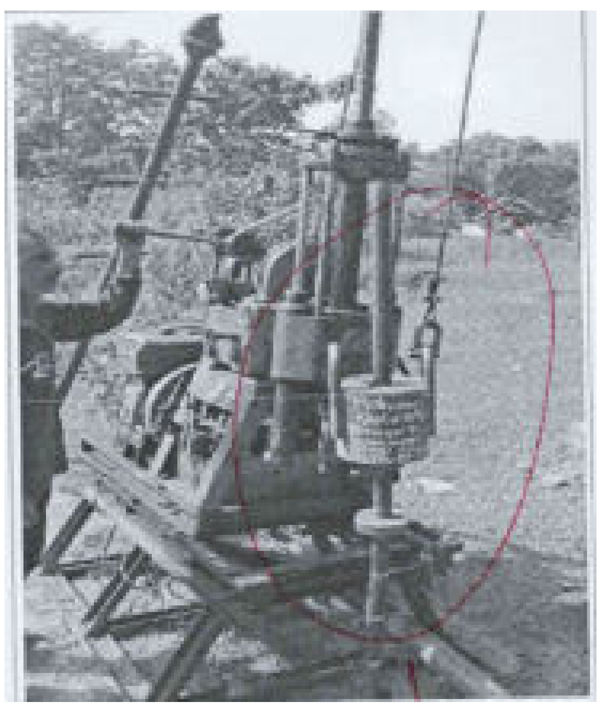
Bridge Construction Issues
Design Practice and Quality Assurance of PoT Bearing
Specification Requirement of DBM/AC

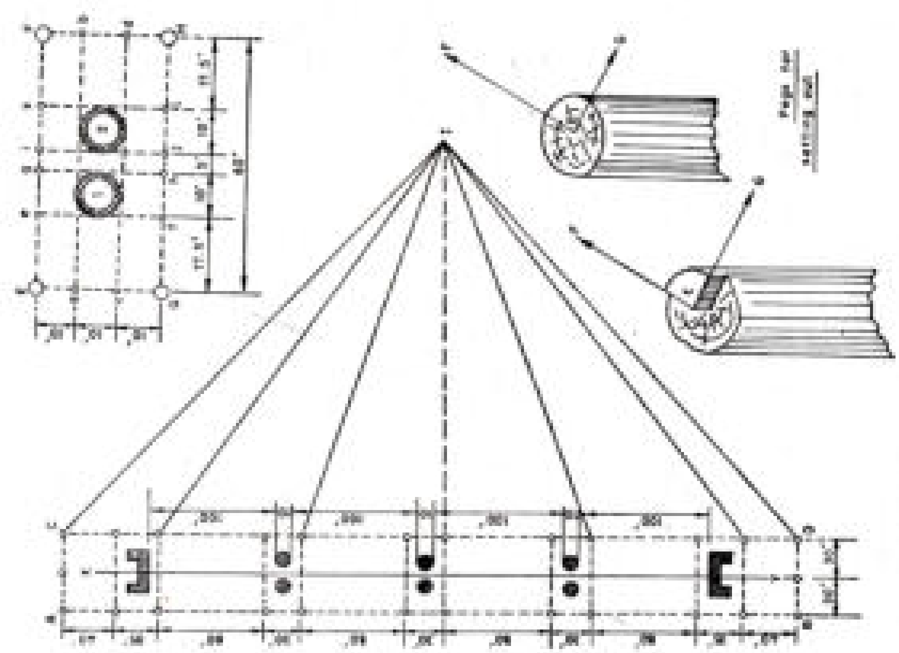
Er. Prabhat Kumar Jha
Senior Divisional Engineer
9841360244
geoprabhat@gmail.com
https://techwingdor.blogspot.com/
https://dor.gov.np/dorqrdc

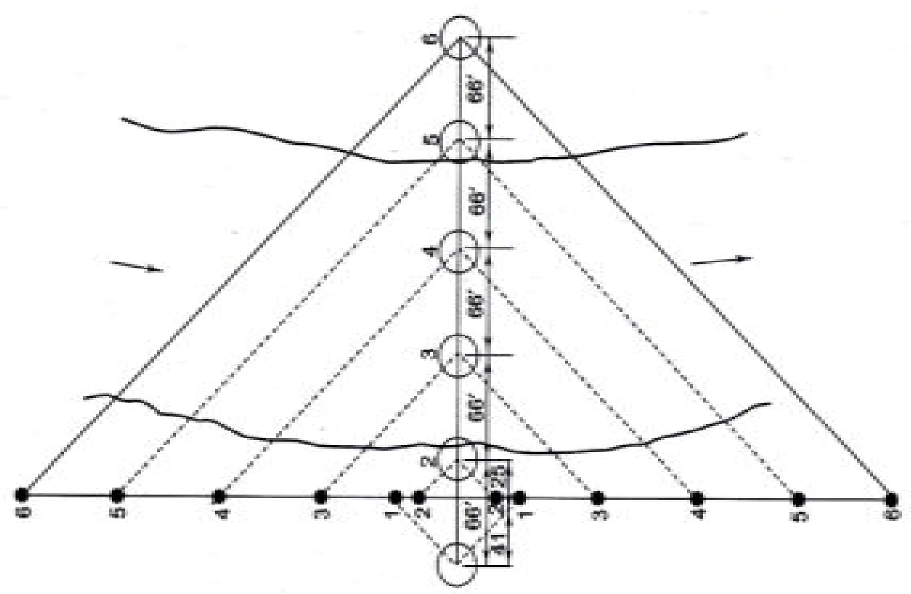


Record Keeping and Documentation

Site Register : with minimum records related to

- Date
- Weather
- Work details
- Labour deployed
- Machine deployed
- Test or Test Samples
- Site Problems





Min. Horizontal distance between bars :

greatest of

dia. of bar

10mm + nominal aggregate size

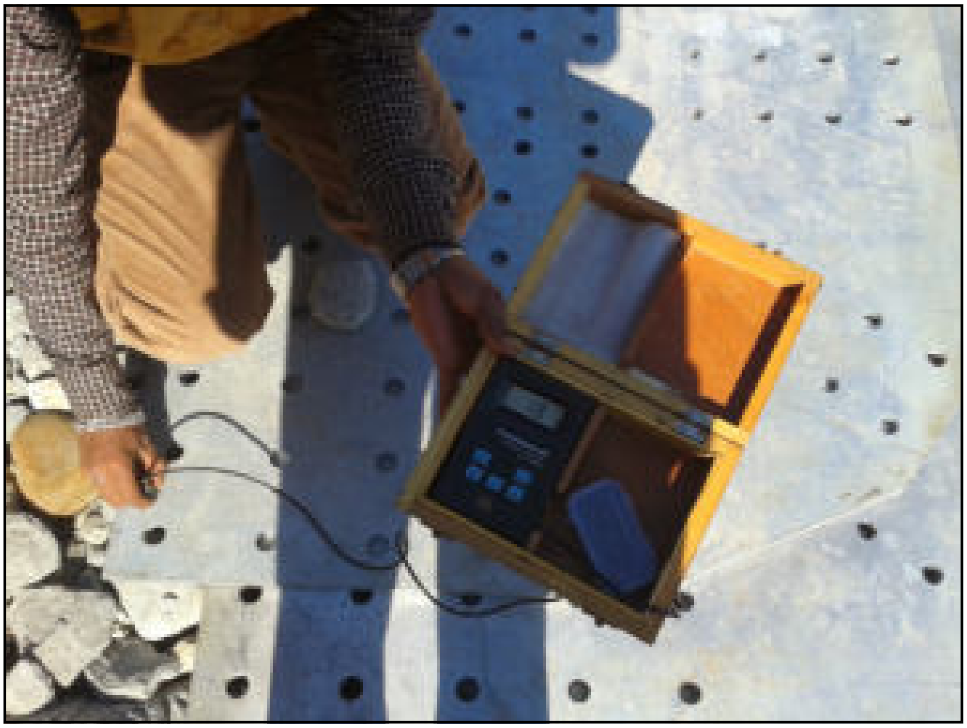
Min vertical distance between bars :

greatest of

12mm or nominal aggregate size

max bar size

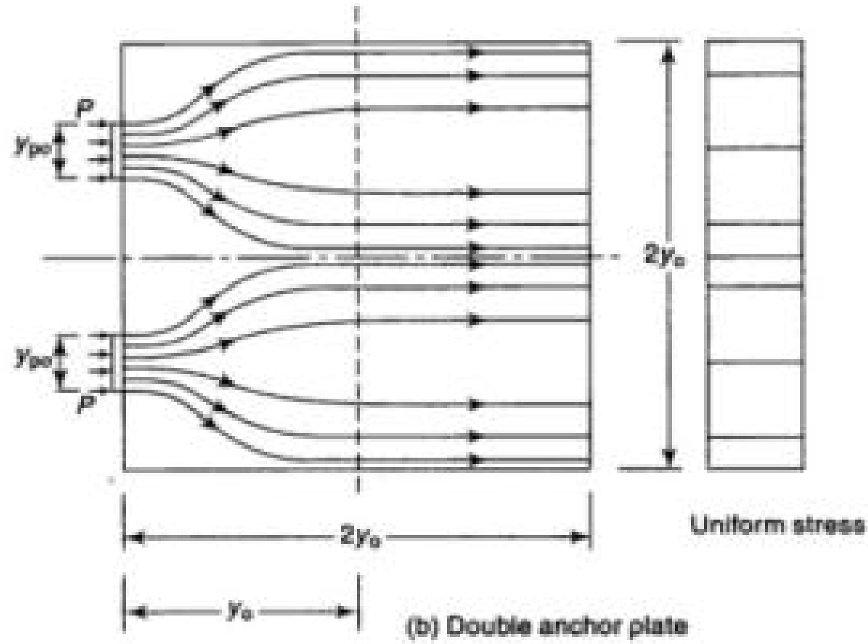
Max. no. of Bar in group = **3**



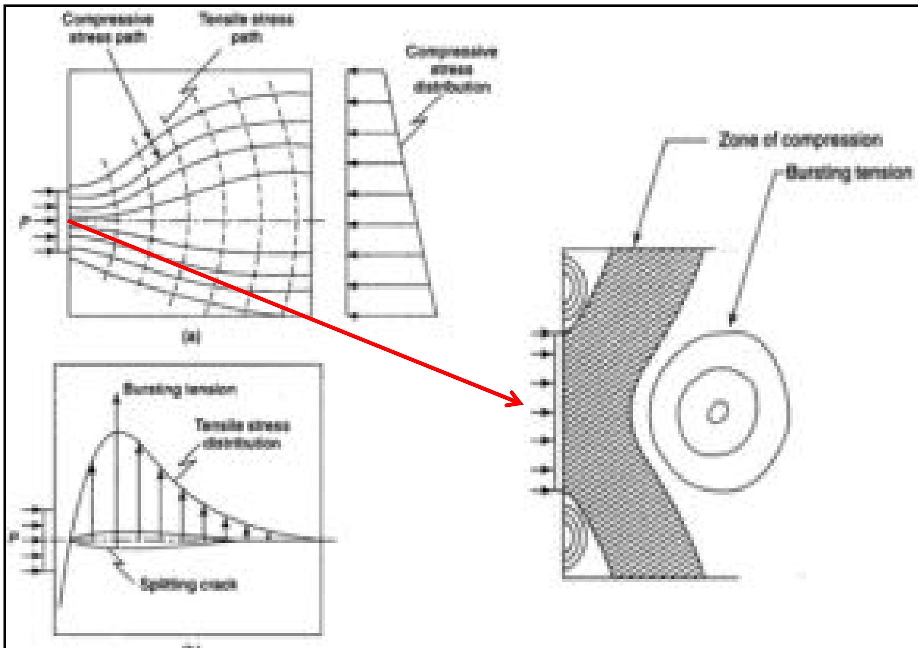

Property Class 8.8 :
Ultimate Strength = 800 Mpa
Yield Strength = 8 x 8 x 10 = 640 MPa

