain	15,000	18,000
Rolling	11,000	13,000
Mountainous and Steep	7,000	9,000

MORT&H Table 900-1, Tolerances in Surface Levels

1.Sub-grade	±20mm
2.Sub-base	
a) Flexible pavement	±10mm
b) Concrete pavement	±6mm
3.Base course for flexible pavement	
a) Bituminous course	+6mm to -6mm
b) Granular	
i) Machine laid	±10mm
ii) Manually laid	±15mm
4. Wearing Course for flexible pavement	
a) Machine laid	±6mm
b) Machine laid	±10mm
5. Cement concrete pavement	±5mm

**MORT&H Table 900–2, Maximum permitted number of irregularities**

Irregularity	Surfaces of carriageways and paved shoulders				Surfaces of laybys, service roads and all bituminous courses			
	4mm		7mm		4mm		7mm	
Length(m)	300	75	300	75	300	75	300	75
National highways/ Expressways	15	9	2	1	40	18	4	2
Roads of lower category	40	18	4	2	60	27	6	3

The longitudinal profile shall be checked with a 3m long straight edge or moving straight edge as desired by engineer at the middle of each traffic lane parallel to the center line of the road

**MORT&H 902.4 :** The maximum allowable difference between the road surface and underside of a 3m straight edge when placed parallel with, or at right angles to the center line of the road at points decided by the Engineer

For pavement surface (bituminous and cement concrete)	3mm
For bituminous courses	6mm
For granular sub-base or base courses	8mm
For sub-base under concrete pavements	10mm
For sub-grade	15mm

**MORT&H 903.2 Tests on Earthwork for embankment, sub-grade construction and cut formation for each source**

Test type	As per code	Frequency of testing
Sand Content	IS:2720 – part 4	2 per 3000 cubic meters
Plasticity	IS:2720 – part 5	2 per 3000 cubic meters
Density	IS:2720 – part 8	2 per 3000 cubic meters
Deleterious Content	IS:2720 – part 27	As and when required by engineer
Moisture Content	IS:2720 – part 2	2 per 3000 cubic meter
Soaked/ un-soaked CBR	IS:2720 – part 16	1 per 3000 cubic meters

**MORT&H 900.3 control tests and their minimum frequency for sub-bases and bases**

Type of Construction	Test	Frequency (min)
Granular	gradation	One test per 400cum
	Atterberg Limits	One test per 400cum
	Moisture content prior to compaction	One test per 400cum
	Density of compacted layer	One test per 1000sq.m
	Deleterious content	As required
	CBR	As required

**MORT&H 900.3 control tests and their minimum frequency for sub-bases and bases**

Type of Construction	Test	Frequency (min)
Lime/Cement stabilised soil sub-base	Quality of lime or cement	One test per each consignment subject to a minimum of 1 test per 5 tonnes
	Lime or cement content	Regularly, through procedural checks
	Degree of pulverisation	Periodically as considered necessary
	CBR or UCS on a set of 3 specimens	As required
	Moisture content prior to compaction	1 set of 2 tests per 500sq.m
	Density of compacted layer	1 set of 2 tests per 500sq.m
	Deleterious constituents	As required

**MORT&H 900.3 control tests and their minimum frequency for sub-bases and bases**

Type of Construction	Test	Frequency (min)
Water Bound macadam	Aggregate Impact Value	One test per 1000cum
	Grading of Aggregate	One test per 250cum
	Combined FIV & EIV	One test per 500cum
	Atterberg limits for binding material	One test per 50cu.m of binding material
	Atterberg limits for screenings	One test per 100cu.m of screenings

**MORT&H 900.3 control tests and their minimum frequency for sub-bases and bases**

Type of Construction	Test	Frequency (min)
Wet Mix Macadam	Aggregate Impact Value	One test per 1000cum
	Grading of Aggregate	One test per 200cum
	Combined FIV & EIV	One test per 500cum
	Atterberg limits for material passing 425 microns	One test per 200cu.m of aggregate
	Density of compacted layer	One set of 3 tests per 1000 sq.m

**MORT&H 900.4 control tests for bituminous works and their minimum frequency**

Type of Construction	Test	Frequency (min)
Prime coat/tack coat/fog spray	Quality of binder	Number of samples per lot and tests as per IS:73, IS:217 and IS:8887 as applicable
	Binder temperature	At regular close intervals
	Rate of spread of binder	3 tests per day

MORT&H 900.4 control tests for bituminous works and their minimum frequency

Type of Construction	Test	Frequency (min)
Seal Coat/ surface dressing	Quality of binder	Number of samples per lot and tests as per IS:73, IS:217 and IS:8887 as applicable
	AIV or LAV	One test per 200cum per source
	Combined FIV & EIV	One test per 100cum per source
	Stripping value of aggregate	One test for each source
	Water absorption of aggregate	One test for each source
	Water sensitivity of mix	One test for each source
	Grading of aggregate	2 tests per day
	Soundness	One test for each source
	Temperatures	At regular intervals
	Rate of spread	Same as for item1
	% fractured faces	One test per 100cu.m
	Stone polishing value	One test of each source

MORT&H 900.4 control tests for bituminous works and their minimum frequency

Type of Construction	Test	Frequency (min)
Open grade pre-mix surfacing/ MSS	Quality of binder	Number of samples per lot and tests as per IS:73, IS:217 and IS:8887 as applicable
	AIV or LAV	One test per 200cum per source
	Combined FIV & EIV	One test per 100cum per source
	Stripping value	One test for each source
	Water absorption	One test for each source
	Water sensitivity of mix	One test for each source
	Grading of aggregates	2 tests per day
	Soundness	One test per 200cum per source
	Polished stone value	One test per 200cum per source
	temperatures	regularly
	Binder content	2 tests per day
	% fractured faces	One test per 100cum of aggregate

MORT&H 900.4 control tests for bituminous works and their minimum frequency

Type of Construction	Test	Frequency (min)
Bituminous Macadam	Quality of binder	Number of samples per lot and tests as per IS:73, IS:217 and IS:8887 as applicable
	AIV or LAV	One test per 350cum per source
	Combined FIV & EIV	One test per 350cum per source
	Stripping value of aggregate	One test for each source
	Water absorption of aggregate	One test for each source
	Water sensitivity of mix	One test for each source
	Grading of aggregate	2 tests per day
	Soundness	One test for each source
	Temperatures	At regular intervals
	Rate of spread	Same as for item1
	% fractured faces	One test per 100cu.m
	Stone polishing value	One test of each source
	Density of compacted layer	1 test per 100sq.m
	Rate of spread of mix	Regular intervals

MORT&H 900.4 control tests for bituminous works additional  
Additional tests over the tests for BM

Type of Construction	Test	Frequency (min)
Dense Bituminous Macadam/ Bituminous Concrete	Mix Grading	One test for individual constituent and mixed aggregate from dryer for each 400t of mix subject to minimum of 2 tests per day per plant
	Stability, voids analysis and theoretical max. sp.gravity of loose mix	3 tests for stability, flow value, void content, density for each 400t of mix subject to 2 tests per day per plant.
	Moisture Susceptibility of Mix (AASHTO T283)	One test for each mix type whenever there is change in quality or source of coarse or fine aggregate
	Density of compacted layer	1 test per 700 sq.m area



# A TECHNICAL PRESENTATION

**D.V. Bhavanna Rao** M.Tech., F.I.E.,  
Retired R&B Chief Engineer  
E-mail: [bhavannarao@yahoo.co.in](mailto:bhavannarao@yahoo.co.in)  
Phone: +919494440202



