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STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

SECTION : II

LOADS AND STRESSES

(Fourth Revision)

THE INDIAN ROADS CONGRESS
2000

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(Fourth Revision)

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LOADS AND STRESSES

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(As on 19.8.2000)

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LOADS AND STRESSES

INTRODUCTION

The brief history of the Bridge Code given in the introduction to Section I "General Features of Design" applies to Section II also generally. The draft of Section II for "Loads and Stresses" as discussed at Jaipur Session of the Indian Roads Congress in 1946 was considered further at a number of meetings of the Bridges Committee for finalisation. In the years 1957 and 1958, the work of finalising the draft was pushed on vigorously by the Bridges Committee.

At the Bridges Committee meeting held at Bombay in August, 1958, all the comments received till then on the different clauses of this Section were disposed off finally and a drafting Committee consisting of Sarvashri S.B. Joshi, K.K. Nambiar, K.F. Antia and S.K. Ghosh was appointed to work in conjunction with the officers of the Roads Wing for finalising this Section.

This Committee at its meeting held at New Delhi in September, 1958 and later through correspondence finalised Section II of the code which was printed in 1958, reprinted in 1962 and 1963.

The second revision of Section II of the Code (1964 edition) included all the amendments, additions and alterations made by the Bridges Committee in their meetings held from time to time.

The Executive Committee of the Indian Roads Congress approved the publication of the third revision in metric units, in 1966.

The Bridges Committee at its meeting held in 1971 approved certain amendments in light of the Fourth Revision of Section I and Section III. These amendments, vide Amendment No. 1 of November 1971 (amending Clauses 204, 207, 209, 212 and 216) and Amendment No. 2 of November 1972, (regarding sub-clause 201.1) have been included in this Edition. The present reprint also incorporates Amendment No. 3 of April 1974, regarding sub-clause 211.2 and erratum to sub-clause 209.4(c).

As suggested by the Bridges Committee and approved by the Council, in the introduction to IRC:78-1979 "Standard Specifications and Code of Practice for Road Bridges, Section : VII-Foundations and Substructure, 2000 Part I : General Features of Design", the provisions given in Appendices 4 and 5 of that Code are transferred and incorporated in this Code (reprinted in September 1981) with necessary editorial changes to convey the correct sense as applicable to this Code. Appendix 4 referred to above is amalgamated in Clauses 202 and 203 and Appendix 5 replaces Clause 222 of IRC:6-1966 Bridge Code Section II. Consequential to the transfer of Appendix 4, Clause 221 of this Code is replaced by note (iv) under item 1 of loads and stresses of Appendix 4 of IRC:78-1979.

As approved by Council in its meeting held at Bangalore on 22.5.98, the changes in Clause 218 - Temperature and a new Clause 223 on Ship/Barge Impact on Bridges have been incorporated.

The Loads and Stresses Committee in its various meetings finalised the Clauses 202.3, 203, 206, 207, 208, 209, 212, 214, 217, 220.1 (c), 224, 225 and 226 on 29.10.99. The personnel of the Committee is given below :

Dr. M.G. Tamhankar	... Convenor
P.K. Agarwal	... Co-Convenor
T. Viswanathan	... Member-Secretary

Members

P.L. Bongirwar	Dr. C.S. Surana
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Dr. G.P. Saha	Rep. of RDSO, Lucknow
C.E.(R) Bhubaneswar	(S.S. Gupta)
(D.K. Nayak)	

The Bridges Specifications and Standards Committee in its meeting held on 19.8.2000 approved Draft Revision to Clauses of IRC-6 except Clause 212 and authorised the Convenor (B-3) Committee to modify the same in light of the comments of members for placing before the Executive Committee. The Executive Committee in its meeting held on 30.8.2000 approved the modified clauses and later by the Council in its 160th meeting held on 4th November, 2000 at Calcutta.

SCOPE

The object of the Standard Specifications and Code of Practice is to establish a common procedure for the design and construction of road bridges in India. This publication is meant to serve as a guide to both the design engineer and the construction engineer but compliance with the rules therein does not relieve them in any way of their responsibility for the stability and soundness of the structure designed and erected by them. The design and construction of road bridges require an extensive and through knowledge of the science and technique involved and should be entrusted only to specially qualified engineers with adequate practical experience in bridge engineering and capable of ensuring careful execution of work.