Example of Freyssinet post tensioning Anchorage and Jack :K-Type

10



(b) Double anchor plate

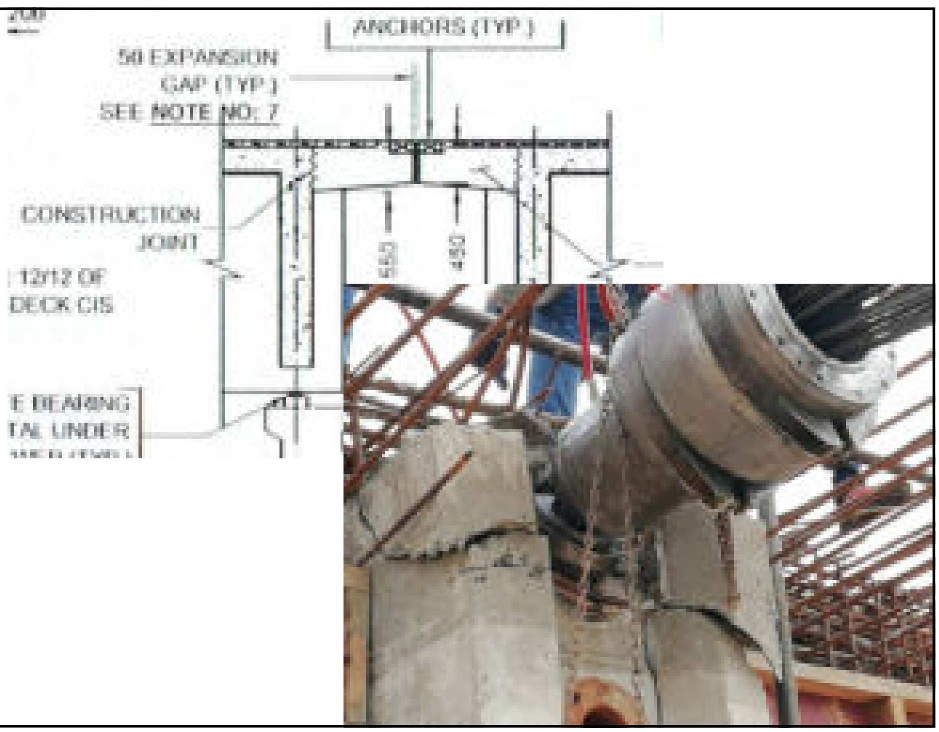


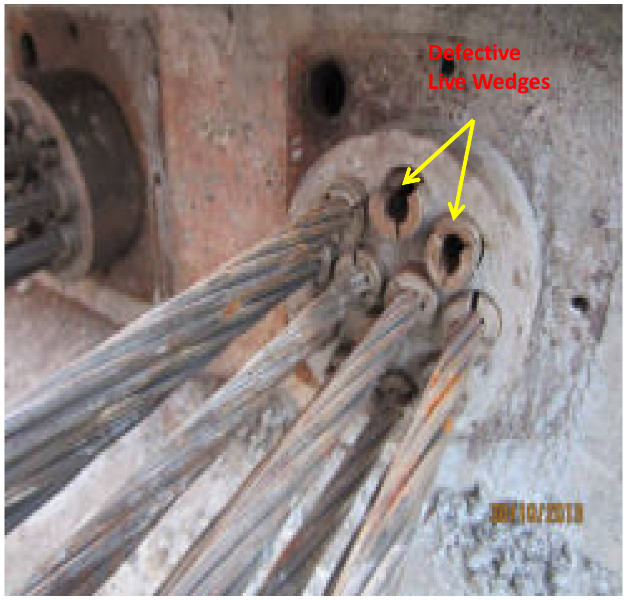
End Blocks of Post-Tensioned Beams (a) Idealized Stress Paths (b) Bursting Tension and Splitting Cracks

Placing Jack

Jack Guage

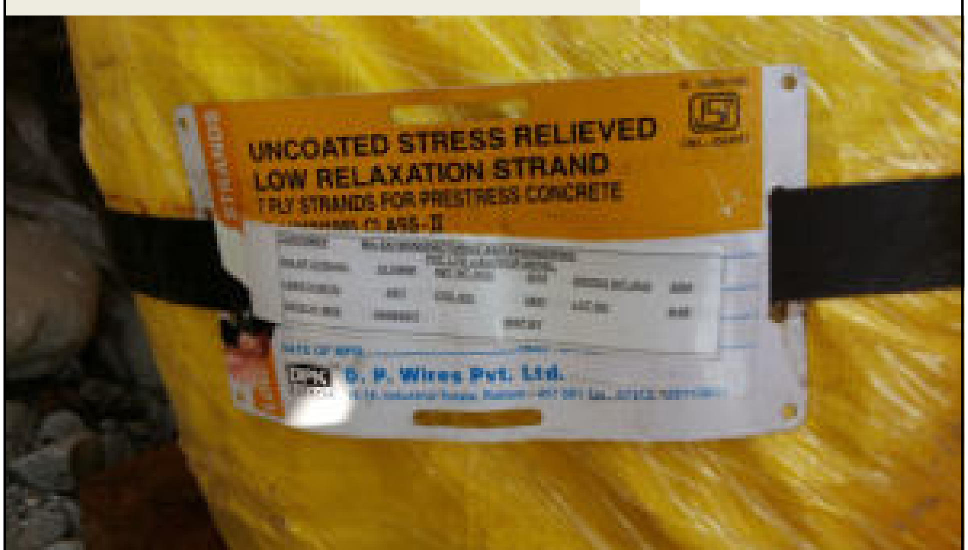
Capping after Grouting





PROBLEM :
Defective Live Wedges

Karnali Bridge



PREPARATION OF PLATFORM

PLACING OF CUTTING EDGE

PLACING REINF. ON CUTTING EDGE

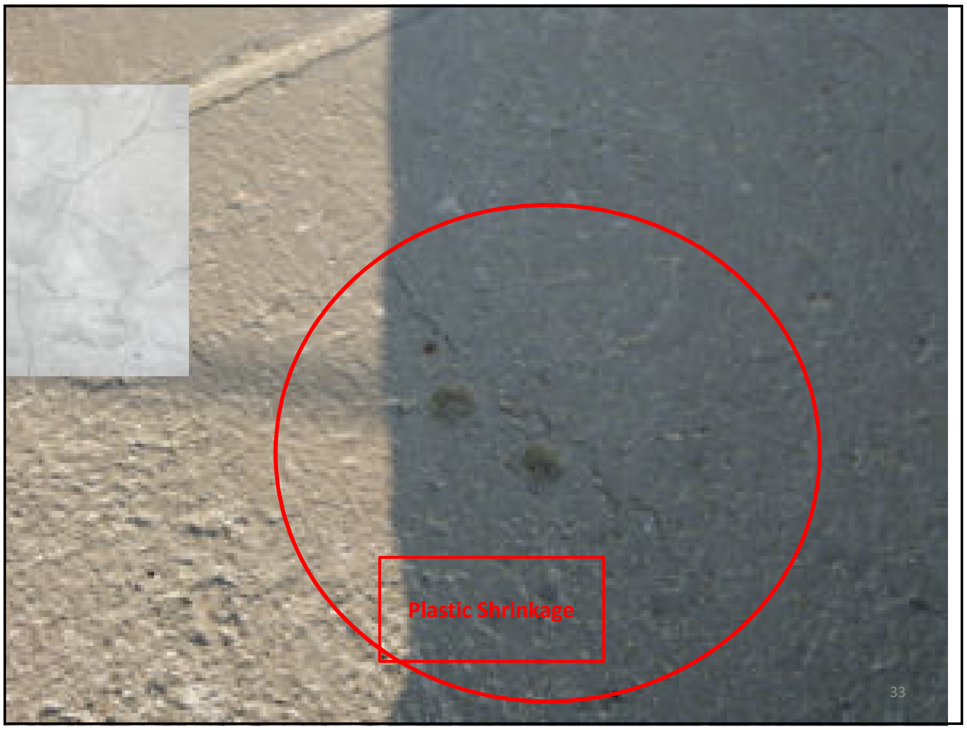
WELL STENNING

WELL STENNING

ADDITIONAL LOAD

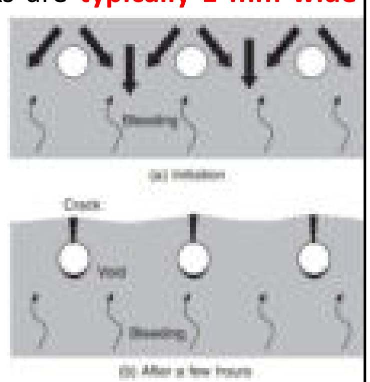
Karnali Bridge

Measuring the depth of



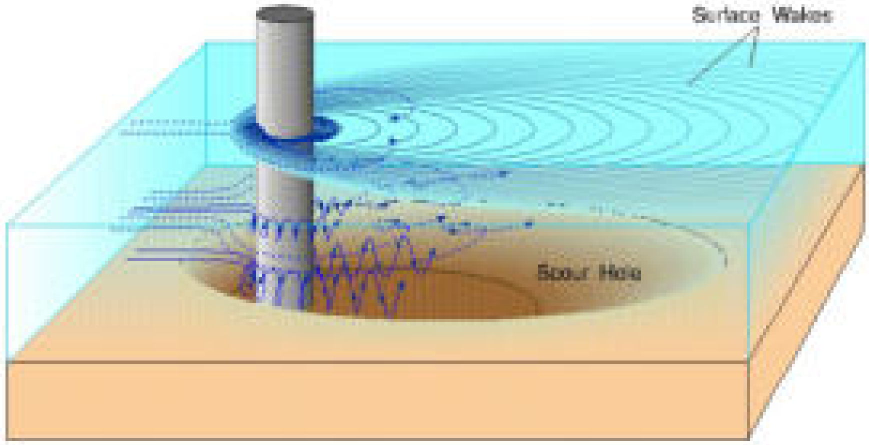
CAUTION AGAINST POSSIBLE DAMAGE DUE TO "PLASTIC SETTLEMENT" CRACKING OF CONCRETE…

•Plastic Settlement cracks occur in not-yet-initially-set concrete when there is a relatively high amount of bleeding through it and some form of obstruction to the downward sedimentation of its solids (e.g. the reinforcement bars). Plastic settlement cracks are **typically 1 mm wide** and usually run from the surface to the bars



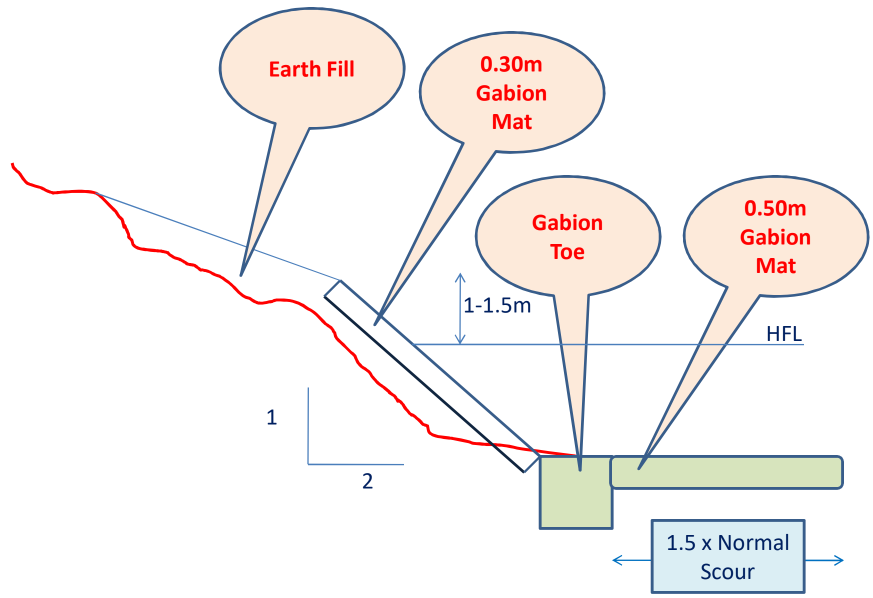
•Plastic Settlement Cracks can be prevented by reducing the bleeding and hence the sedimentation, and by reducing the obstructions to sedimentation.

34

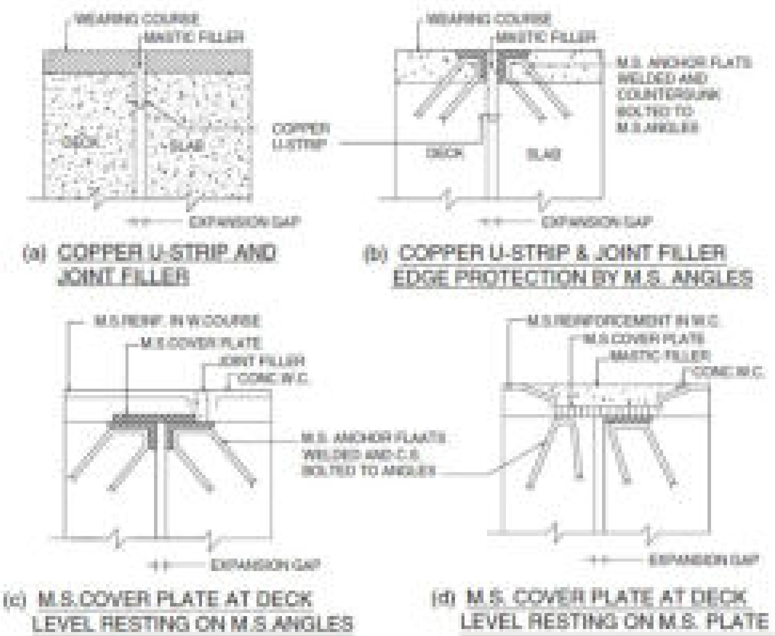


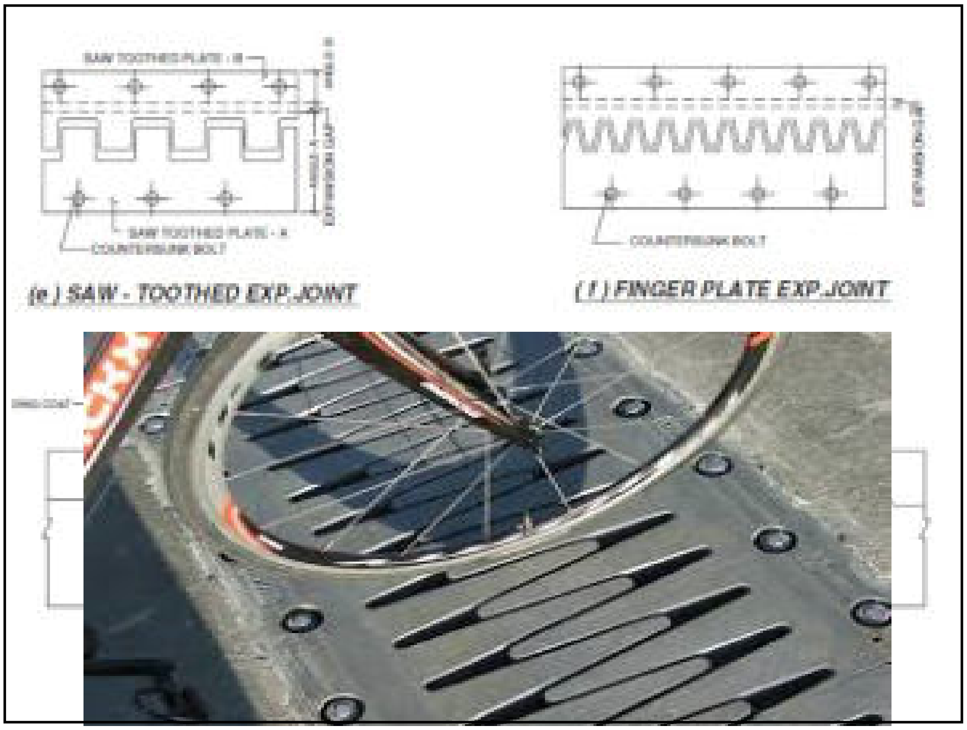
35

River training Work



Expansion Joints




SAW TOOTHED PLATE - B
SAW TOOTHED PLATE - A
COUNTERSUNK BOLT
(e) SAW - TOOTHED EXP.JOINT
COUNTERSUNK BOLT
(f) FINGER PLATE EXP.JOINT