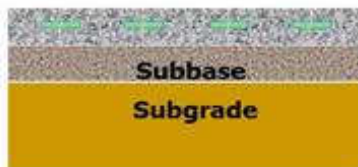
for all my presentations, please visit  
<http://aproadbuildqa.blogspot.com>

**Construction and Quality Control of Rigid Pavements  
as per MORTH 2013, IRC:58-2015 and IRC:15-2011**

- IRC: 58-2015, Guidelines for the design of Plain Jointed Rigid Pavements for Highways
- IRC: 15-2011, Code of practice for Construction of Cement Concrete Roads
- IRC: 44-2008, Guidelines for cement concrete mix design for pavements
- IRC: 57-2006: Sealing Joints in CC roads
- Federal Highway Administration: HIF – 07- 004: Integrated materials and construction practices for concrete pavement: practice manual
- IRC:SP 62 – 2014, Guidelines for design of CC roads for Rural Roads
- IRC:SP:83-2008, guidelines for maintenance and rehabilitation of CC pavements

## Different Pavement Types

**Concrete Section**



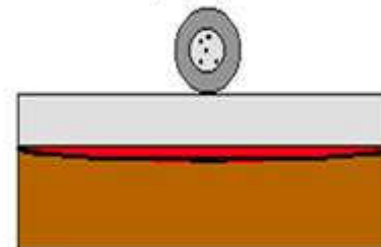
**Rigid Pavement**

**Asphalt Section**

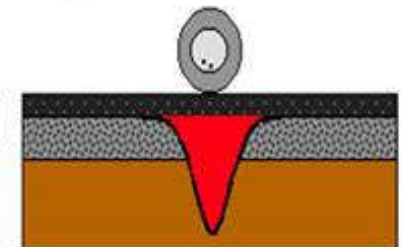


**Flexible Pavement**

**Concrete (Rigid) Pavement**

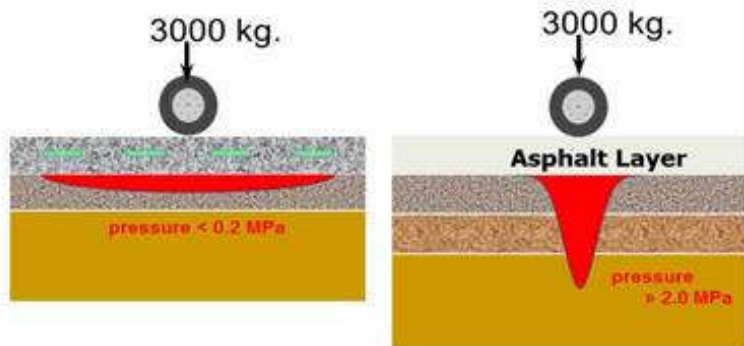


**Asphalt (Flexible) Pavement**



*Concrete acts more like a bridge over the subgrade. Inch-for-inch much less pressure is placed on materials below concrete than asphalt pavements.*

### How Pavements Carry Loads



Concrete's Rigidness spreads the load over a large area and keeps pressures on the sub-grade low.

**Design Guidelines of IRC:58 are applicable for roads having a daily commercial traffic (vehicles with laden weight more than 3t) over 450**

**For low traffic volume roads, IRC:SP:62-2014 shall be followed.**

### Recommended Temperature Differentials for Concrete Slabs as per IRC: 58-20015

Zone	Stages	Temperature Differential, °C In Slabs of Thickness			
		150 mm	200 mm	250 mm	300 to 400mm
1	Punjab, U.P. Rajasthan, Haryana and North M.P. excluding hilly regions and coastal areas	12.5	13.1	14.3	15.8
2	Bihar, West Bengal Assam and Eastern Orisa excluding hilly regions and coastal areas	15.6	16.4	16.6	16.8
3	Maharashtra, Karnataka, South M.P., Andhra Pradesh, Telangana, Western Orissa and North Tamil Nadu excluding hilly regions and coastal areas	17.3	19.0	20.3	21.0
4	Kerala and South Tamil Nadu excluding hilly regions and coastal areas	15.0	16.4	17.6	18.1
5	Coastal areas bounded by hills	14.6	15.8	16.2	17.0
6	Coastal areas unbounded by hills	15.5	17.0	19.0	19.2

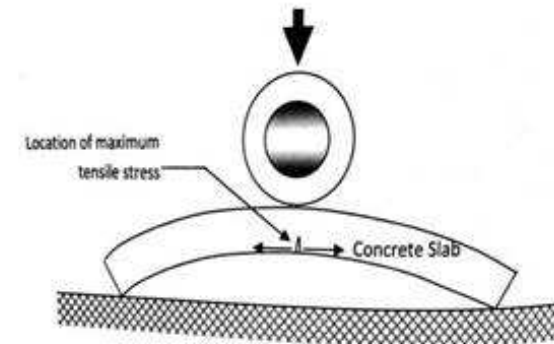
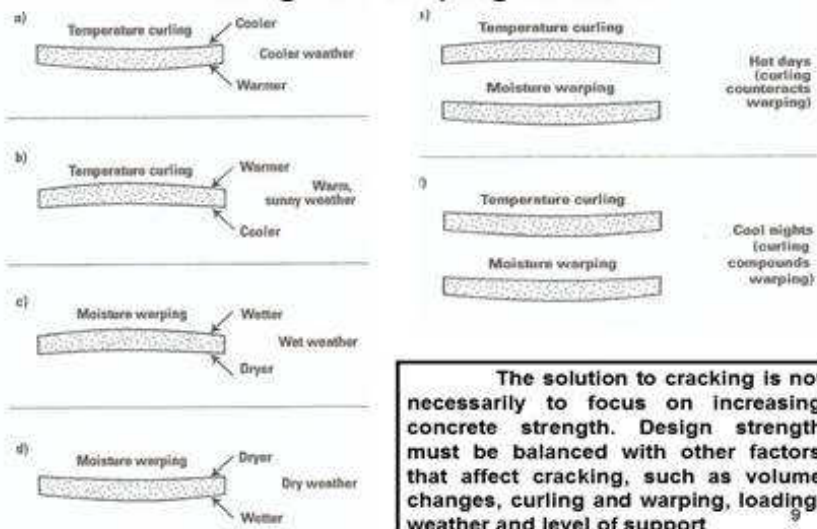
### Relationship between k value and CBR value of homogeneous sub grade

CBR Values %	2	3	4	5	7	10	15	20	50	100
K-Value (MPa/m)	21	28	35	42	48	55	62	69	140	220

K-Value of sub grade (Mpa/m)	Effective k of untreated granular sub base of thickness in mm			Effective k value of cement treated sub base of thickness in mm		
	150	225	300	100	150	200
28	39	44	53	76	108	141
56	63	75	88	127	173	225
84	92	102	119	-	-	-

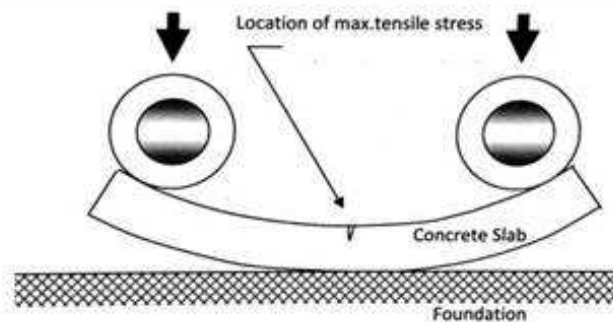
K-value of sub grade (MPa/m)	21	28	42	48	55	62
Effective k for 100mm DLC (MPa/m)	56	97	166	208	278	300
Effective k for 150mm DLC (MPa/m)	97	138	208	277	300	300