201. CLASSIFICATION

201.1. Road bridges and culverts shall be divided into classes according to the loadings they are designed to carry.

I.R.C. Class AA Loading : This loading is to be adopted within certain municipal limits, in certain existing or contemplated industrial areas, in other specified areas, and along certain specified highways. Bridges designed for Class AA Loading should be checked for Class A Loading also, as under certain conditions, heavier stresses may be obtained under Class A Loading.

Note : "Where Class 70-R is specified, it shall be used in place of IRC Class AA loading".

I.R.C. Class A Loading : This loading is to be normally adopted on all roads on which permanent bridges and culverts are constructed.

I.R.C. Class B Loading : This loading is to be normally adopted for temporary structures and for bridges in specified areas. Structures with timber spans are to be regarded as temporary structures for the purpose of this Clause.

For particulars of the above three types of loading, see Clause 207.

201.2. Existing bridges which were not originally constructed or later strengthened to take one of the above specified I.R.C. Loadings will be classified by giving each a number equal to that of the highest standard load class whose effects it can safely withstand.

Appendix-1 gives the essential data regarding the limiting loads in each bridge class, and forms the basis for the classification of bridges.

201.3. Individual bridges and culverts designed to take electric tramways or other special loadings and not constructed to take any of the loadings described in Clause 201.1 shall be classified in the appropriate load class indicated in Clause 201.2.

202. LOADS, FORCES AND STRESSES

202.1. The loads, forces and stresses to be considered in designing road bridges and culverts are :

1.	Dead load	G
2.	Live load	Q
3.	Snow load (See note i)	G_s
4.	Impact due to vehicles	Q_{im}
5.	Impact due to floating bodies or vessels as the case may be	F_{im}
6.	Vehicle Collision load	V_c
7.	Wind load	W
8.	Water current	F_{wc}

9.	Longitudinal forces caused by tractive effort of vehicles or by braking of vehicles and/or those caused by restraint of movement of free bearings by friction or deformation	$F_a/F_b/F_f$
10.	Centrifugal force	F_{cf}
11.	Buoyancy	G_b
12.	Earth pressure including live load surcharge, if any	F_{ep}
13.	Temperature effects (see note ii)	F_{te}
14.	Deformation effects	F_d
15.	Secondary effects	F_s
16.	Erection effects	F_{er}
17.	Seismic force	F_{eq}
18.	Wave pressure (see note iii)	F_{wp}
19.	Grade Effect (see note iv)	G_e

Notes : (i) The snow loads may be based on actual observation or past records in the particular area or local practices, if existing.

(ii) Temperature effects (F_{te}) in this context is not the frictional force due to the movement of bearing but that which is caused by rib shortening, etc.

(iii) The wave forces shall be determined by suitable analysis considering drawing and inertia forces etc. on single structural members based on rational methods or model studies. In case of group of piles, piers etc., proximity effects shall also be considered.

(iv) For bridges built in grade or cross-fall, the bearings shall normally be set level by varying the thickness of the plate situated between the upper face of the bearing and lower face of the beam or by any other suitable arrangement. However, where the bearings are required to be set parallel to the inclined grade or cross-fall of the superstructure, an allowance shall be made for the longitudinal and transverse components of the vertical loads on the bearings.

202.2. All members shall be designed to sustain safely most critical combination of various loads, forces and stresses that can co-exist, and all calculations shall tabulate distinctly the various combinations of the above loads and stresses covered by the design.

202.3. **Combination of Loads and Forces and Permissible Increase in Stresses** : The load combination shown in Table 1 shall be adopted for working out stresses in members. The permissible increase of stresses in various members due to these combinations are also indicated therein. These combinations of forces are not applicable for working out base pressure on foundations for which provision made in relevant IRC Bridge Code shall be adopted.

***203. DELETED**

****204. DELETED**

205. DEAD LOAD

The dead load carried by a girder or member shall consist of the portion of the weight of the superstructure (and the fixed loads carried thereon) which is supported wholly or in part by the girder or member including its on weight. The following unit weights of materials shall be used in determining loads, unless the unit weights have been determined by actual weighing of representative samples of the materials in question, in which case the actual weights as thus determined shall be used.