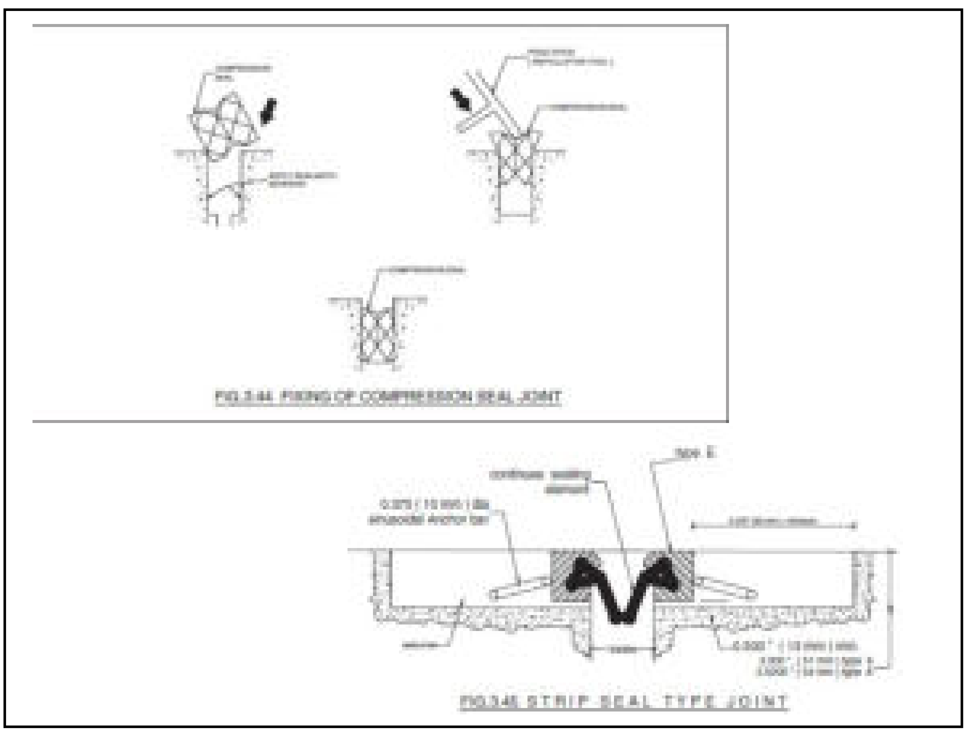


FIG.3.44. FIXING OF COMPRESSION SEAL JOINT
FIG.3.45 STRIP SEAL TYPE JOINT

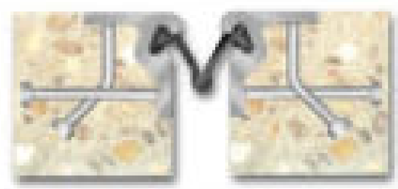
EXPANSION JOINTS

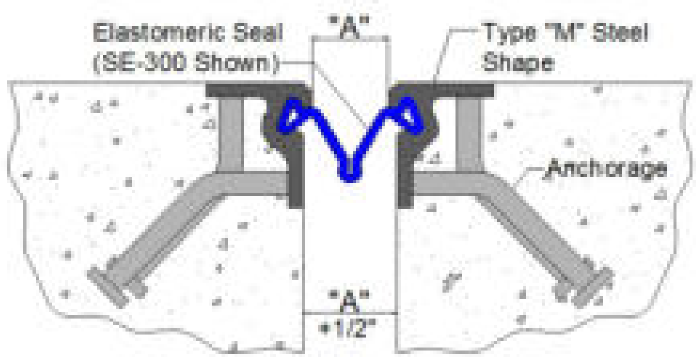
1. Necessary pockets shall be left in Deck Slab and Dirt Wall (of Abutment) for fixing Expansion joints/armour Angles.
2. Stipulated Expansion Joint WABO STRIP SEAL SE-200 or WABOFLEX SR 3A or equivalent to cater for 50 mm total movement shall be provided in the Deck over 'Abutment with Free Bearings' and over 'Pier with Free and Fixed lines of Bearings'.
3. Over Abutment with FREE BRGS.: Expansion Gap of 50mm required, and hence the stipulated Expansion Joint required.

Wabo®StripSeal

Armored small movement expansion joint system

Features	Benefits
• Flexible applications	Variable steel extrusions provide greater flexibility to accommodate any new construction or repair project condition.
• Versatile movement	Accommodates various expansion joint movements and configurations.
• Heavy duty	Accommodates heavy duty loads and bridge deflections.





Movement Table

Model Number	Movement Range "A"						Min. Install Width	
	Min.		Max.		Total			
	in	mm	in	mm	in	mm	in	mm
SE-300	0.00	0	3.00	76	3.00	76	1.50	38
SE-400	0.00	0	4.00	102	4.00	102	1.50	38
SE-500	0.00	0	5.00	127	5.00	127	2.00	51
EFE-400	0.50	13	4.50	114	4.00	102	2.00	51
SE-800	0.50	13	8.50	216	8.00	203	3.00	80

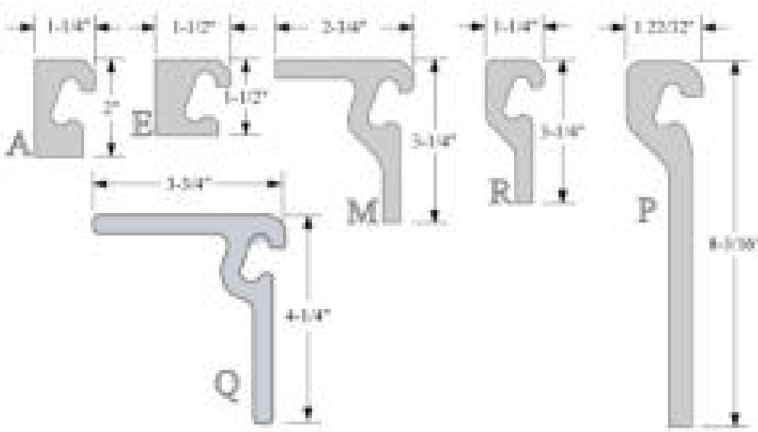
Consult your WBA Representative for factory molded horizontal changes, severe skews or joint intersections.

Physical Properties (Elastomeric Gland)

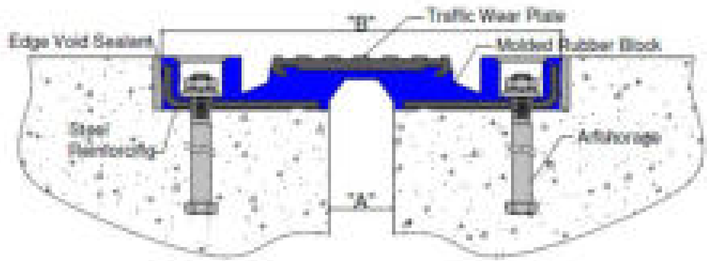
PHYSICAL PROPERTY	ASTM TEST METHOD	REQUIREMENTS
Tensile Strength, min	D 412	2,000 psi (13.8 Mpa)
Elongation at Break, min	D 412	250%
Hardness, Shore A	D 2240	55 +/- 5
Oven Aging, 70 hrs. @ Tensile, max loss Elongation, max loss Change in Hardness	D 573	20% 20% 0 to 10 pts.
Oil Swell, 70 hrs. @212°F(100°C) Weight Change, max	D 471	45%
Ozone Resistance 70 hrs. @ 104°F(40°C)	D 1149	no cracks
Low Temperature Stiffening	D 2240	0 to +15

Steel Edge Members

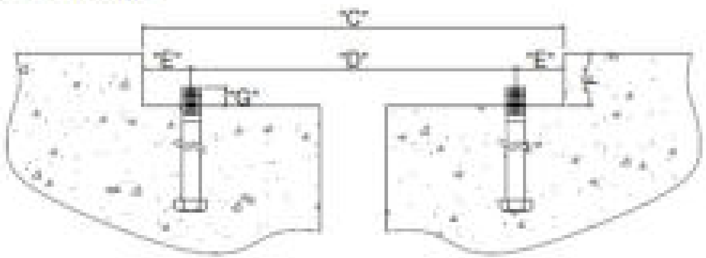
The WaboStripSeal system incorporates the use of six standard profile configurations. See details for profile configurations. All steel edge members are machined from ASTM A588 or A36 grade steel. Available in coated or uncoated finishes. Customers need to specify options when ordering.



Wabo Flex



Blockout Data



Movement Table:

Model Number	Molded Dimensions				Joint Opening "A"						System Width "B"			
	Width		Height		Min.		Max.		Total		Min.		Max.	
	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
SR 2A	10.625	270	1.563	40	1.000	25	3.000	77	2.000	51	9.625	244	11.625	296
SR 2.5A	13.750	349	1.813	46	1.375	35	3.875	98	2.500	64	12.500	318	15.000	381
SR 4A	23.000	584	2.125	54	1.000	25	5.000	127	4.000	102	21.000	533	25.000	635
SR 6.5A	28.000	711	3.000	76	1.500	38	8.000	203	6.500	165	24.750	629	31.250	794
SR 9	37.375	949	3.750	95	1.750	44	10.750	273	9.000	229	32.875	835	41.875	106
SR 13	55.000	1397	5.000	127	2.000	51	15.000	381	13.000	330	48.500	1232	61.000	155

Model Number	"C"				"D"				"E"		"F"		"G"	
	Min.		Max.		Min.		Max.							
	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
SR 2A	10.125	257	12.125	308	7.375	187	9.375	238	1.375	35	1.813	46	1.250	32
SR 2.5A	13.000	330	15.500	394	9.750	248	12.250	311	1.625	41	2.063	52	1.500	38
SR 4A	21.500	546	25.500	648	17.625	448	21.625	549	1.938	49	2.375	60	1.750	44
SR 6.5A	25.250	641	31.750	806	21.000	533	27.500	699	2.125	54	3.250	83	2.000	51
SR 9	33.375	848	42.375	1076	29.000	737	38.000	965	2.188	56	4.000	102	2.250	57
SR 13	49.000	1245	62.000	1575	43.500	1105	56.500	1435	2.750	70	5.250	133	2.750	70

PHYSICAL PROPERTIES:

Metal Components

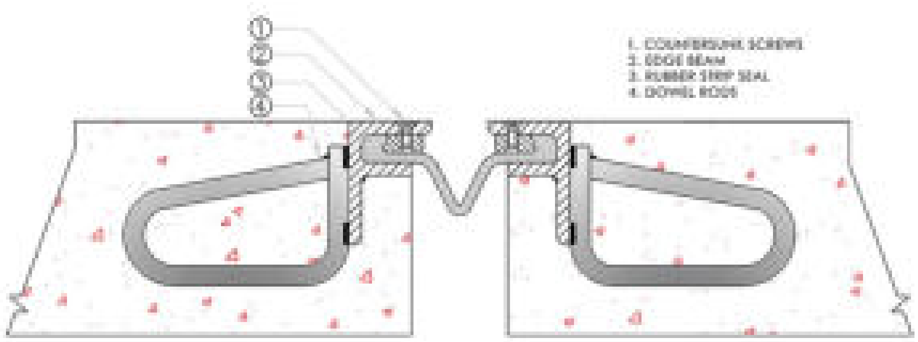
The aluminum plate utilized for the skid resistant surface shall be from alloy 60661-T6 (ASTM B-221-73). The steel angles imbedded in the molded neoprene panels are formed ASTM A36 steel