## Curling and warping of slabs



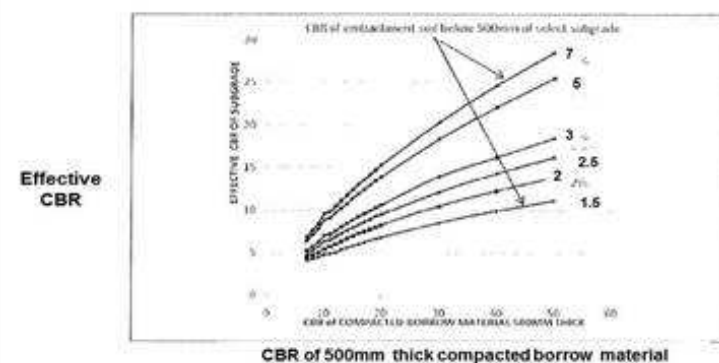
Axle load placed in the middle of the slab during mid day

10



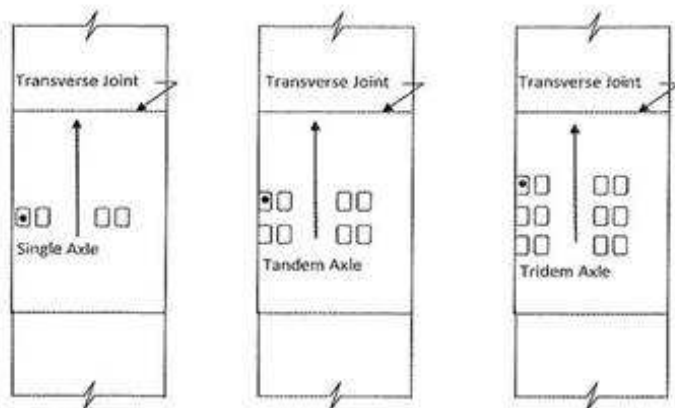
Placement of two axles of a commercial vehicle curled during night hours

11



12

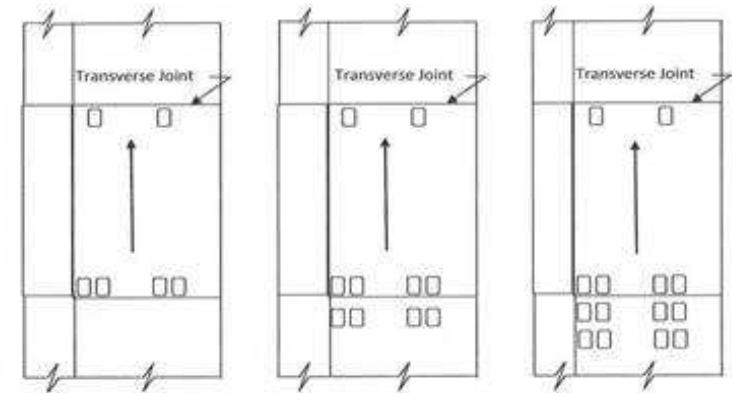




- Location of Maximum Tensile Stress at bottom of slab without concrete shoulders.

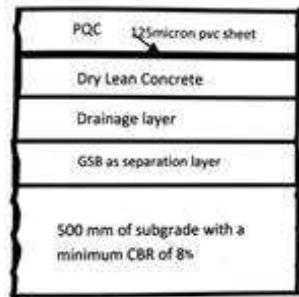
Placement of axles for maximum edge flexural stress at bottom of the slab without concrete shoulders

13

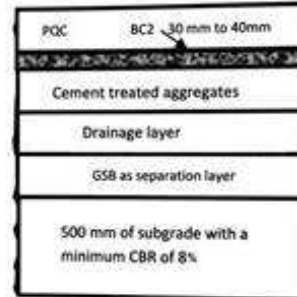


Different axle load positions causing tensile stress at the top fiber of the slab with tied concrete shoulder

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Debonding layer of polythene sheet over DLC



Debonding layer of 30 to 40mm BC over cement treated aggregate sub base layer

Typical cross section of concrete pavement for high volume traffic roads

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IRC:68-2015 Guidelines for Design of Plain Jointed Rigid Pavements for Highways									
Example of Design of Sub-Thickness for Pavement									
Axle Load Spect									
Type of pavement considered									
Proposed Structural Details									
Design Data		Proposed Structural Details							
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**Pavement Thickness for traffic up to 50 CVPD as per IRC:SP:62-2014**

**WBM or WMM 75mm thick over GSB(min.CBR=30, LL<25% and PI<6%) 100mm is considered.** Alternately 150mm thick Cementitious granular layer using marginal aggregates with minimum UCS of 3MPa at 7days with cement or at 28days with lime or lime-fly ash

**Sub-Grade CBR is 4%. Effective k is  $35+7=42\text{MPa}(35+20\%\text{of } 35)$ .**

**Thickness for dual wheel load of 60KN is 160mm for all the joint spacing of 2.5m, 3.25m and 4m.**

**Temperature stresses not considered.**

**For other k values, excel sheet can be used to get thickness.**

**A minimum thickness of 150mm is recommended for even higher values of effective k.**

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**M30(minimum flexural strength of 3.8MPa at 28days) Concrete Pavement thickness for traffic between 50 to 150 CVPD and sub-grade CBR 4% as per IRC: SP:62-2014**

Joint spacing in m	Pavement Thickness(mm)					
	Wheel load – 50 kN					
	Zone-i	Zone-ii	Zone-iii	Zone-iv	Zone-v	Zone-vi
4.00	180	180	190	180	180	180
3.25	170	170	170	170	170	170
2.50	160	160	160	160	160	160

GSB 100mm + WBM or WMM 75mm. Alternately 100mm thick Cementitious granular layer with minimum UCS of 3MPa at 7days with cement or at 28days with lime or lime-fly ash+100mm thick cementitious layer with natural material having minimum UCS of 1.5MPa at 7days with cement or at 28 days with lime or lime-fly ash

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**M30(minimum flexural strength of 3.8MPa at 28days) Concrete Pavement thickness for traffic of 250 CVPD and sub-grade CBR 8% as per IRC: SP:62-2014**

Joint spacing in m	Pavement Thickness (mm)					
	Wheel load – 50 kN					
	Zone-i	Zone-ii	Zone-iii	Zone-iv	Zone-v	Zone-vi
4.00	180	180	190	180	180	180
3.25	170	170	170	170	170	170
2.50	160	160	160	160	160	160

(GSB 100mm+WBM/WMM150mm )  
or Cementitious base 200mm (100+100)

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**MORT&H(5<sup>th</sup> revision) TABLE 400-1, GSB grading requirements**

IS Sieve size	Percent by weight passing through the IS sieve					
	Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
75.0mm	100	--	--	-	100	-
53.0mm	80-100	100	100	100	80-100	100
26.5mm	55-90	70-100	55-75	50-80	55-90	75-100
9.50mm	35-65	50-80	-	-	35-65	55-75
4.75mm	25-55	40-65	10-30	15-35	25-50	30-55
2.36mm	20-40	30-50	-	-	10-20	10-25
0.85mm	-	-	-	-	2-10	-
0.425mm	10-15	10-15	-	-	0-5	0-8
0.075 mm	< 5	< 5	< 5	< 5	-	0-3

**MORT&H (5<sup>th</sup> revision) TABLE 400-2, Physical Requirements of GSB materials**

Aggregate Impact Value (AIV)	IS:2386-part 4 or IS:5640	40 Maximum
Liquid Limit	IS:2720-part 5	25 Maximum
Plasticity Index	IS:2720-part 5	6 maximum
CBR at 98% dry density (IS:2720-part 8)	IS:2720-part 16	Minimum 30 unless otherwise specified

If water absorption is greater than 2%, Wet Aggregate Impact test shall be done. Grading III and IV are preferable for LSB. Gradings V and VI are for USB and drainage layer.