---

* Deleted as permissible increase in stress covered under Table 1

** Deleted as relevant provisions are covered in IRC:78-2000 Standard Specifications & Code of Practice for Road Bridges, Section VII

Table 1. Load combinations and permissible stresses (CL.202.3)

No	G Dead Load	Q Live Load	G_s Snow Load	Q_{im} Vehicle Impact	F_{im} Impact Floating Bodies	V_c Vehicle Collision Load	W Wind	F_{wc} Water Current	F_q or Tractive	F_b &/or Braking	F_f Bearing Friction	F_{cf} Centrifugal Force	G_b Buoyancy	F_{ep} Earth Pressure	F_{te} Temperature	F_d Deformation Effects	F_s Secondary Effects	F_{er} Erection Effects	F_{eq} Seismic	F_{wp} Wave Pressure	G_e Grade Effect	% Permissible Stresses	Remarks
I	1	1	*	1				1	1	1	1	1	1	1							1	100	Service conditions
II A	1	1	*	1				1	1	1	1	1	1	1	1	1	1				1	115	
II B	1	(0.50)		(0.50)				1	(0.50)	(0.50)	(0.50)	(0.50)	1	1	(1)	1	1				1	115	
III A	1	1	*	1			1	1	1	1	1	1	1	1	1	1	1			1	1	133	
III B	1	(0.50)		(0.50)					(0.50)	(0.50)	(0.50)	(0.50)	1	1	(1)	1	1			1	1	133	
IV	1	1	*	1			1	1	1	1	1	1	1	1		1	1			1	1	133	
V	1					1																150	
VI	1	0.50		0.50				1	0.50	0.50	0.50	0.50	1	1	1	1	1		1	1	1	150	
VII	1	1	*	1	1		1	1	1	1	1	1	1	1	1	1	1				1	133	
VIII	1					•	1	1			1		1	1				1			1	133	Construction condition
IX	1							1			1		1	1				1	0.5		1	150	

Note 1 * Where Snow Load is applicable, clause 224 shall be referred for combinations with Live Load

2 Any load combination involving temperature, wind and/or earthquake acting independently or in combination, maximum permissible tensile stress in Prestressed Concrete Members shall be limited to the value as per relevant code (IRC:18).

3 Live Load factors indicate the maximum value for the particular load combination. The structure must also be checked with no live load.

4 In load combinations with temperature where (0.5) has been adopted, it relates to the gradient effect due to temperature.

5 Seismic effect during erection stage is reduced to half in load combination IX when construction phase does not exceed 5 years.

	Materials		Weight t/m³
1.	Ashlar (granite)	...	2.7
2.	Ashlar (sandstone)	...	2.4
3.	Stone setts :		
	(a) Granite	...	2.6
	(b) Basalt	...	2.7
4.	Ballast (stone screened, broken, 2.5 cm to 7.5 cm gauge, loose) :		
	(a) Granite	...	1.4
	(b) Basalt	...	1.6
5.	Brickwork (pressed) in cement mortar	...	2.2
6.	Brickwork (common) in cement mortar	...	1.9
7.	Brickwork (common) in time mortar	...	1.8
8.	Concrete (asphalt)	...	2.2
9.	Concrete (breeze)	...	1.4
10.	Concrete (cement-plain)	...	2.2
11.	Concrete (cement-plain with plums)	...	2.3
12.	Concrete (cement-reinforced)	...	2.4
13.	Concrete (cement-prestressed)	...	2.5
14.	Concrete (lime-brick aggregate)	...	1.9
15.	Concrete (lime-stone aggregate)	...	2.1
16.	Earth (compacted)	...	1.8
17.	Gravel	...	1.8
18.	Macadam (binder premix)	...	2.2
19.	Macadam (rolled)	...	2.6
20.	Sand (loose)	...	1.4
21.	Sand (wet compressed)	...	1.9
22.	Coursed rubble stone masonry (cement mortar)	...	2.6
23.	Stone masonry (lime mortar)	...	2.4
24.	Water	...	1.0
25.	Wood	...	0.8
26.	Cast iron	...	7.2
27.	Wrought iron	...	7.7
28.	Steel (rolled or cast)	...	7.8