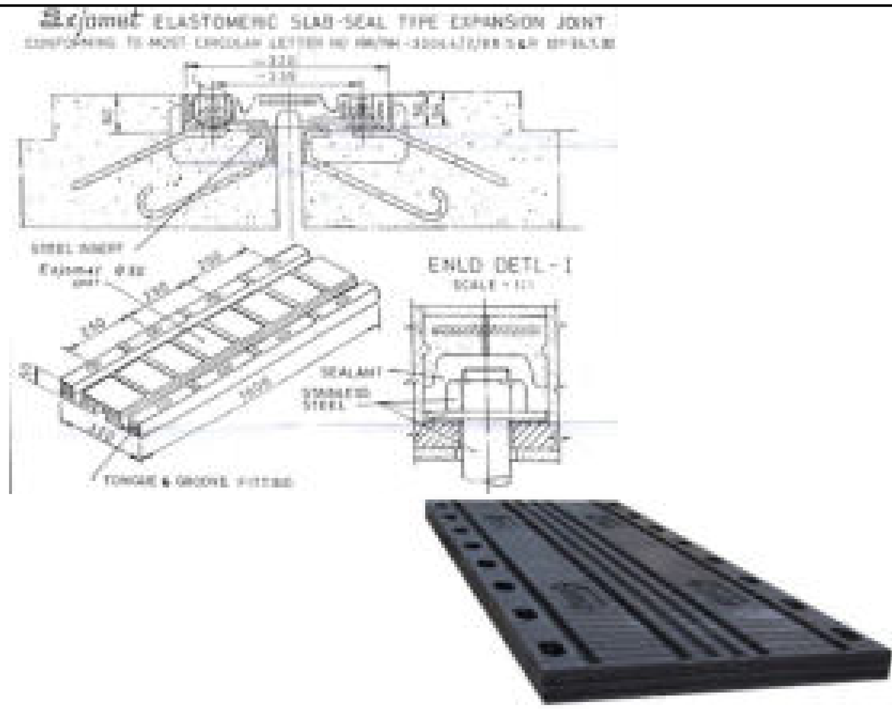
Elastomeric Seal

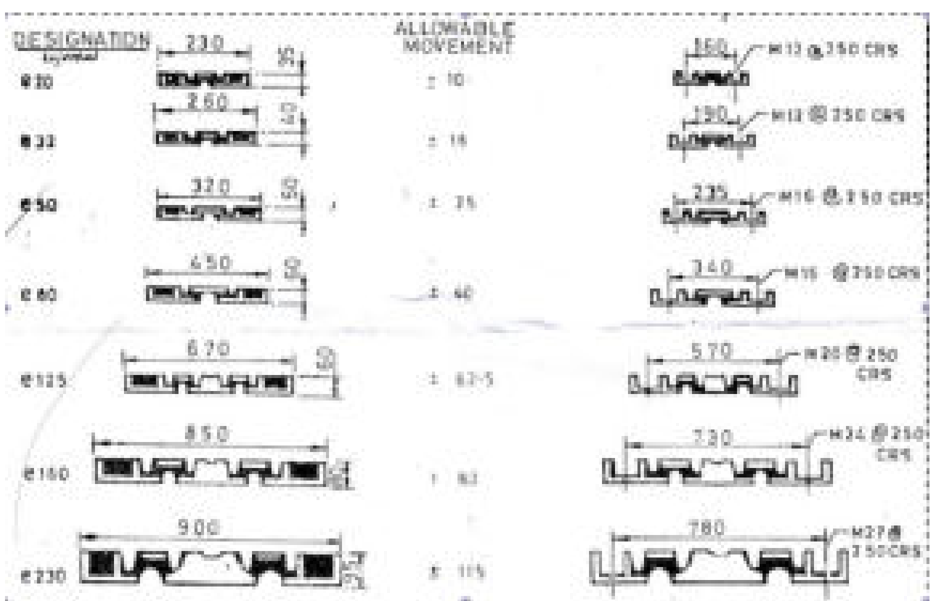
The neoprene material shall have the physical properties conforming to the following requirements:

PHYSICAL PROPERTY	ASTM TEST METHOD	REQUIREMENTS
Tensile Strength, min	D 412	1,800 psi
Elongation at Break, min	D 412	400%
Hardness, Shore A	D 2240	45 +/-5
Compression Set, 22 hrs@158F	D 395	20%
Oil Swell, 70 hrs. @ 212°F(100°C)	D 471	120%
Ozone Resistance	D 1149	no cracks
Low Temperature Brittleness	D 746	not brittle

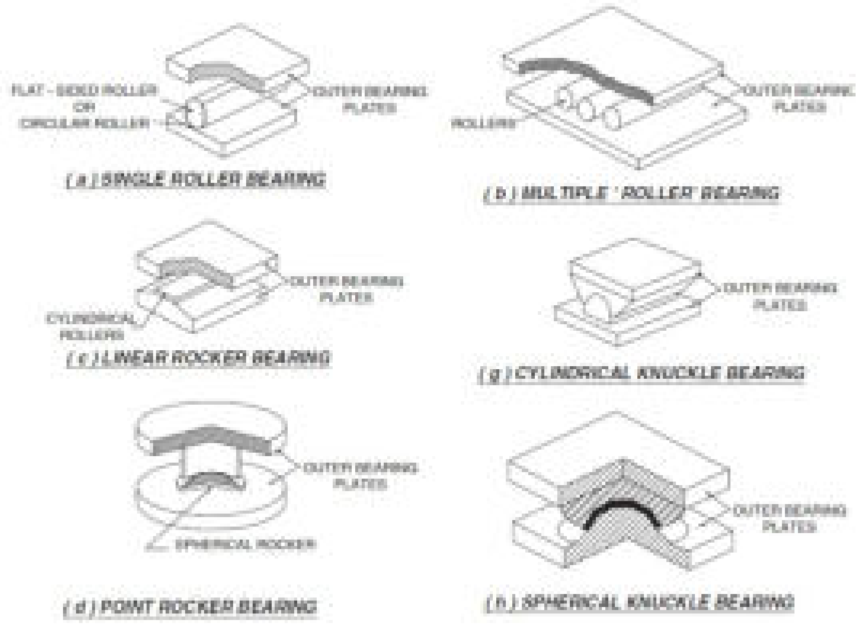
Strip Seal




ELASTOMERIC SLAB-SEAL TYPE EXPANSION JOINT
STEEL INSERT
ENLD DETL - I
SEALANT
TONGUE & GROOVE FITTING


DESIGNATION
ALLOWABLE MOVEMENT
230
260
320
450
670
850
900
± 10
± 16
± 25
± 40
± 62·5
± 115
160
190
235
340
570
730
780
e125
e160
e230

Bearing



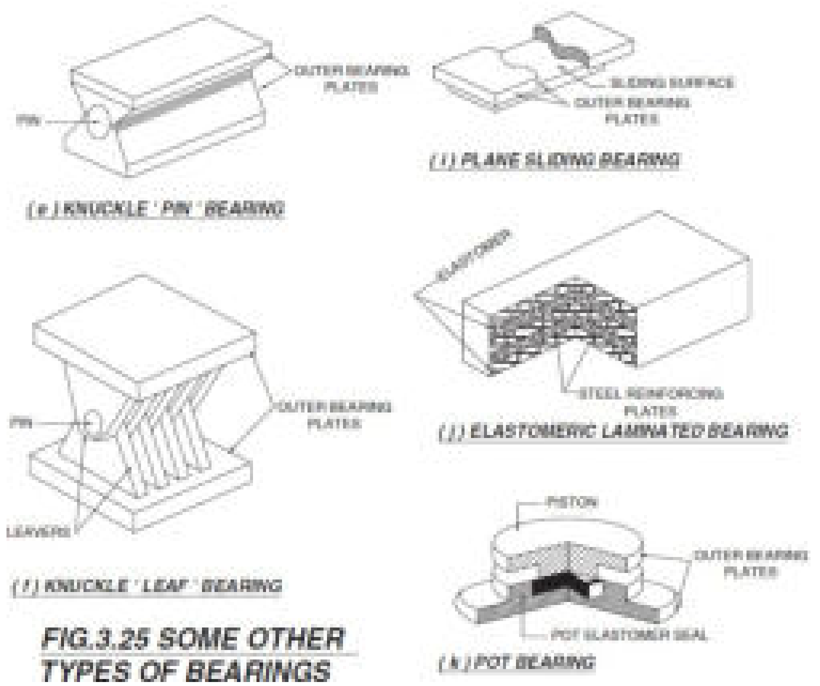
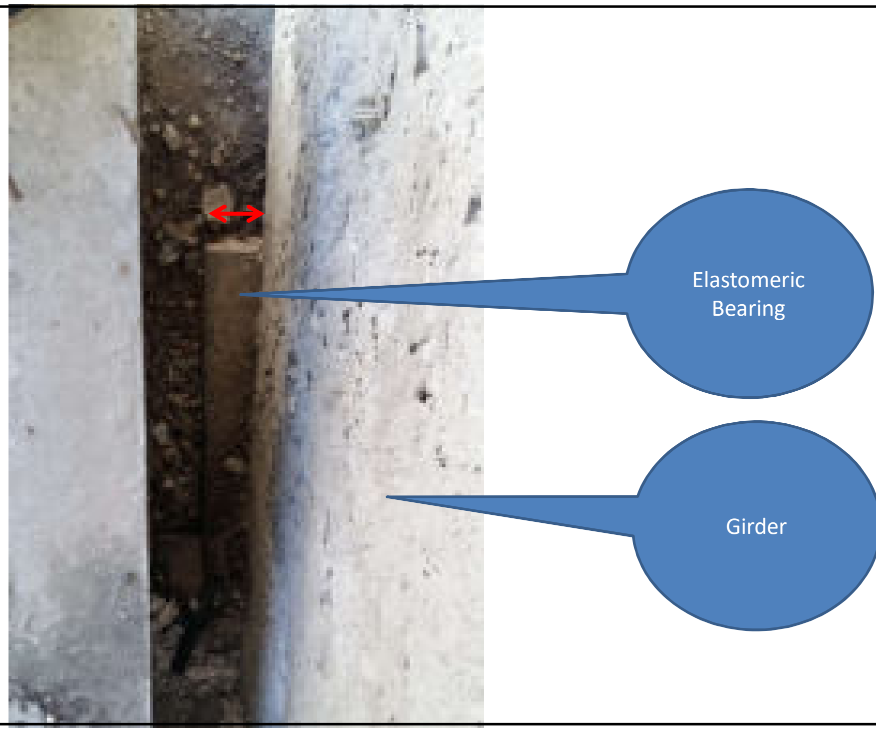


FIG.3.25 SOME OTHER TYPES OF BEARINGS



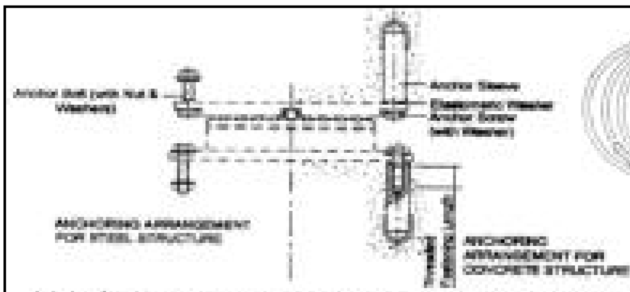
Bearing Design Details

- IRC-83-1982 Metalic Bearing
  Part-III

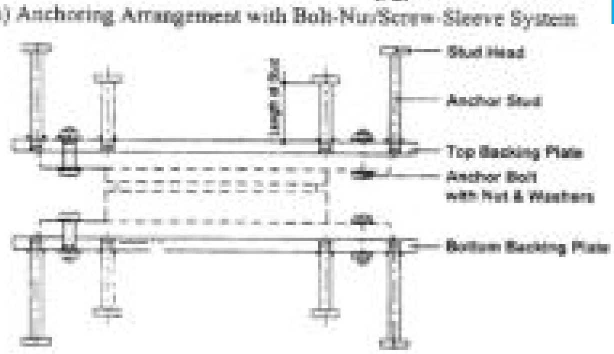
924. SYMBOLS AND NOTATIONS

924.1. Symbolic Representation of Bearing Function

Symbol	Bearing Type	Resists Vertical Load	Resists Horizontal Force Along Direction (In The Horizontal Plane)	Permits Translation Along Direction (In The Horizontal Plane)	Permits Rotation Axis (In The Horizontal Plane)
	Fixed Pot	Yes	Any	No	Any
	Free Sliding Pot-cum-PTFE	Yes	No	Any	Any
	Guided Sliding Pot-cum-PTFE	Yes	Uni-directional	Uni-directional	Any
	Free PTFE Sliding Assembly	Yes	No	Any	No
	Guided PTFE Sliding Assembly	Yes	Uni-directional	Uni-directional	No
	Pin	No	Any	No	Any
	Metallic Guide	No	Uni-directional	Uni-directional	Uni-directional



(a) Anchoring Arrangement with Bolt-Nut/Screw-Sleeve System



(b) Anchoring Arrangement with Backing Plates & Studs

Fig. 20. Anchoring arrangement

Internal Seal by 20x2mm thick Brass Ring, min. 2 No.

For Fixed Pot Bearing

Design of Elastomer
Design of Anchor Arrangement
Design of Pot Cylinder

For Guide Pot Bearing

Design of Elastomer
Design of Anchor Arrangement
Design of Pot Cylinder
Design of PTFE and Guide

Design of Elastomer

926.2.3. **Particular recommendations for confined elastomeric pressure pad**

926.2.3.1. Permissible limits for confined elastomeric pressure pad depend on the effectiveness of the internal seal preventing it from extruding between the piston and the cylinder wall and as such shall be verified by load testing of assembled bearing.