### **Granular Sub Base as per IRC:15 and 58-2015**

- 1) Material passing 75 micron sieve shall be less than 5%. It shall be restricted to 2% for drainage layer in high rainfall areas.
- 2) Material in mix shall have 10% fines value > 50 KN
- 3) For drainage layer, the Los Angeles Abrasion value shall not be less than 40%
- 4) Material in mix passing 425 micron sieve shall have Liquid limit < 25% and Plasticity index < 6%.
- 5) Material in the mix shall satisfy specified grading
- 6) CBR: It shall not be less than 30%
- 7) Minimum permeability coefficient is 30m/day (for low rainfall area) It is 300m/day for drainage layer.
- 8) Water absorption of aggregates shall be less than 2%. If not, soundness test shall be conducted as per IS:383

### **Cements that can be used as per IRC: 44-2008**

Any of the following types of cements capable of achieving the design strength and durability may be used with the prior approval of the Engineer.

1. Ordinary Portland Cement, 43 grade, IS: 8112
2. Ordinary Portland Cement, 53 grade, IS: 12269
3. Portland Pozzalona Cement (fly ash based, IS: 1489, part1) Fly ash conforming to IS:3812 part 1 shall not exceed 20%
4. Portland Slag Cement, IS: 455 with GBFS conforming to IS:12089 shall not exceed 50%

### **Minimum Cement content as per IRC:15-2011**

Design Flexural strength = 4.5MPa at 28 days

- 1)For OPC, the minimum cement content is 360Kg/Cum.
- 2)For fly ash (20% max) blending at site, the minimum OPC shall not be less than 340Kg/Cum.

Maximum limit of OPC content = 425Kg/Cum

- 3)For PPC(max fly ash 20%), minimum PPC is 425Kg/Cum.

- 4) For PSC, maximum PSC shall be 510Kg/Cum

Additional OPC may be added at contractor's cost to achieve desired strength.

Strength should be checked at 3/7/28 days for PPC/PSC cements

### Physical characteristic requirement of cement

Characteristic	Requirements		
	33 grade IS: 269-1989	43 grade IS: 8112-1989	53 grade Is: 12269-1987
Minimum compressive strength in N/mm <sup>2</sup>			
3 days	16	23	27
7 days	22	33	37
28 days	33	43	53
Fineness (minimum) (M <sup>2</sup> /Kg)	225	225	225
Setting time (minutes)			
Initial – (minimum)	30	30	30
Final – (maximum)	600	600	600
Soundness, expansion			
Le Chatleier– (maximum) mm	10	10	10
Autoclave test–(maximum) %	0.80	0.80	0.80 <sup>25</sup>

Table 1 of IRC:15-2011 or Table 4 of IS:383 for fine aggregates

IS Sieve Designation	Percent passing			
	Grading Zone-I	Grading Zone-II	Grading Zone-III	Grading Zone-IV
10mm	100	100	100	100
4.75mm	90 – 100	90 – 100	90 – 100	95 – 100
2.36mm	60 – 95	75 – 100	85 – 100	95 – 100
1.18mm	30 – 70	55 – 90	75 – 100	90 – 100
600microns	15 – 34	35 – 59	60 – 79	80 – 100
300microns	5 – 20	8 – 30	12 – 40	15 – 50
150microns	0 – 10	0 – 10	0 – 10	0 – 15

Fineness Modulus of fine aggregates: 2.0 to 3.5.  
Total % of all Deleterious materials be less than 5%



### Physical Requirements of Coarse Aggregates They shall satisfy requirements of IS:383 and

**Los Angeles Abrasion Value  $\leq$  30%**  
**Maximum size is 26.5mm.**  
**Water Absorption  $\leq$  3%.**

**No aggregates failing soundness test as per IS:2386 part V shall be used.**  
**Loss shall not be more than 12% in Sodium Sulphate solution and 18% in Magnesium sulphate solution.**  
**Combined FIV and EIV  $\leq$  35%**



## Dry Lean Concrete Sub Base

Size of coarse aggregate: 26.5mm preferably

Fine aggregate:

Clean natural sand or crushed grit or both

Cement: 150 kg minimum

28 day Average Compressive Strength  
of 5 cubes  $\geq 10\text{MPa}$

7 day Compressive Strength  
of any single cube  $\geq 7.5\text{ MPa}$

Table 2 of IRC:15-2011: Combined Gradation of Coarse and fine aggregates for Dry Lean Concrete

IS Sieve Size	Percent by Weight Passing the Sieve
26.5mm	100
19 mm	80-100
9.5 mm	55-75
4.75 mm	35-60
0.600mm	10-35
0.075mm	0-5

Table 3 of IRC:15-2011: Combined Gradation of Coarse and fine aggregates for Pavement Quality Concrete

IS Sieve Size	Percent by Weight Passing the Sieve
31.5mm	100
26.5mm	85-95
19 mm	68-88
9.5 mm	45-65
4.75 mm	30-55
600 micron	8-30
150 micron	5-15
75 micron	0-5

### Mineral Admixtures as per IRC:15-2011

Mix design shall be done as per IRC:44-2008

Fly Ash as per IS:3812 (Part-I)-2003. Maximum dosage 20 percent by mass of cementitious materials.

Granulated blast furnace slag as per IS:12089. (up to 50% as per IS 455 ). Good in coastal region.

Silica Fume as per IS:15355 and IS:456, IRC :SP:70, up to 10%. Use of silica fume is generally advantageous for higher grades of concrete i.e. M50 and above.



### Fibers

Fibers may be used subject to the provision in the design/approval by the engineer to reduce shrinkage cracking and post cracking. The fibers may be steel fibers as per IRC:SP:46 or polymeric synthetic fibers.

When fibers are used the mix shall be so designed that the slump of concrete at paving shall be in the range of  $25 \pm 10$  mm and that in manual construction the slump shall be in the range of  $40 \pm 10$  mm

Permissible limits for solids in Water  
Cl. 5.4 of IS: 456-2000

	Tested as per	Permissible limit maximum
Organic	IS 3025 part 18	200 mg/l
Inorganic	IS 3025 part 18	3000 mg/l
Sulphate as $\text{SO}_3$	IS 3025 part 24	400 mg/l
Chloride as cl	IS 3025 part 32	2000 mg/l for PCC 500 mg/l for RCC
Suspended matter	IS 3025 part 18	2000 mg/l

pH value of water shall not be less than 6.

### Water for mixing and curing as per IS:456

Potable water is generally considered satisfactory for both mixing and curing.