*206. DELETED

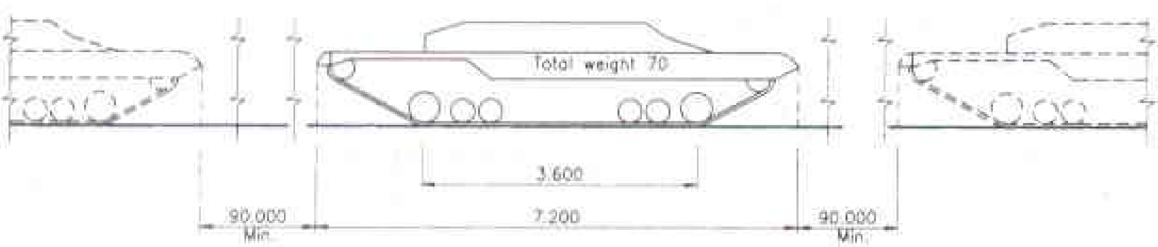
207. LIVE LOADS

207.1. Details of I.R.C. Loadings

207.1.1. For bridges classified under Clause 201.1, the designed live load shall consist of standard wheeled or tracked vehicles or trains of vehicles as illustrated in Figs. 1 to 3 and *Appendix 1*. The trailers attached to the driving unit are not to be considered as detachable.

207.1.2. Within the kerb to kerb width of the roadway, the standard vehicle or train shall be assumed to travel parallel to the length of the bridge, and to occupy any position which will produce maximum stresses provided that the minimum clearances between a vehicle and the roadway face of kerb and between two passing or crossing vehicles, shown in Figs. 1 to 3, are not encroached upon.

207.1.3. For each standard vehicle or train, all the axles of a unit of vehicles shall be considered as acting simultaneously in a position causing maximum stresses.



TRACKED VEHICLE

Fig. 1. Class AA tracked and wheeled vehicles (Clause 207.1) (contd.)