926.2.3.2. Average stress in confined elastomeric pressure pad of Pot bearing shall not exceed 35 MPa and extreme fibre pressure shall not exceed 40 MPa.

926.2.3.3. Minimum average stress in confined elastomeric pressure pad of Pot bearing, under any critical combination of loads and forces that can coexist, shall in no case be less than 5 MPa.

926.2.3.4. The dimension of the confined elastomeric pressure pad shall be such that at design rotation the deflection at the perimeter shall not exceed 15 per cent of the pad thickness below the internal seal, Fig. 26.

926.2.3.6. The minimum thickness of the confined elastomeric pressure pad shall not be less than 1/15th of its diameter or 16 mm, whichever is higher and the diameter shall not be less than 180 mm.

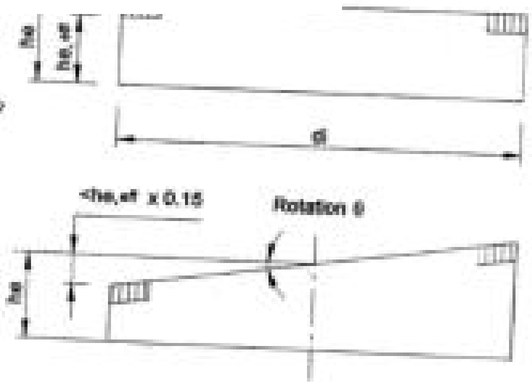


Fig. 26. Allowable strain in elastomeric pressure pad

926.2.3.5. No increase in permissible limits of stresses and strain is allowed for seismic, wind or any other load combinations.

Design of Elastomer

926.1.5.1. Induced moment resulting from resistance to rotation due to the effect of tilting stiffness of elastomeric pressure pad shall be determined as follows:

$$M_{e,d} = di^3 \times (k_1.\theta p + k_2.\theta v),$$

Where,

- di = diameter of elastomeric pressure pad in mm
- he = thickness of confined elastomeric pressure pad in mm.
- k_1 and k_2 shall be as per Table 3. Intermediate values may be obtained by linear interpolation.
- θp = calculated value of resultant rotation angle due to permanent actions and long term effects, in radian
- θv = calculated value of resultant rotation angle due to variable actions, in radian, and
- $M_{e,d}$ = induced moment in N-mm.

TABLE 3. VALUES OF CONSTANTS K_1 AND K_2

di/he	k_1	k_2
15	2.2	101
12.5	1.8	58.8
10	1.5	30.5
7.5	1.1	13.2

926.1.5.2. Induced moment resulting from resistance to rotation due to friction at the piston-cylinder contact surface due to coexisting horizontal force shall be determined as follows:

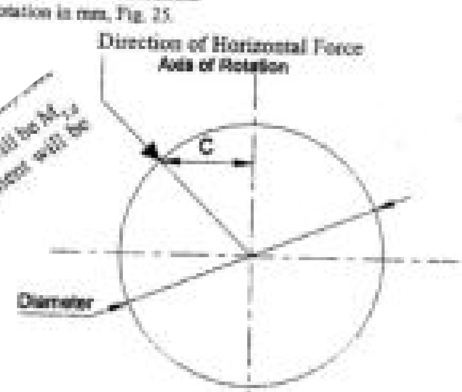
$$M_{fd} = 0.2 \times C \times H_t$$

Where,

C = the perpendicular distance from the point of action of horizontal force on cylinder wall to the axis of rotation in mm, Fig. 25.

H = design horizontal force in N

M_{fd} = induced moment in N-mm.



926.1.5.3. For Pot bearings total induced moment will be $M_{td} = M_{ed} + M_{fd}$ and for Pin bearings total induced moment will be $M_{td} = M_{ed}$

Fig. 25. Moment arm for rotation resistance due to friction

Design of Elastomer

$$Extreme\_Comp.\_Stress = \frac{V\max}{(0.25 \times \Pi \times d_i^2)} + \frac{M_{td}}{(\Pi \times \frac{d_i^3}{32})}$$

$$Average\_Stress = \frac{V\max}{(0.25 \times \Pi \times d_i^2)}$$

$$Minimum\_Stress = \frac{V\min}{(0.25 \times \Pi \times d_i^2)}$$

Dia. of Elastomeric pressure pad, mm (di)	450	Ok
Thickness of confined elastomeric pressure pad,mm (he)	35	Ok
Induced Moment, Mtd = Med+Mrd	6.35E+07	Nmm
Area,Ae	159043	mm2
Extreme Compressive Stress, Mpa	28.91	<40 Mpa,Ok
Average Stress	21.82	<35 Mpa,Ok
Min Stress	13.46	>5 Mpa,Ok
Max. Strain	0.54	<15%,Ok

Design of Anchor Arrangement

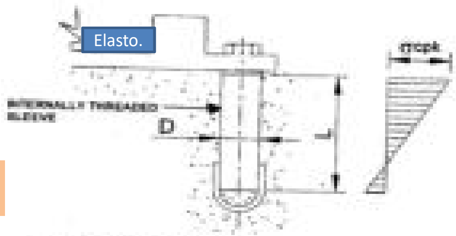


Fig. 34. Stress distribution in concrete adjacent to sleeve

H max < No. of Bolt x R_v

Sleeve, D ≥ 2 . Bolt Dia.

L ≤ 5.D

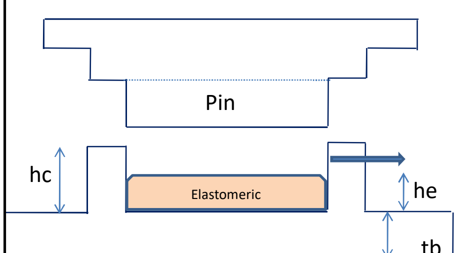
Peak Stress in Concrete

$$= \frac{3 \times Area_{bolt} \times \sigma_{tf}}{D \times L} < \sigma cbc$$

Fixed Pot Bearing

Design of Anchor Arrangement

Resultant Co-existing moment =
Hmax . (he+0.5(hc-he)+tb)



$$< \frac{f_y \times 0.66 \times MoI_{bolt}}{\sum x_i}$$

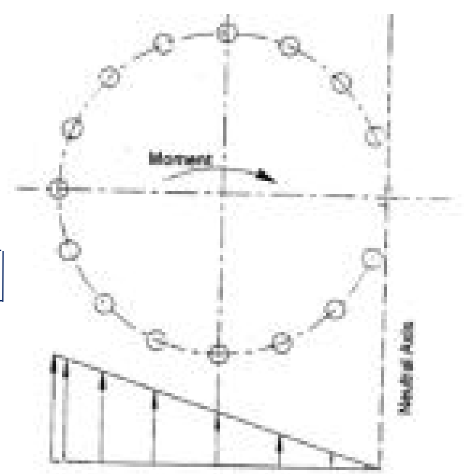


Fig. 32. Distribution of forces on bolt/screw/stud group

Fixed Pot Bearing

Design of Pot Cylinder

hc ≥ he + pin depth – gap (not less than 5mm)

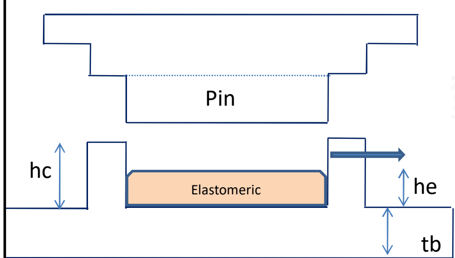
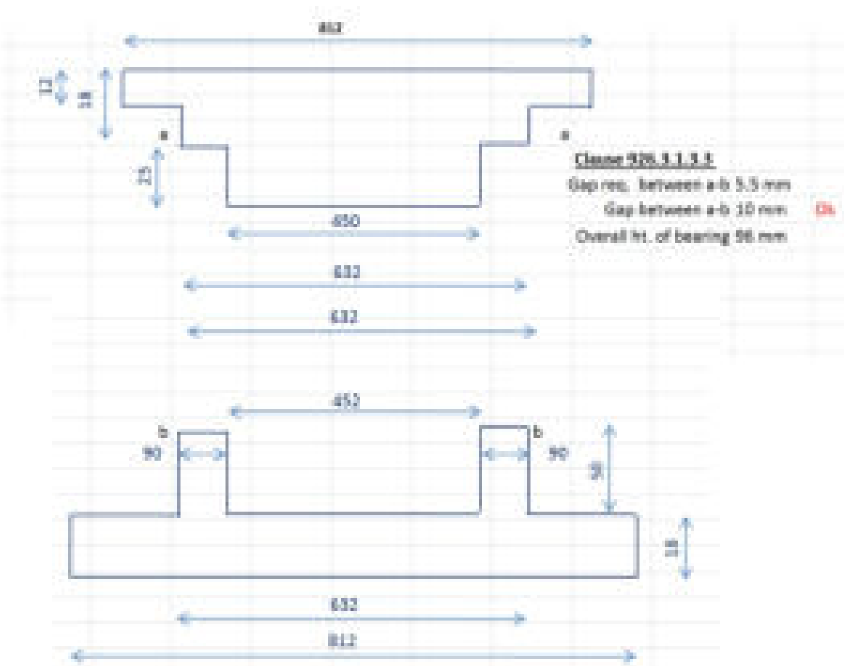


Fig. 20. Interconnection and clearance of components

Check for

Tensile Stress in cylinder,Mpa
Hoop Tensile Stresss(Fluid Pressure+H-Force),Mpa
Shear stress at wall-base inerface,Mpa
Bending Stress at wall-base inerface,Mpa
Combined Stress,Mpa
Hertz Stress, Mpa
Ave. permissible direct Bearing Stress (Concrete)
Actual direct bearing stress,Mpa



Design of Pot Cylinder

Tensile Stress in cylinder,Mpa

$$= \frac{H\max}{2 \times hc \times bp} < 0.60 \times f_y$$

Hoop Tensile Stresss(Fluid Pressure+H-Force),Mpa

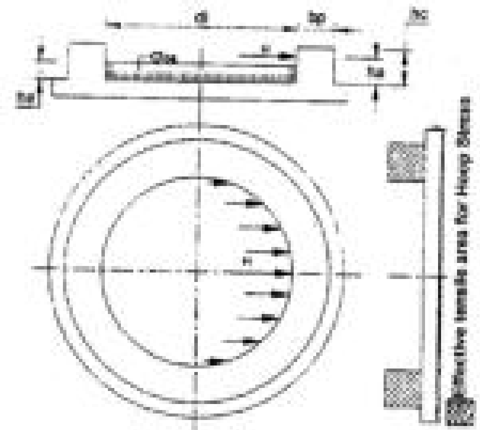


Fig. 28. Design principle of cylinder wall

Design of Pot Cylinder

Hoop Tensile Stresss(Fluid Pressure+H-Force),Mpa

926.3.1.1.7.1. Hoop tensile stress in the cross section of cylinder wall due to:

(i) Fluid pressure, σ_{at_1} = (di × he × σ_{ce})/(2 × bp × hc)

(ii) Horizontal force, σ_{at_2} = H/(2 × bp × hc)

Where,

di = diameter of confined elastomeric pressure pad in mm,

he = thickness of confined elastomeric pressure pad in mm,

σ_{ce} = fluid pressure in confined elastomeric pressure pad due to vertical load in MPa,

bp = thickness of cylinder wall in mm,

hc = height of cylinder wall in mm,

Design of Pot Cylinder

Shear stress at wall-base interface,Mpa

926.3.1.1.7.2. Shear stress at cylinder wall and base interface calculated considering 1mm radial slice of the cylinder due to:

(i) Fluid pressure, $\tau_{vm_1} = (he \times \sigma_{co})/bp$

(ii) Horizontal force, $\tau_{vm_2} = 1.5 \times H/(di \times bp)$

Where,

Parabolic distribution factor is considered as 1.5.

Bending Stress at wall-base interface,Mpa

926.3.1.1.7.3. Bending stress at cylinder and base interface calculated considering 1mm radial slice of the cylinder due to:

(i) Fluid pressure, $\sigma_{bt1} = (6 \times \sigma_{co} \times he^2)/(2 \times bp^2)$

(ii) Horizontal force, $\sigma_{bt2} = 1.5 \times 6 \times H \times ha/(di \times bp^2)$

Where,

ha = height of line of application of design horizontal force from cylinder wall above base interface in mm,

H = design horizontal force in N.

Combined Stress,Mpa

obtained from the following formula and shall not exceed 0.9 fy.

$\sigma_{e,cal} = \sqrt{(3 \times \tau_{vm,cal}^2 + \sigma_{bt,cal}^2)}$ or

$\sigma_{e,cal} = \sqrt{(3 \times \tau_{vm,cal}^2 + \sigma_{bc,cal}^2)}$

Hertz Stress Concept

Hertz Stress, Mpa

926.3.3.2.1. The effect of the Hertz stress ($\sigma_{p,Hertz}$) at the mating interface shall be calculated using the following expression:

$$\sigma_{p,Hertz} = 0.6 \sqrt{[\{(H \times Es)/(w_e \times dc)\} \times (1 - dn/dc)]}$$

Where,

H = design horizontal force in N,

Es = static modulus of elasticity of steel in MPa.

w_e = effective contact width of contact surface in mm,

dc = inner diameter of cylinder in mm.

dn = diameter of pin in mm.

σ_p, Hertz shall not exceed the value of permissible bearing stress as specified in Clause 926.2.2.