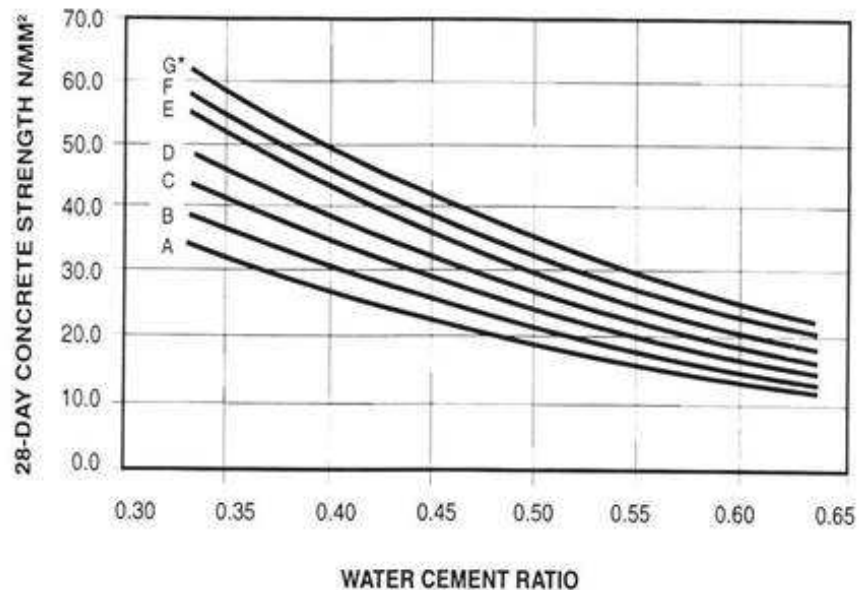
In case of doubt, 28 days average compressive strength of at least three 150mm cubes prepared with water proposed to be used shall not be less than 90% of the average strength of 3 similar cubes prepared with distilled water.

Initial setting time of test block made with water proposed to be used shall not be less than 30 minutes and shall not differ by  $\pm 30$  minutes from the initial setting time of test block prepared with distilled water.

### Concreting in Hot weather

No concreting shall be done when the concrete temperature is above  $30^\circ\text{C}$ . It is desirable to install a chilling plant to control the concrete temperature.

As placing of concrete in air ambient temperature above  $35^\circ\text{C}$ , relative humidity less than 25% or wind velocity more than 15kmph requires adequate protective measures. Otherwise defects like loss of workability through accelerated setting, rapid hydration, loss of workability, increase in water requirement and formation of shrinkage cracks are likely.



### Coefficient of Permeability for different W/C ratios

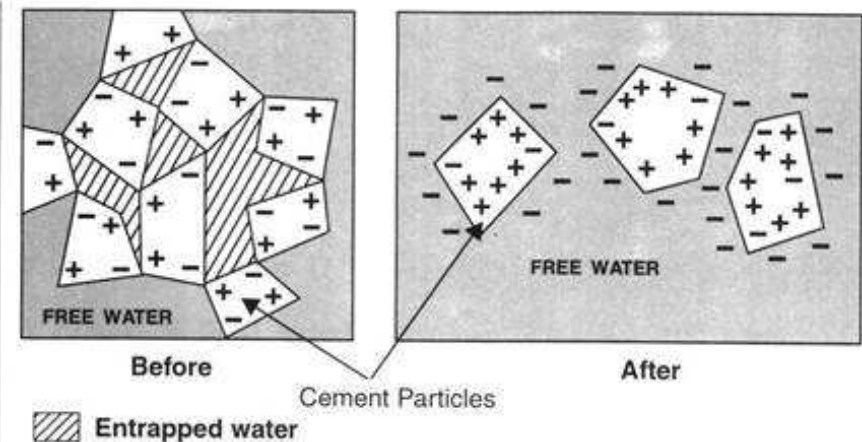
S.No	W/C ratio	Coefficient of Permeability
1	0.35	$1.05 \times 10^{-3}$
2	0.50	$10.30 \times 10^{-3}$
3	0.65	$1000 \times 10^{-3}$

### Function of Plasticizers

(Admixtures conforming to IS:6925 and IS:9103 may be used up to 2% by weight as per IS:456)

Fine cement particles being very small clump together and flocculate when water is added to concrete. This ionic attraction between the particles trap considerable volume of water and hence water required for workability of concrete mix is not fully utilised. Negative charges are induced on the fine cement particles causing flocks to disperse and release the entrapped water. Water reducing admixtures or plasticizers therefore help to increase the flow of the concrete mix considerably.

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## Compaction of Concrete

Compaction is necessary to remove entrapped air present in concrete after it is mixed, transported and placed. Compaction also eliminates stone pockets and remove all types of voids. Consolidation is the process of making the freshly placed PCC into a more uniform and compact mass by eliminating undesirable air voids and causing it to move around potential obstructions (such as reinforcing steel).

Vibrators work by rotating an eccentric weight which causes the entire vibrator to move back and forth. This movement excites particles within the PCC mass, causing them to move closer together and better flow around obstructions. On vibration, concrete mix gets fluidized resulting in entrapped air raising to the surface and concrete becoming denser

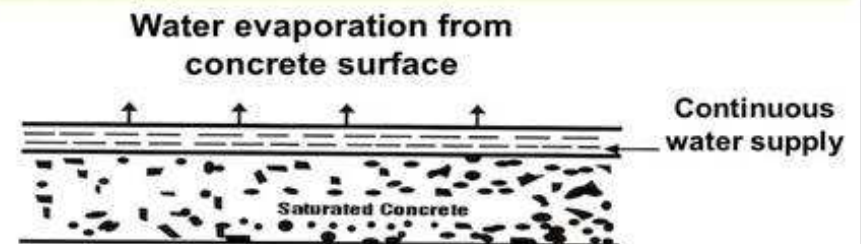


### Guidelines for compaction with Pin Vibrator

- 1) Insert poker quickly and allow it to penetrate by its own weight to the bottom of layer so that the entrapped air is removed uniformly.
- 2) Leave the poker in concrete for 10 seconds. Compaction time depends on slump.
- 3) Poker must be inserted quickly, but withdrawal must be slow so that the hole left by the poker is filled up as it is being withdrawn.
- 4) Locations of poker insertion should be staggered.
- 5) Avoid touching the form work and reinforcement with poker.
- 6) Poker should extend upto 100mm into the previous layer.

### Concrete Curing

Curing is the process of maintaining a satisfactory moisture content and favorable temperature in the concrete during hydration of cementitious material so that the desired properties of the concrete are developed. Its objective is specifically to keep the concrete saturated until the water filled spaces in the fresh cement paste are filled to the desired extent by products of the hydration.





## **Factors Affecting Water Evaporation from Concrete Surface**

**Air Temperature  
Fresh Concrete Temperature  
Relative Humidity  
Wind Velocity**

## **Methods of Curing**

1. **Ponding with water**
2. **Covering concrete with wet burlaps which are maintained close to the concrete surface**
3. **Intermittent spraying with water and continuous sprinkling of water**
4. **Covering concrete with wet sand, saw dust etc.,**
5. **Covering with polyethylene sheets or water proof paper and holding it in position**
6. **Curing with liquid membrane forming curing compounds**

## **Effects of Improper Curing**

- ❖ **Lowering of compressive and flexural strengths**
- ❖ **Sanding and dusting of surface and lower abrasion resistance**
- ❖ **Higher permeability and lower durability**
- ❖ **Cracks due to plastic shrinkage, drying shrinkage and thermal cracking**
- ❖ **Increased rate of Carbonation and chloride ingress**
- ❖ **Lower weathering and frost resistance**

**Observe the freshly laid concrete in dried up condition.**





Gunny rolls used for primary curing.