* Refer to Clause 112 of IRC:5-1998

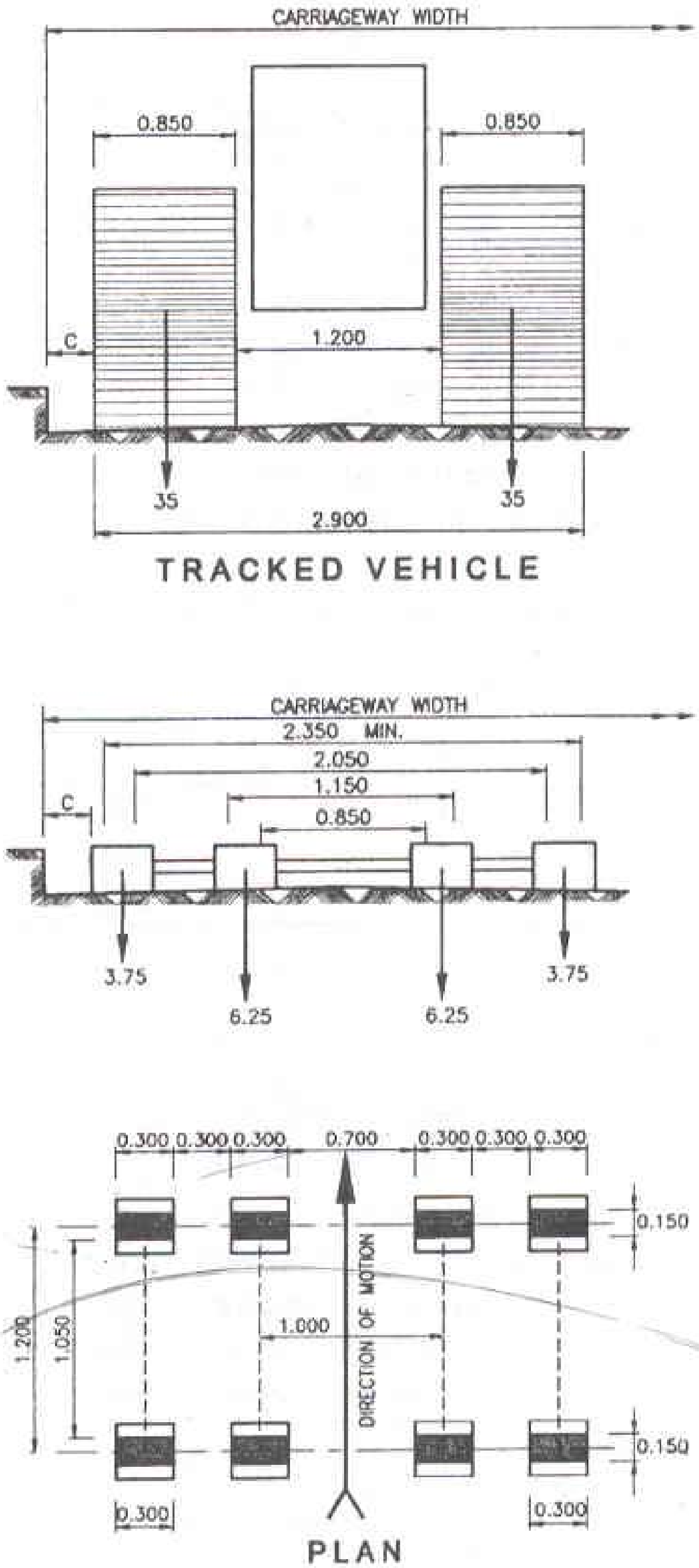


Fig. 1. Class AA tracked and wheeled vehicles (Clause 207.1)

Notes :

1. The nose to tail spacing between two successive vehicles shall not be less than 90 m.

2. For multi-lane bridges and culverts, one train of Class AA tracked or wheeled vehicles whichever creates severer conditions shall be considered for every two traffic lane width.

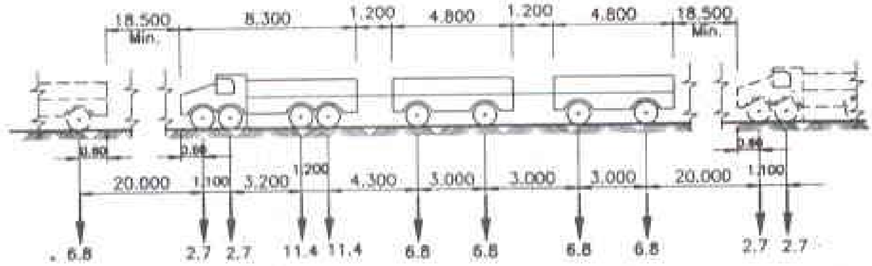
No other live load shall be considered on any part of the said 2-lane wide carriageway of the bridge when above mentioned train of vehicles is crossing the bridge.

3. The maximum loads for the wheeled vehicle shall be 20 tonnes for a single axle or 40 tonnes for a bogie of two axles spaced not more than 1.2 m centres.

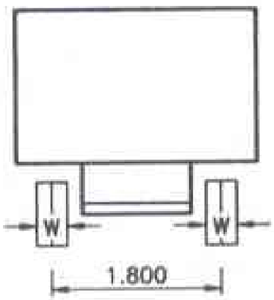
4. The minimum clearance between the road face of the kerb and the outer edge of the wheel or track, C, shall be as under:

Carriageway width	Minimum value of C
Single-Lane Bridges	
3.8 m and above	0.3 m
Multi-Lane Bridges	
Less than 5.5 m	0.6 m
5.5 m or above	1.2 m

5. Axle loads in tonne linear dimensions in metre.



Class A train of vehicles



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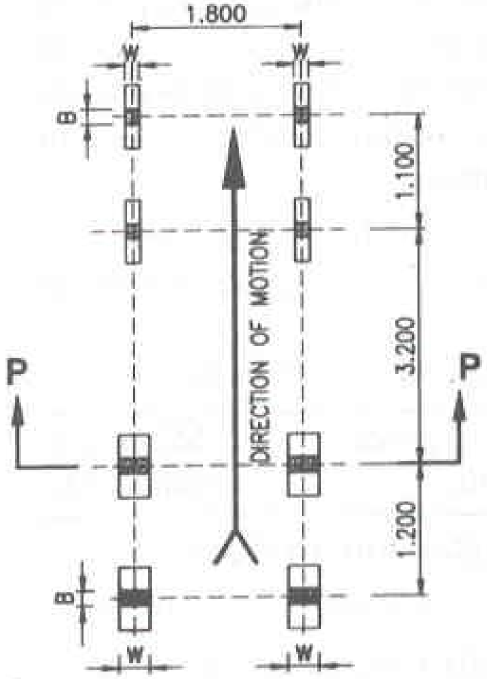