Ave. permissible direct Bearing Stress (Concrete) > Actual direct bearing stress,

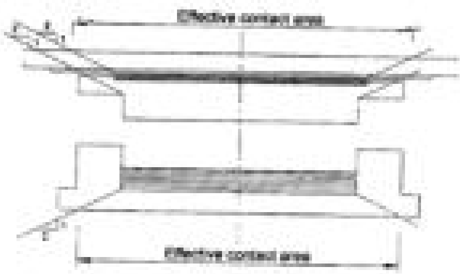


Fig. 27. Load dispersion through bearing components

$$\sigma cc = \sigma co \sqrt{(A_1/A_2)}$$

σco = permissible direct compressive stress in concrete = 0.25 *f*ck, where *f*ck is the characteristic compressive strength of concrete.

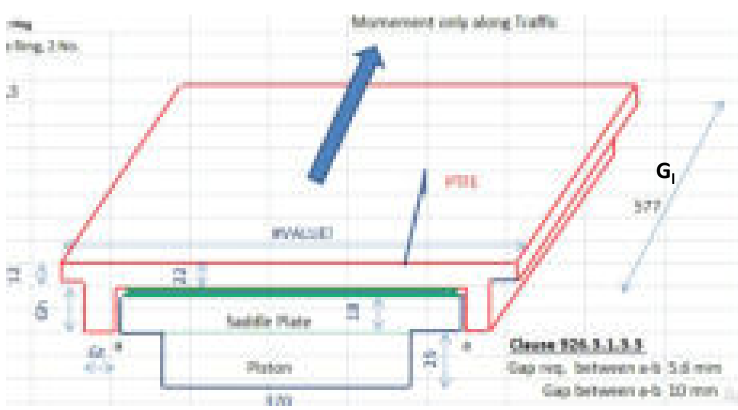
A_1 = dispersed concentric area, which is geometrically similar to the loaded area A_2 and also the largest area that can be contained in a plane of A_1 (maximum width of dispersion beyond the loaded area face shall be limited to twice the height).

A_2 = loaded area and,

$$\sqrt{(A_1/A_2)} \le 2$$

The projection of the adjacent structure beyond the loaded area shall not be less than 150 mm. Adequate reinforcement for spalling and bursting tension shall be provided.

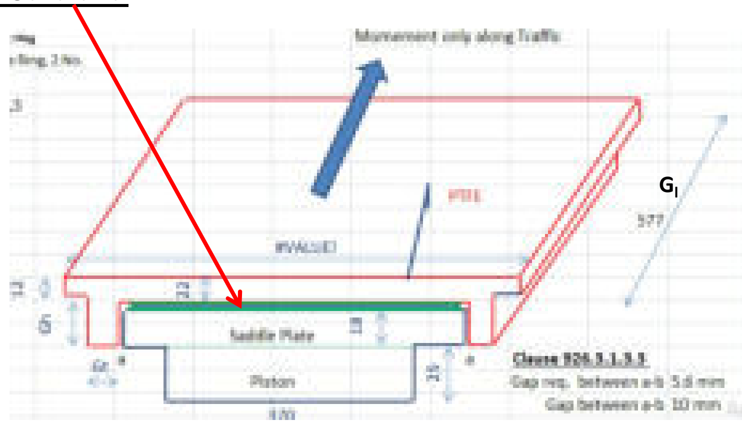
Design of Guide



$$Shear\_Stress = \frac{H_{\max}}{Gt \times G_l}$$

$$Bending\_Stress = \frac{H_{\max} \times G_h / 2}{G_t \times G_h^2 / 6}$$

Design of PTEF



$$Induced\_Moment = \frac{V_{max} \times \mu \times t}{2}$$

$$Bending\_Stress < 45\,MPa$$

2. BEARING LOADS & MOVEMENTS

		NORMAL	SEISMIC Long.	SEISMIC Trans.	UNIT
A.	LOAD CAPACITY VERTICAL (MAX)	2024	3028	2508	KN
B.	LOAD CAPACITY VERTICAL (MIN)	1332	1512	1512	KN
C.	HORIZONTAL (MAX) LONGITUDINAL	81	757	00	KN
	HORIZONTAL (MAX)TRANSVERSE	00	00	490	KN

MOVEMENT		
LONGITUDINAL	0	MM
LATERAL	0	MM
ROTATION	0.0024	RAD.
TOP/BOTTOM DISP.	884/884	MM

3. MATERIAL

A. CONCRETE AT TOP BEARING SHALL BE OF M-45
CONCRETE AT BOTTOM BEARING SHALL BE OF M-45

B. CAST STEEL IN POT CYLINDER AND BASE PLATE, PISTON, SADDLE PLATE, TOP PLATE SHALL CONFIRM TO I.S.-1030 GRADE 340-570W

Test for Pot Bearing

928.6.2.3.1. **Load test:** Bearings shall be load tested for direct loads for a test load equal to 1.25 times the specified design vertical load for Pot and PTFE bearings or to 1.25 times the specified design horizontal load for Pin and Metallic Guide Bearings. Additionally, for testing of Pot or PTFE bearings under a combination of loads acting in different axes the test loads shall be 1.1 times of the respective design loads. The test load shall be applied in stages and held for 30 minutes. For Pot bearings the vertical deflection under sustained test load shall not increase by more than 4 per cent of the thickness of the confined elastomeric pressure pad. The load shall then be removed and the bearing shall be dismantled and visually examined as given in Clause 928.6.2.3.4.

Test for Pot Bearing

928.6.2.3.2. **Friction test:** For bearings with sliding component friction test shall be performed on properly lubricated PTFE-stainless steel sliding interface at constant vertical load equal to the i) design vertical load and ii) permanent vertical load. The horizontal load shall be applied till sliding occurs. Co-efficient of friction (µ) shall be determined on the basis of applied vertical and horizontal load. The value of coefficient of friction shall not exceed 2/3rd of the value specified in Clause 926.2.4.2 depending on the actual average pressure on PTFE due to the applied vertical load.

928.6.2.3.3. **Rotation test:** Rotation test shall be performed on Pot bearing with properly lubricated elastomeric pressure pad for design rotation, under a constant vertical load equal to permanent vertical load.

- Name of manufacturer
- Month and year of manufacture
- Bearing designation
- Type of bearing
- Load and movement capacity
- Centerline markings to facilitate installation
- Direction of major and minor movement, if any
- Preset, if any

Bearings

Bearings

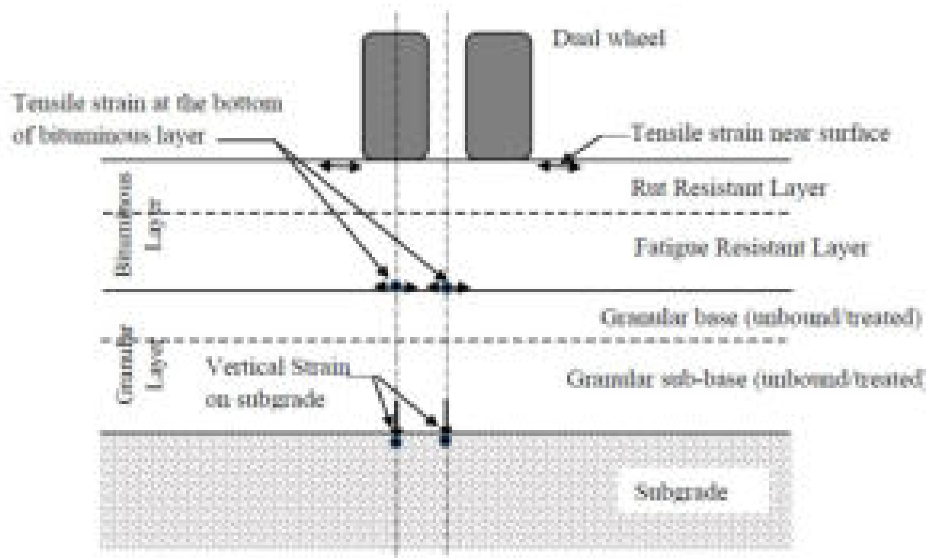
Bearings

Fixed/Free

Bearings

Specification Requirement for Dense Graded Bituminous Mixes (DBM/BC)

Er. Prabhat Kumar Jha
Senior Divisional Engineer
9841360244
geoprabhat@gmail.com
https://techwingdor.blogspot.com/
https://dor.gov.np/dorqrdc



IRC 37:2018

- The pavement s**tructural catalogues** presented in these guidelines for design traffic levels up to 50 msa are **intended for initial cost estimation and for guidance only.**
- For all roads with **more than 2 msa design** traffic, the design shall be carried out using site specific inputs to satisfy the mechanistic-empirical performance models given in these guidelines which may require analysis of different trial pavement sections using IITPAVE software.

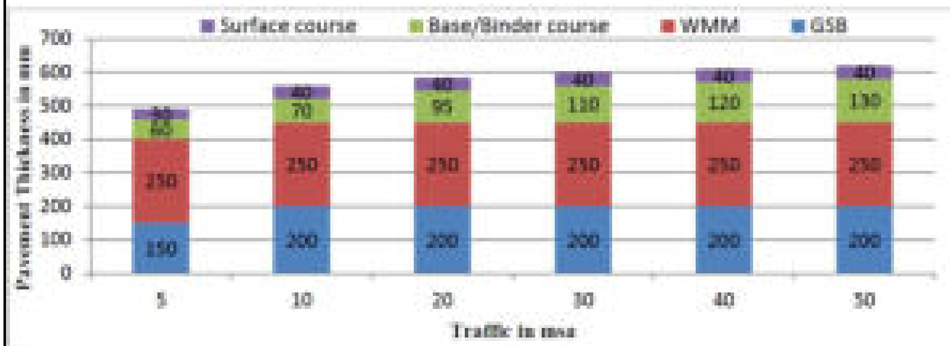


Figure 12.2 Catalogue for pavement with bituminous surface course with granular base and sub-base - Effective CBR 6% (Plate-2)

Plate in IRC 37:2018 : DBM for all case

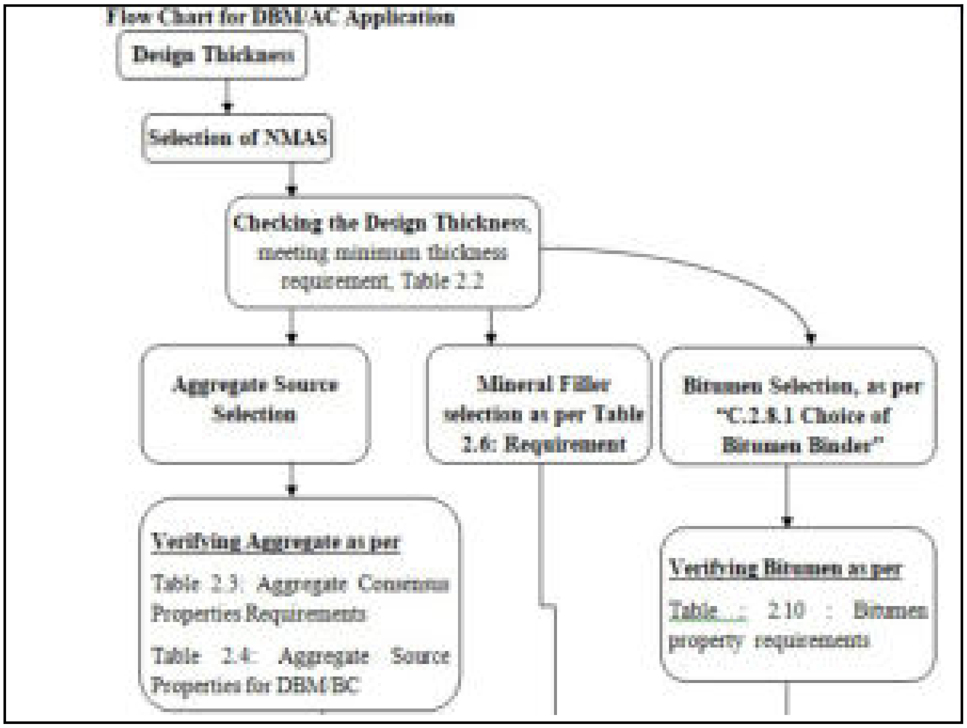
Government of Nepal

Ministry of Physical Infrastructure and Transport

Department of Roads

Maintenance Branch

Manual for Dense Graded Bituminous Mixes (DBM/BC)
(Final)


Flow Chart for DBM/AC Application
Design Thickness
Selection of NMAS
Checking the Design Thickness, meeting minimum thickness requirement, Table 2.2
Aggregate Source Selection
Mineral Filler selection as per Table 2.6: Requirement
Bitumen Selection, as per "C.2.8.1 Choice of Bitumen Binder"
Verifying Aggregate as per
Table 2.3: Aggregate Consensus Properties Requirements
Table 2.4: Aggregate Source Properties for DBM/BC
Verifying Bitumen as per
Table : 2.10 : Bitumen property requirements