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Coconut coir for both primary and secondary curing



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### Joints in Rigid pavements

Joints are provided in cement concrete roads for expansion, contraction and warping of slabs due to the variation in the temperature of slab.

Initial cut or slot not less than 3mm and a depth of  $\frac{1}{3}$ rd to  $\frac{1}{4}$ th of PQC slab at transverse or longitudinal joint as soon as concrete hardens.

During summer (ambient temperature is more than 30°C), cutting may be carried after 4-8 hours of laying.

When the temperature is less than 30°C, joint cutting may be done 8-12 hours of laying.

Where the use of maturity meter is specified, sawing shall be carried out when the compressive strength of concrete is in the range from 2MPa to 7MPa.

### Types of joints

- a) Contraction joints
- b) longitudinal joints
- c) Expansion joints
- d) Construction joints

### Requirement of good joints

- a) Joints must move freely
- b) Joints must not allow infiltration of rain water and ingress of stone grits
- c) Joints must not protrude out the general level of the slab

**Note:** It is desirable that joints be constructed in line across the full width of pavement. Staggered or skew joints are not desirable.

### Formation of joints

**Use of Preformed strips for forming joints**

**Metal T or flat**

**Crack inducers**

**Sawn joints**

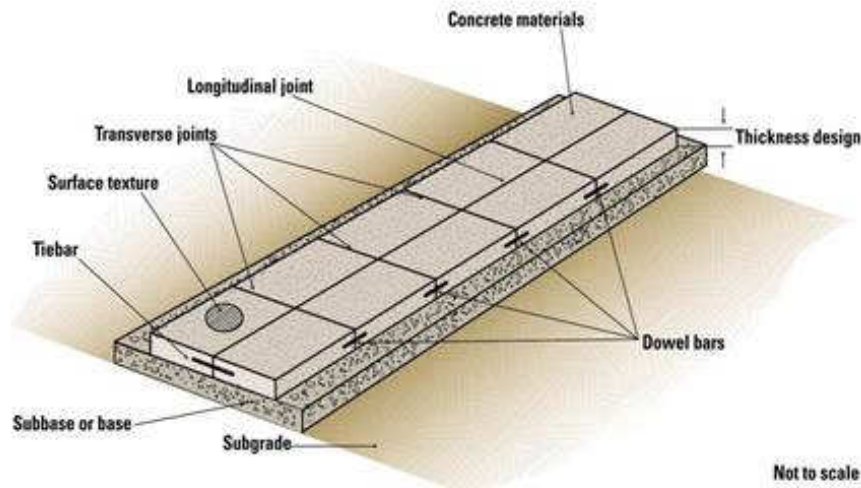
### a) Contraction joints:

These are purposely made weakened planes which relieve the tensile stresses in the concrete caused due to changes in the moisture content (Drying shrinkage) and/or temperature and prevent the formation of irregular cracks due to restraint in free contraction of concrete.

They are also provided to

- 1) Relieve stresses due to warping.
- 2) To permit the contraction of the slab.

The spacing of Contraction joints should be limited to 4.5m





### **Why are Controlled Cracks at contraction Joints Preferable to Random Cracks?**

- 1) Properly constructed contraction joints have many benefits.
- 2) Joints can be sealed more efficiently to limit infiltration of harmful materials.
- 3) Joints prevent the slab from randomly cracking into small, weak pieces.
- 4) Joints can be constructed with dowel bars and tie bars to prevent slab deflection at the joints and to allow proper transfer of vehicle loads between pavement sections (panels).
- 5) Joints help designate lanes.
- 6) Joints generally provide a smoother ride than random cracks

Details of the contraction joints are given in IRC:15. They are formed initially by sawing a groove of 3-5 mm with up to about one-fourth to one-third the slab thickness. This facilitates the formation of a natural crack at this location extending to the full depth. In order to seal the joint, the top 10-20 mm of this groove is widened to 6-10 mm.

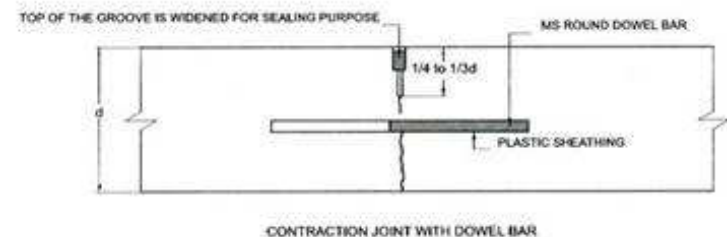
For heavy traffic, greater than 450CVPD, these joints are provided with steel dowel bars to improve the continuity of slab and improved performance of joints, including load transfer.

A saw cut that has cracked through as planned



### **Contraction Joint details at 4.5m C/C**

IRC:57-2006



Joints 3 to 5mm wide are to be cut to  $\frac{1}{3}$  to  $\frac{1}{4}$  depth  
Dowel bars (MS Rounds) are to be placed at mid depth and covered with thin plastic sheathing for  $\frac{2}{3}$  length  
Dowel bars at contraction joints shall be provided for heavy traffic roads (>450CVPD) to increase service life.

### **b) Longitudinal joints:**

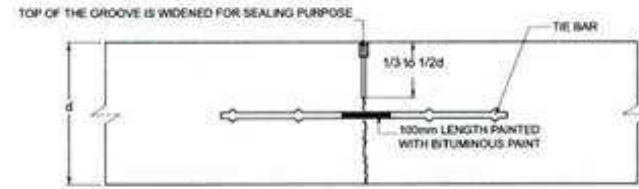
Lanes are jointed together by joint known as Longitudinal joint

Longitudinal joints are provided in multilane pavements and also when the pavement is more than 4.5 m wide.

They are provided normally at 3.5m c/c to

- 1) Relieve stresses due to warping.
- 2) To allow differential shrinkage & swelling due to changes of sub grade moisture
- 3) To prevent longitudinal cracking

### **Longitudinal Joint**



LONGITUDINAL JOINT WITH TIE - ROD BETWEEN TWO LANES

Longitudinal Joints are to be provided when width is more than 4.5m. Joints are to be saw cut to  $\frac{1}{3}$ rd slab thick  $\pm 5$ mm. Bars are to be placed middle third of slab thickness. Tie bars are to be coated with bitumen paint for 75mm on either side

### **c) Expansion joints**

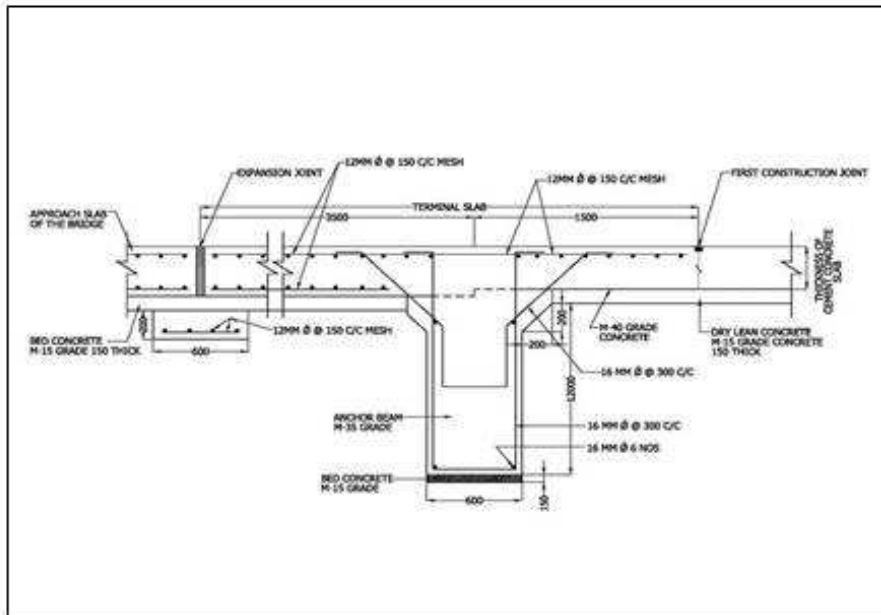
There are full-depth joints provided transversely into which pavement can expand, thus relieving compressive stresses due to expansion of concrete slabs, and preventing any tendency towards distortion, buckling, blow-up and spalling.