PLAN

DRIVING VEHICLE

Fig. 2. Class 'A' train of vehicles (Clause 207.1)

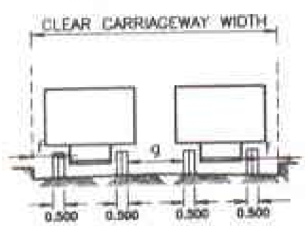
Notes :

1. The nose to tail distance between successive trains shall not be less than 18.4 m.

2. No other live load shall cover any part of the carriageway when a train of vehicles (or trains of vehicles in multi-lane bridge) is crossing the bridge.

3. The ground contact area of the wheels shall be as under :

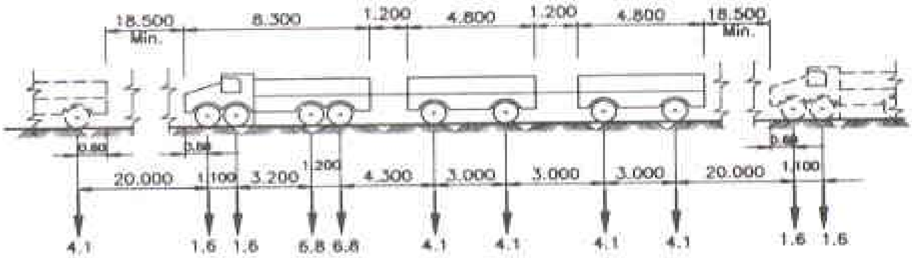
Axle load (tonne)	Ground contact area	
	B mm	W mm
11.4	250	500
6.8	200	380
2.7	150	200



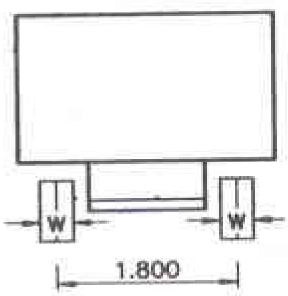
4. The minimum clearance, *f*, between outer edge of the wheel and the roadway face of the kerb, and the minimum clearance, *g*, between the outer edges of passing or crossing vehicles on multi-lane bridges shall be as given below :

Clear carriageway width	g	f
5.5. m to 7.5 m	Uniformly increasing from 0.4 m to 1.2 m	150 mm for all carriageway widths
Above 7.5 m	1.2 m	

5. Axle loads in tonne linear dimensions in metre.



Class B train of vehicles



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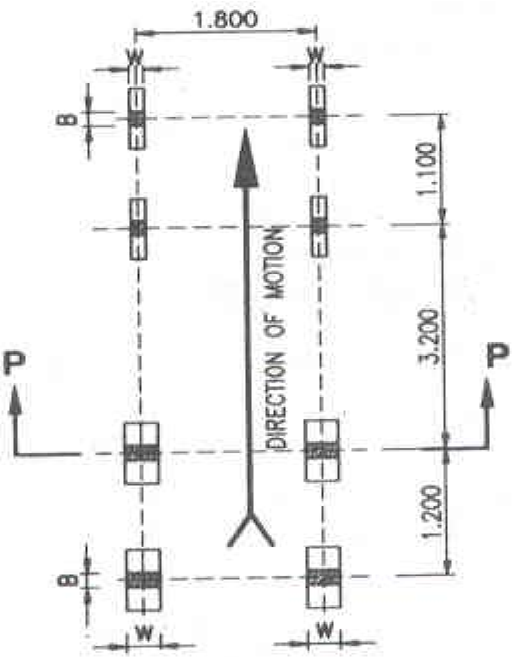


PLAN

DRIVING VEHICLE

Fig. 3. Class 'B' train of vehicles (Clause 207.1)

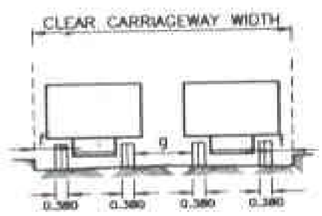
Notes :

1. The nose to tail distance between successive trains shall not be less than 18.4 m.

2. No other live load shall cover any part of the carriageway when a train of vehicles (or trains of vehicles in multi-lane bridge) is crossing the bridge.