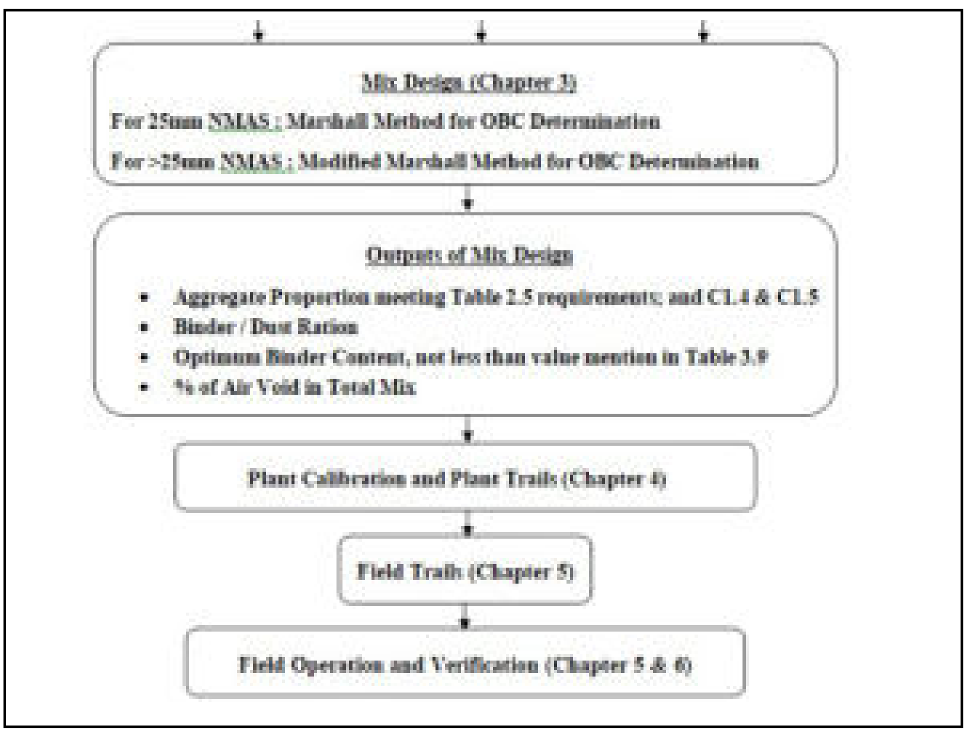

Mix Design (Chapter 3)
For 25mm NMAS : Marshall Method for OBC Determination
For >25mm NMAS : Modified Marshall Method for OBC Determination
Outputs of Mix Design
Aggregate Proportion meeting Table 2.5 requirements; and C1.4 & C1.5
Binder / Dust Ration
Optimum Binder Content, not less than value mention in Table 3.0
% of Air Void in Total Mix
Plant Calibration and Plant Trails (Chapter 4)
Field Trails (Chapter 5)
Field Operation and Verification (Chapter 5 & 6)

Table 2.2: The limits on permissible lift thickness with reference of IRC :111:2009, Specification for Dense Graded Bituminous Mixes and the New York State Highway Design Manual

Specification	Purpose	No. of Layers	Minimum lift thickness	Maximum lift thickness
DBM	Base/Binder Course, Overlay for Strengthening	Single or Multiple	For NMAS 35.5mm : 100mm For NMAS 26.5mm: 75mm	For NMAS 35.5mm : 150mm For NMAS 26.5mm: 150mm
Bituminous Concrete(BC)/	Wearing Course	Single	For NMAS 19mm : 60mm For NMAS 13.2 mm: 40mm	For NMAS 19mm : 75mm For NMAS 13.2 mm: 50mm

Table 2.3: Aggregate Consensus Properties Requirements

Design ESALs[1] (In Millions)	Course Aggregate Angularity (CAA) (Percent), minimum		Un-compacted Void Content of Fine Aggregate Angularity (FAA) (Percent),		Sand Equivalent (SE) (Percent), minimum	Flat and Elongated[2,3] (F&E) (Percent), maximum
	≤100 mm	> 100 mm	≤100 mm	> 100 mm		
< 0.3	55/-	-/-	-	-	40	-
0.3 to < 3	75/-	50/-	40	40	40	10
3 to < 10	85/80[2]	60/-	45	40	45	10
10 to < 30	95/90	80/75	45	40	45	10
≥30	100/100	100/100	45	45	50	10

Table 2.4: Aggregate Source Properties for DBM/BC

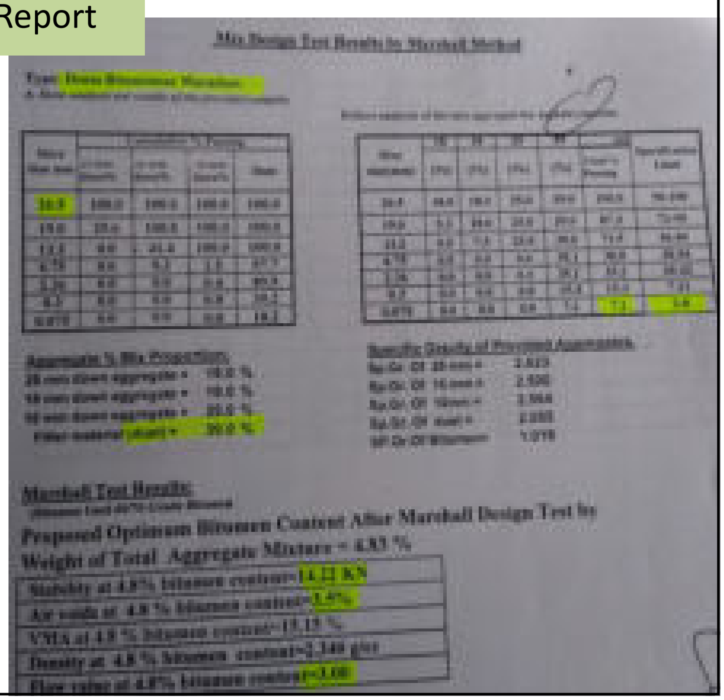
Property	Test	Specification	Method of Test
Deleterious materials: Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part I
Toughness/Strength	Los Angeles Abrasion Value or Aggregate Impact Value	DBM : Max 35% BC : Max 30% DBM: Max 27% BC : Max. 24%	IS:2386 Part IV
Durability	Soundness either Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part V
Polishing	Polished Stone Value	Min 55	BS:812-114
Water Sensitivity	Retained Tensile Strength*	Min 80%	AASHTO 283
Water Absorption	Water Absorption	Max 2%	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%	IS: 6241

Table 2.5: Gradation requirement

Composition for	BC		DBM	
Nominal Maximum aggregate size(NMAS)	13.2 mm	19 mm	26.5 mm	35.5 mm
Gradation Type	(Ref. Table1.1)			
IS Sieve (mm)	Cumulative % by weight of total aggregate passing			
45				100
37.5			100	95-100
26.5		100	90-100	63-93
19	100	90-100	71-95	-
13.2	90-100	59-79	56-80	55-75
9.5	70-88	52-72	-	-
4.75	53-71	35-55	38-54	38-54
2.36	42-58	28-44	28-42	28-42
1.18	34-48	20-34	-	-
0.6	26-38	15-27	-	-
0.3	18-28	10-20	7-21	7-21
0.15	12-20	5-13	-	-
0.075	4-10	2-8	2-8	2-8

To avoid gap grading, the combined aggregate gradation should not vary from the lower limit on one sieve to higher limit on the adjacent sieve.

Sample MD-Report


Mix Design Test Results by Marshall Method

Marshall Test Results:

Proposed Optimum Bitumen Content After Marshall Design Test by Weight of Total Aggregate Mixture = 4.83 %

C2.8 Bituminous Binder

C.2.8.1 Choice of Bitumen Binder

a) As per IS 73:2013

Bitumen shall be classified into four grades based on the viscosity, and suitability recommended for maximum air temperature as given below:

Table 2.7: Recommended Bitumen based on maximum air temperature

Grade (1)	Penetration (2)	Suitable for 7 day Average Maximum Air Temperature, °C (3)
VG10	80-100	< 30
VG20	60-80	30-38
VG30	50-70	38-45
VG40	40-60	> 45

NOTE — This is the 7 day average maximum air temperature for a period not less than 5 years from the start of the design period.

b) As per DoR Specification:

Selection criteria for viscosity grade bitumen, based on highest and lowest daily mean temperatures at a particular site, Table 2.8.

Table 2.8:Selection Criteria for Viscosity-Graded (VG) Paving Bitumen Based on Climatic Conditions

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

Highest Mean Temp : May or June

Lowest Mean Temp : January

Theoretical maximum specific gravity of an asphalt mixture (G_{mm}) is not determined by any mix designer,

resulting error in calculation of
effective specific gravity of the aggregate G_{se}

causing faulty
% Air Void (Pa)
% VMA &
% VFA calculation.

Thus, the mix design practicing is wrong.

IRC 37:2018

Table 9.1 Summary of Bituminous layer options recommended in these guidelines

S.No	Traffic Level	Surface course		Base/Binder Course	
		Mix type	Bitumen type	Mix type	Bitumen type
1	>50 msa	SMA	Modified bitumen or VG40	DBM	VG40
		GGRB	Crumb rubber modified bitumen		
		BC	With modified bitumen		
2	20-50 msa	SMA	Modified bitumen or VG40	DBM	VG40
		GGRB	Crumb rubber modified bitumen		
		BC	With modified bitumen or VG40		
3	<20 msa[1]	BC/SDBC/PMC/MSS/ Surface Dressing	VG40 or VG30	DBM/ BM	VG40 or VG30

[1]For expressways and national highways, even if the design traffic is 20 msa or less, VG40 bitumen shall be used for DBM layers.

For snow bound locations, softer binders such as VG10 may be used to limit thermal transverse cracking (especially if the maximum pavement temperature is less than 300 C).

The original Marshall method is applicable only to hot mix asphalt paving mixtures containing aggregates with maximum sizes of 25 mm or less.

A modified Marshall method has been developed for aggregates with maximum sizes up to 38 mm. Procedures for 6-inch diameter specimen are given by ASTM D5581.

Table 3.1: Approximate asphalt content of mix, percent by weight of mix for specimen preparation, based on above equation

Nominal Maximum Aggregate Size, mm	Approximate asphalt content of mix, percent by weight of mix
13.2	5.344
19.0	4.855
26.5	4.610
35.5	4.610

(b) ***Preparation of aggregates*****—**dry aggregates to constant weight at 105°C to 110°C and separate the aggregates by dry sieving into the desired size fractions. ***These size fractions are recommended:***

- 38.0-25.0 mm
- 25.0 to 19.0 mm
- 19.0 to 13.2 mm
- 13.2 to 4.75 mm
- 4.75 to 2.36 mm (No. 4 to No. 8)
- Passing 2.36 mm (No. 8)

Practice : Common ration of mix. (16-10mm agg. : 10-6mm agg. : Sand : Stone dust)

Table 3.5: Approximate Batching Proportion#

Nominal Maximum Aggregate Size,mm	Approximate Batching Proportion, %				
	Aggregate passing the size				
	38-25mm	25-19mm	19-13.2mm	13.2-4.75mm	Fine(passing 2.36mm)
13.2	-	-	-	47-59	35-47
19	-	-	16-32	45-56	22-28
26.5	-	16-27	24-33	16-33	22-27
35.5	11-22	27-43	-	16-27	27-32

 # All individual case should be batched to meet the table 2.5

The typical allowable range for dust to binder ratio ($P_{0.075}/P_{be}$) is 0.6–1.2, with the following exceptions: for coarse-graded mixes whose gradation plots below the Primary Control Sieve (PCS) on a 0.45 power chart, the allowable range may be increased to 0.8–1.6.

If the flow at the selected optimum binder content is above the upper specified limit, the mix is considered too plastic or unstable. If the flow is below the lower specified limit, the mix is considered too brittle. The stability and flow results are highly dependent on binder grade, binder quantity and aggregate structure.

Table 3.8 Marshall Mix Design Criteria

Marshall Method Criteria[1]	As per MS-2						As per DOR Specification	
	Light Traffic[2] Surface & Base		Medium Traffic[2] Surface & Base		Heavy Traffic[2] Surface & Base		Viscosity Grade Paving Bitumen	
	Min	Max	Min	Max	Min	Max	Min	Max
Compaction, number of blows each end of specimen	35		50		75		75	
Stability, N	3336	-	5338	-	8006	-	9000	-
Flow[3,4], 0.25 mm (0.01 in.)	8	18	8	16	8	14	8	16
Percent Air Voids[6]	3	5	3	5	3	5	3	5
Percent Voids in Mineral Aggregate (VMA)[5]	NMAS, mm		Minimum VMA, percent					
			3.0		4.0		5.0	
	13.2		13		14		15	
	19		12		13		14	
	26.5		11		12		13	
	37.5		10		11		12	
Percent Voids Filled With Asphalt (VFA)	70	80	65	78	65	75	65	75

For DBM : The minimum stability should be 2.25 times, and the range of flow values should be 1.5 times the criteria listed in Table 3.8.

notes:

1. All criteria, not just stability value alone, must be considered in designing an asphalt paving mix.
2. Traffic classifications
   Light Traffic conditions resulting in a 20-year Design ESAL < 10^4
   Medium Traffic conditions resulting in a 20-year Design ESAL between 10^4 and 10^6
   Heavy Traffic conditions resulting in a 20-year Design ESAL > 10^6
3. The flow value refers to the point where the load begins to decrease. When an automatic recording device is used, the flow should be corrected.
4. The flow criteria were established for neat asphalts. The flow criteria are often exceeded when polymer modified or rubber-modified binders are used. Therefore, the upper limit of the flow criteria should be waived when polymer modified or rubber-modified binders are used.
5. Percent voids in the mineral aggregate are to be calculated on the basis of the ASTM bulk specific gravity for the aggregate.
6. Percent air voids should be targeted at 4 percent. This may be slightly adjusted if needed to meet the other Marshall criteria.