These joints are very difficult to maintain and they get filled up with dirt etc. causing locking of joints. They are therefore not in use. The current practice is to provide these joints only when concrete slab abuts with bridge or culvert.

### **Anchor Beam and terminal slab adjoining Bridge and Culvert structures.**

Cement Concrete slab will expand during hot season and this will aid in the building up of horizontal thrust on adjoining bridge structure. To contain this thrust RCC anchor beams or approach slab are to be provided in the terminal slab with reinforcement. In case of culverts etc., where the concrete slabs are provided above the superstructure, there is no need to construct anchor beam or approach slab in the terminal slab.



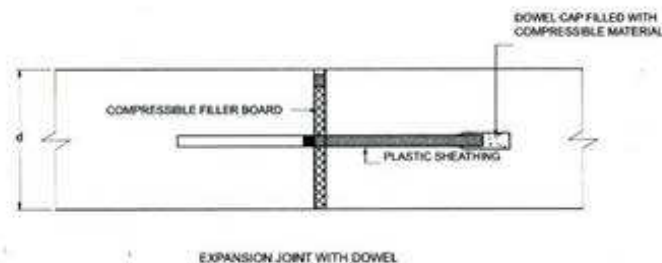


## Pre-moulded joint filler

Joint filler board for expansion joints which are proposed for use only at bridges and culverts shall be of a synthetic compressible material having compressibility more than 25% as per IS:1838

Holes to accommodate dowel bars shall be accurately bored or punched out to give sliding fit on the dowel bars.

## Expansion Joint



**Filler board: compressible Joint filler 20 to 25mm  $\pm$  1.5mm**  
**Filler depth 25mm  $\pm$  3mm lower than slab thickness**  
**Dowel bars (MS rounds) to be covered with plastic sheathing for  $\frac{1}{2}$  length +50mm**

## d) Construction joints:

The need for such joint arises when construction work is required to be stopped at a place other than the location of contraction or an expansion joint, due to some breakdown of the machinery or any other reason. Such joints are of butt type and extend to the full depth of the pavement. The sealing of such joints shall be done in the same manner as for contraction joints, by cutting a groove 10-12 mm wide and 20-25 mm deep. Generally, such joints are avoided in highways. The work is normally terminated at a contraction or expansion joint.

### Dowel bars

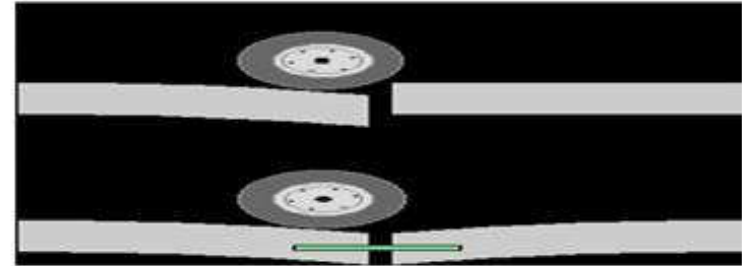
a) Load transfer to relieve part of load stresses in edge and corner regions at transverse joints is provided by mild steel Dowel bars. Coated Dowel bars are often to prevent corrosion. Dowel bars are assumed to transfer about 40% of wheel load.

b) Dowel bars embedded and fixed in concrete at one end and kept free to expand / contract at the other end

c) Spacing between dowel bars normally 30 cm

d) The size varies from 25 - 38 mm and length 36-50 cm

### Necessity of providing dowel bars



**Table 5 of IRC:58-2015 Recommended Dimensions of Dowel bars**

Slab thickness mm	Dowel bar details		
	Diameter mm	Length mm	Spacing mm
200	25	360	300
230	30	400	300
250	32	450	300
280	36	450	300
300	38	500	300
350	38	500	300

Note: Dowel bars shall not be provided for slabs of less than 200mm thick. For heavy traffic, more than 450 CVPD, dowel bars shall be provided at contraction joints also,

Shuttering sheets for MS dowels just removed, Removed bulkhead is also seen.



Contraction joint 3 to 5 mm wide  
1/3 to 1/4 in depth



Table 6 of IRC:58-2015, Details of tie bars for longitudinal joint

Slab thickness mm	Dia mm	Max. spacing mm		Max. length mm	
		Plain bars	deformed	Plain bars	deformed
150	8	330	530	440	480
	10	520	830	510	560
200	10	390	620	510	560
	12	560	900	580	640
250	12	450	720	580	640
300	12	370	600	580	640
	16	660	1060	720	800
350	12	320	510	580	640
	16	570	910	720	800

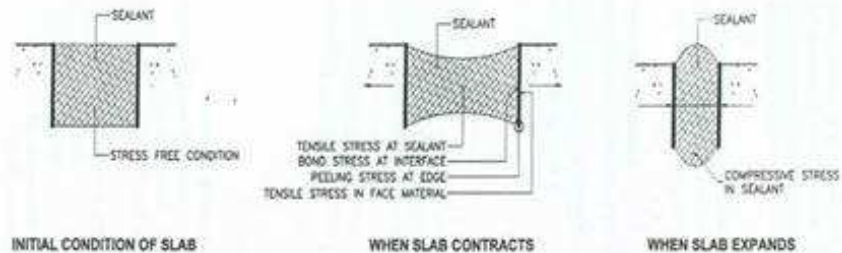
## Requirements of joint sealants

- Elastic even at low temperatures
- Should not flow in summer
- Should not become sticky resulting in loss of sealant
- Should not undergo permanent deformation
- Should have resistance to intrusion of solids
- Should have high resistance to hardening with age
- Should have high bonding property with adjoining concrete
- Should not shrink after they have been poured

## Types of sealants

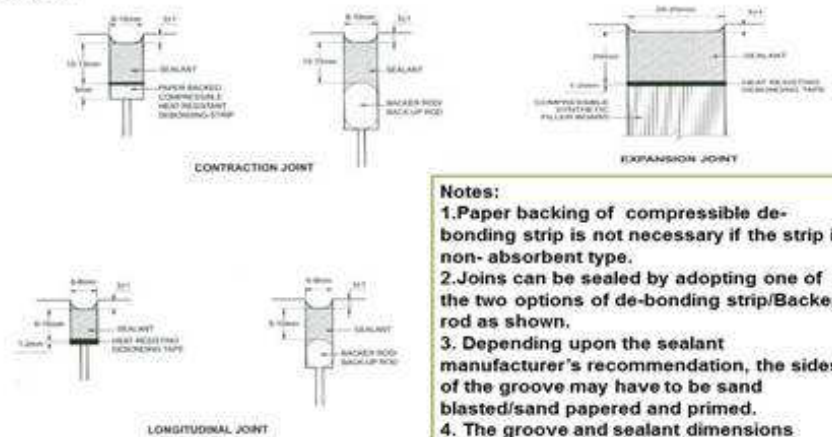
- Polysulphide: IS:11433 part , BS:5212 part2
- Polyurethane: BS 5212
- Silicone: ASTM 5893-04
- Preformed Seals: ASTM D 2628





**Stress Generated in Field-Moulded Sealants due to Temperature Changes as per IRC:57-2006**

IRC:57-2006



**Sealing Details of Joints  
(Grooves Suitable for Hot Poured  
Rubberised Bitumen Sealant)**

**Notes:**

1. Paper backing of compressible de-bonding strip is not necessary if the strip is non-absorbent type.
2. Joints can be sealed by adopting one of the two options of de-bonding strip/Backer-rod as shown.
3. Depending upon the sealant manufacturer's recommendation, the sides of the groove may have to be sand blasted/sand papered and primed.
4. The groove and sealant dimensions shown are only for guidance.
5. Backer rod/Back-up rod shall be expanded closed-cell polyethylene foam.
6. Ends of the sealing groove shall be plugged.
7. All dimensions are in mm.

**EXECUTION METHODOLOGY  
Pavement Quality Concrete (PQC)**



**Fixing of Back up Rod after Initial Cut**

**EXECUTION METHODOLOGY  
Pavement Quality Concrete (PQC)**



**Cleaning of Groove with Compressed Air**



EXECUTION METHODOLOGY  
Pavement Quality Concrete (PQC)



**Finishing of Sealant**

EXECUTION METHODOLOGY  
Pavement Quality Concrete (PQC)



**Finished PQC surface with Sealed Joints**

EXECUTION METHODOLOGY  
Pavement Quality Concrete (PQC)



**Finished PQC Surface showing Texturing**

Joints sealed with hot-pour liquid sealants. Normally these joints should coincide with lane divisions



Groove before sealant fill.



Removing surplus sealant



View after filling sealant.



Preparation for slump test, casting cubes (150 mm) and beams (70 x 15 x 15 cm)





**12.8 of IRC:15-2011 Accepting Criteria of  
Strength  
Flexural Strength:**

i) The mean strength determined from any group of 4 consecutive samples (each sample containing 3 beam specimen) at 28 days should exceed the specified characteristic flexural strength (4.5MPa) by at least 0.3MPa

ii) The strength of any specimen is not less than the specified characteristic flexural strength (4.5MPa) minus 0.3MPa

**12.8 of IRC:15-2011 Accepting Criteria of  
Strength  
Compressive Strength:**

i) The mean strength determined from any group of 4 consecutive samples (each sample containing 3 cube specimen) at 28 days should exceed the specified characteristic compressive strength by at least 0.3MPa

ii) The strength of any specimen is not less than the specified characteristic compressive strength minus 0.3MPa

**12.21 of IRC:15-2011 Quality Control Chart-Cores**

A quality control chart indicating the strength values of individual specimens shall be maintained for continuous quality assurance. Where the requirements are not met with, or the quality of concrete or compaction is suspect, the actual strength of concrete in slab shall be ascertained by carrying out tests on cores at the rate of 2 cores /150cu.m of concrete. The average crushing strength of these cores shall not be less than  $0.8 \times 0.85$  times the corresponding characteristic compressive strength of cubes, where the height to diameter ratio is 2.0.

Dia. of core shall not be less than 150mm.

Core cutting to verify inner depth and compressive strength.



Correction factor is to be applied if the height to diameter of core is 1 to 2

$$f = 0.11 n + 0.78$$

where f = correction factor and  
n = height to diameter ratio

The corrected test results shall be analysed for conformity with specification requirement for cube samples.

If the cores are cut within 90 days of casting the slab, no allowance for age factor is required. The strength of the core may be considered as at 28 days. However, if the cores are cut after 90 days, an age factor of 115% of 28 days' strength of core may be applied.

### Physical and Chemical Tests on Cement

As per  
requirements of IS  
Codes:  
455, 1489, 8112,  
12269 and 12330

Once for each source of supply and occasionally when called for long/improper storage. Besides, the contractor will submit daily test data on cement released by the contractor.

### Physical tests on Coarse and Fine Aggregates 1

Gradation as per IS:2386 part 1 and deleterious constituents as per IS:2386 part 2

One test for every day's work of each fraction of coarse aggregate and fine aggregate, initially; may be relaxed at the discretion of engineer

Water Absorption as per IS: 2386 part 3

Regularly as required subject to a minimum of one test a day for coarse aggregate and 2 tests a day on fine aggregate. This data shall be used for correcting the water demand of the mix on daily basis

### Physical tests on Coarse and Fine Aggregates 2

Los Angeles Abrasion Value or Aggregate Impact Value  
As per IS:2386 part 4

Once for each source of supply and on monthly basis

Soundness as per IS:2386 part 5

Before approving the aggregates and monthly subsequently

Alkali aggregate reactivity as per IS:2386 part 7

Before approving the aggregates and monthly subsequently



### Tests on Water and Mineral Admixtures

<b>Mineral Admixtures</b>	One from each source as per IS:3812, IS:12089 and IS: 15388
<b>Water Chemical tests As per IS:456</b>	Once for approval of source of supply, subsequently only in case of doubt

### Tests on concrete 1

<b>Strength of Concrete as per IS: 516</b>	3 cubes and 3 beams per 200 cu.m or minimum 6 cubes and 6 beams per day's work whichever is more
<b>Core Strength on hardened Concrete as per IS:516</b>	As per the requirement of Engineer or 2 cores/km
<b>Workability of fresh concrete as per IS:1199</b>	1 test per dumper load at both batching plant site and paving site initially when work starts. Subsequently sampling may be done from alternate dumper

### Tests on concrete 2

<b>Thickness Determination</b>	From the level data of concrete pavement surface and sub base at grid points of 5m×3.5m or 6.25m×3.5m. Cores may be cut in case the Engineer desires.
<b>Thickness measured for trial length</b>	3 cores per trial length
<b>Verification of level of string line in the case of slip form paving and steel form in case of fixed form paving</b>	String line or steel forms shall be checked for level at an interval of 5m or 6.25m. The level tolerance allowed shall be $\pm 2$ mm. These shall be got approved 1-2 hours before the commencement of concrete activity.

**Concrete overlay over bituminous surface is known as white-topping**

**IRC:SP:76-2015: Tentative Guidelines for Conventional and Thin White Topping**

## Types of White-topping

<b>Conventional</b>	<b>200mm or more</b>	<b>Used on Heavily Trafficked Corridors</b>
<b>Thin</b>	<b>More than 100mm and less than 200 mm</b>	<b>Used for Collector Streets</b>
<b>Ultra Thin</b>	<b>Up to 100 mm</b>	<b>Used for Collector And Local Streets</b>

## Thin White-topping

- Thickness 100-200 mm
- Joint Spacing 1.0 x 1.0 m (0.6m to 1.25m as per IRC: 76)
- Existing Bituminous Layer is Milled to Bond Well to Ensure Composite Action
- Polypropylene Fibers (0.2-0.4% Weight of Cement) Added
- M-40 Concrete is Used

## Ultra Thin White-topping

1. Thickness 50-100 mm
2. Joint Spacing about 1.0 x 1.0 m (0.6m to 1.25m as per IRC: 76)
3. Existing BT is Milled and Concrete is Made to Bond Well to Ensure Composite Action
4. Polypropylene Fibers added (0.2-0.4% Weight of Cement)
5. M-40 Concrete is Used

150mm thick white topping over existing BT road laid for 1km on Banjara Hills road no.10 in Hyderabad