Table 3.9 Minimum Bitumen Content

Composition for	BC		DBM	
NMAS	19 mm	13.2 mm	26.5 mm	35.5 mm
Bitumen content % by mass of total mix	Min 5.2	Min 5.4	Min 4.5	Min 4.0

Corresponds to specific gravity of aggregates being 2.7. In case aggregate have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is - 10°C or lower, the bitumen content may be increased by 0.5 percent.

C3.10 Modified Marshall method for large aggregate

The procedure is basically the same as the original Marshall mix design method except for these differences that are due to the larger specimen size:

- The hammer weighs 10.2 kg and has a 149.4-mm flat tamping face. Only a mechanically operated device is used for the same 457-mm drop height.
- The specimen has a 152.4-mm diameter by 95.2-mm height.
- The batch weights are typically 4,050 g.

Test Report Showing Typical Lab Data for Design by the Marshall Method

Name of Project: Location: Date:

Proportion of Aggregate fraction: 38.0-25.0 mm : 25.0 to 19.0 mm : 19.0 to 13.2 mm : 13.2 to 4.75 mm : 4.75 to 2.36 mm : Passing 2.36 mm

Compaction: Bitumen Viscosity Grade: Sp.Gravity of Bitumen (G_b):

Sp.Gravity of Aggregate blend (G_{sb}): Theoretical max. Sp.Gravity of mix (G_{mm}): Effective Sp. Gravity of Aggregate (G_{se}):

Absorbed Bitumen (P_{ba}): Specimen Diameter (in mm):

SN	Bitumen, % (P_b)	Filler Dust %	Aggregate Mix. % (P_s)	Specification Mass, gm			Bulk Volume, cm³	Bulk S.G. of Specimen (G_{mb})	% Air Void (P_a)	% VMA	% VFA	Stability N		Flow
				In air	In water	SSD in air						Measured	Corrected	

Chapter 4 Hot-Mix Asphalt Plant Operations

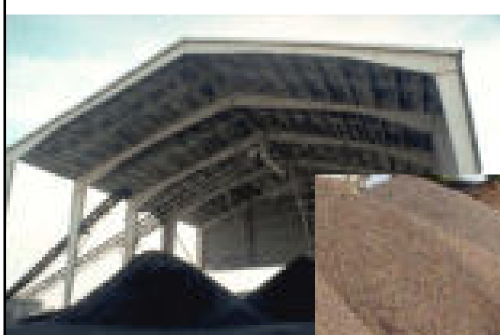


Figure 4.8 Covered aggregate stockpiles.

Figure 4.9 Horizontal stockpiles.

Plant Trials

Table 6.1 Permissible Variations in the Actual Mix from the Job Mix Formula

Description	DBM	AC
Aggregate passing 19 mm sieve or larger	± 8%	±7%
Aggregate passing 13.2 mm, 9.5 mm	±7%	±6%
Aggregate passing 4.75 mm	±6%	±5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	±5%	±4%
Aggregate passing 0.3 mm, 0.15 mm	±4%	±3%
Aggregate passing 0.075 mm	±2%	±1.5%
Binder content	± 0.3%	± 0.3%
Mixing temperature	± 10°C	± 10°C

5.3 Weather limitations

It is not desirable to place HMA on wet surfaces or in weather conditions that would inhibit the proper placement and compaction of the HMA mixture. In case of following situation, laying should be suspended:

i. In presence of standing water on the surface.
ii. When rain is imminent, and during rains, fog or dust storm;
iii. When the base/binder course is damp;
iv. When the air temperature on the surface on which it is to be laid is less than 10°C for mixes with conventional bitumen and is less than 15°C for mixes with modified bitumen;
v. When the wind speed at any temperature exceeds the 40 km per hour at 2 m height.

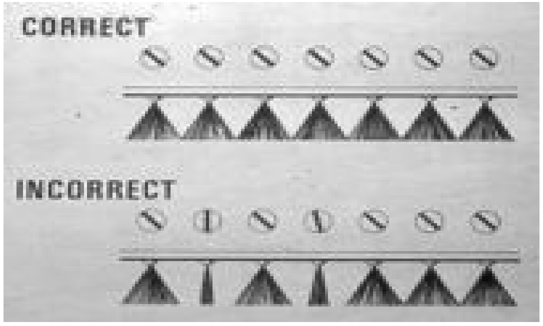
The temperature guidelines is presented in table 5.1

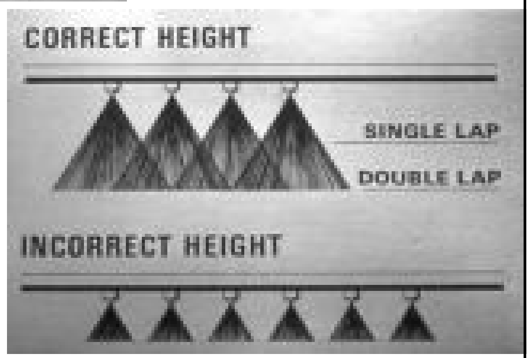
Table 5.1 Temperature and seasonal requirements

Nominal compacted lift thickness	Surface temperature minimum[1] with dry surface
• 100 mm	5°C
• 50 mm, but <100 mm	8°C
<50 mm	10°C

Table 5.2 Rate of Application of Tack Coat

Type of Surface	Rate of Spray (kg/sq.m)
Bituminous surfaces	0.40-0.60
Granular surfaces treated with primer	0.50- 0.60
Cement concrete pavement	0.60-0.70





should follow the laying plant as closely as possible. The rollers should be operated with the drive roll nearest the laying plant, at a slow and uniform speed (not exceeding 5 km/h).

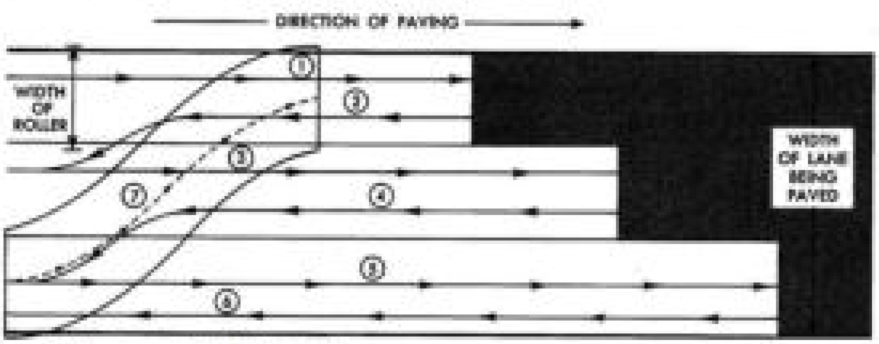


Figure 5.5 Recommended rolling pattern

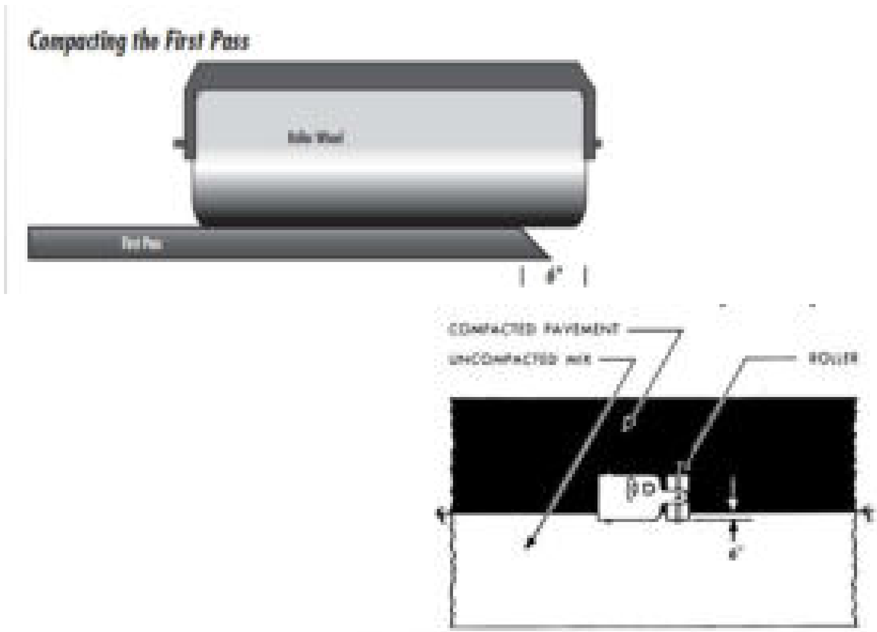


Figure 5.8 Rolling a longitudinal joint

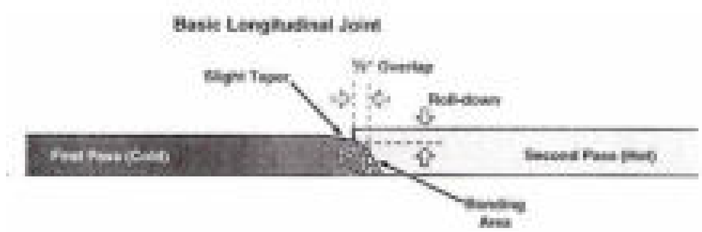


Figure 5.6 Traditional "butt" joint

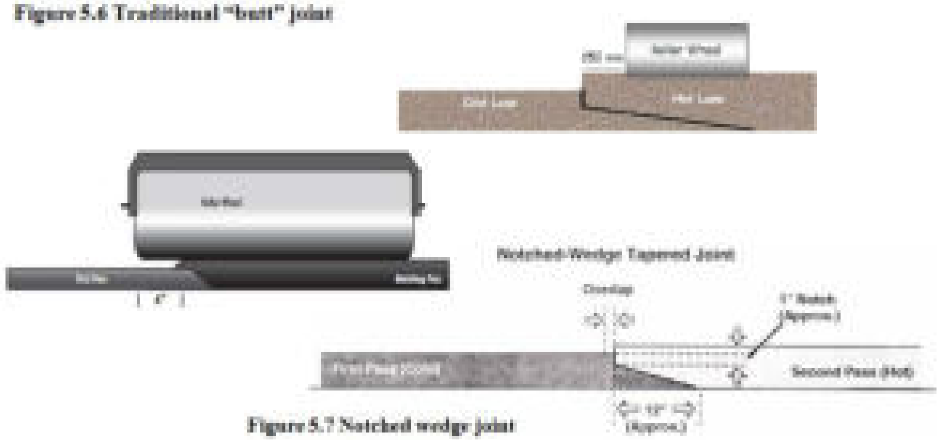


Figure 5.7 Notched wedge joint

Daily mix verification

Daily field verification tests are typically performed on random samples taken from a set quantity of material called a lot. A lot is typically a day's production or a 400 tonnage of material.

Figure 6.1 Template Placed in A
Container

Figure 6.2 Sampling from a Truck Scraping Sample Off Shovel into Sample Box

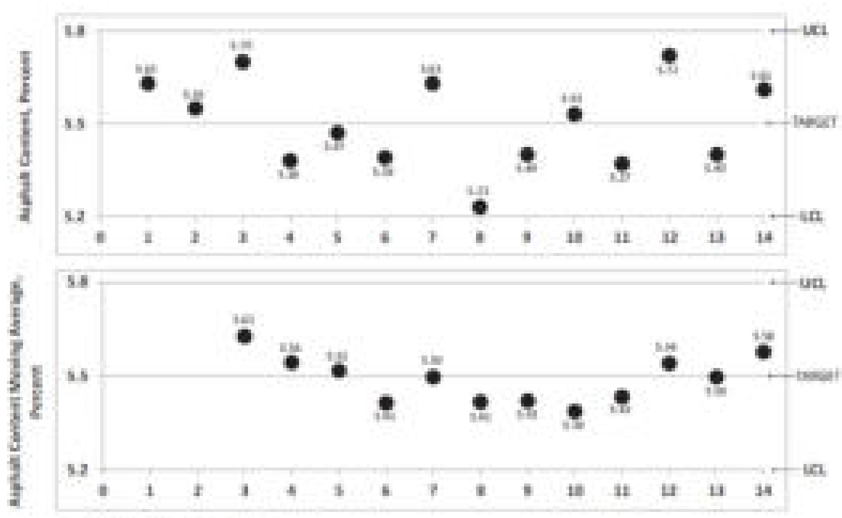


Figure 6.3 Typical mixture production quality control charts

C6.5 Density specifications

The goal of compaction is to achieve a smooth, uniform surface at optimum air voids content that ultimately determines whether the pavement will perform as expected. The in-place air voids of HMA after compaction is a very important factor that affects performance of the mixture throughout the life of the pavement. Achieving compliance with compaction specifications is the final step in the quality management of the HMA construction procedures and must be accomplished to produce a quality asphalt pavement.

The Engineer can direct additional testing as required to fulfil the requirement as specified in specification. **The acceptance criteria for tests on density shall subject to the condition that the mean value is not less than the specified value plus:**

$$\left[1.65 - \frac{1.65}{\sqrt{(No\ of\ samples)}}\right] x\ standard\ deviation$$

If the results of any tests show that any of the constituent materials fail to comply with this Specification, the Contractor should carry out whatever changes may be necessary to the materials and/or to the source of supply to ensure compliance.