3. The ground contact area of the wheels shall be as under :

Axle load (tonne)	Ground contact area	
	B mm	W mm
6.8	200	380
4.1	150	300
1.6	125	175



4. The minimum clearance, *f*, between outer edge of the wheel and the roadway face of the kerb, and the minimum clearance, *g*, between the outer edges of passing or crossing vehicles on multi-lane bridges shall be as given below :

Clear carriageway width	g	f
5.5. m to 7.5 m	Uniformly increasing from 0.4 m to 1.2 m	150 mm for all carriageway widths
Above 7.5 m	1.2 m	

5. Axle loads in tonne linear dimensions in metre.

207.1.4. Vehicles in adjacent lanes shall be taken as headed in the direction producing maximum stresses.

207.1.5. The spaces on the carriageway left uncovered by the standard train of vehicles shall not be assumed as subject to any additional live load.

207.2. **Deleted**

207.3. **Dispersion of Load through Fills of Arch Bridges**

The dispersion of loads through the fills above the arch shall be assumed at 45 degrees both along and perpendicular to the span in the case of arch bridges.

207.4. **Combination of Live Load**

This clause shall be read in conjunction with Clause 112.1 of IRC:5-1998. The carriageway live load combination shall be considered for the design as shown in Table 2.

Table 2. Live Load Combination

<table>
<tr><th>Carriageway width</th><th>Number of Lanes for Design purposes</th><th>Load combination</th></tr>
<tr><td>1. Less than 5.3m</td><td>1</td><td>One lane of Class A considered to occupy 2.3m. The remaining width of carriageway shall be loaded with 500 Kg/m^2</td></tr>
<tr><td>2. 5.3m and above but less than 9.6m</td><td>2</td><td>One lane of Class 70R OR two lanes of Class A</td></tr>
<tr><td>3. 9.6m and above but less than 13.1m</td><td>3</td><td>One lane of Class 70R with one lane of Class A OR 3 lanes of Class A</td></tr>
<tr><td>4. 13.1m and above but less than 16.6m</td><td>4</td><td rowspan="3">One lane of Class 70R for every two lanes with one lane of Class A for the remaining lanes, if any, or one lane of Class A for each lane</td></tr>
<tr><td>5. 16.6m and above but less than 20.1m</td><td>5</td></tr>
<tr><td>6. 20.1 m and above but less than 23.6m</td><td>6</td></tr>
</table>

208. REDUCTION IN THE LONGITUDINAL EFFECT ON BRIDGES ACCOMMODATING MORE THAN TWO TRAFFIC LANES

Reduction in the longitudinal effect on bridges having more than two traffic lanes due to the low probability that all lanes will be subjected to the characteristic loads simultaneously shall be in accordance with the table shown below.

Number of lanes	Reduction in longitudinal effect
For two lanes	No reduction
For three lanes	10% reduction
For four lanes	20% reduction
For five or more lanes	20% reduction

Note : However, it should be ensured that the reduced longitudinal effects are not less sever than the longitudinal-effect, resulting from simultaneous load on two adjacent lanes.

209. FOOTWAY, KERB, RAILINGS, PARAPET AND CRASH BARRIERS

209.1. For all parts of bridge floors accessible only to pedestrians and animals and for all footways the loading shall be 400 kg/m^2. Where crowd loads are likely to occur, such as on bridges located near towns, which are either centres of pilgrimage or where large congregational fairs are held seasonally, the intensity of footway loading shall be increased from 400 kg/m^2 to 500 kg/m^2.

209.2. Kerbs, 0.6 m or more in width, shall be designed for the above loads, and for a local lateral force of 750 kg per metre, applied horizontally at top of the kerb. If kerb width is less than 0.6 m, no live load shall be applied in addition to the lateral load specified above.

Note : The horizontal force need not be considered in the design of the main structural members of the bridge.

209.3. **Deleted**

209.4. In bridges designed for any of the loadings described in Clause 207.1, the main girders, trusses, arches, or other members supporting the footways shall be designed for the following live loads per square metre for footway area, the loaded length of footway taken in each case being such as to produce the worst effects on the member under consideration :

(a) For effective span of 7.5 m or less, 400 kg/m^2 or 500 kg/m^2 as the case may be, based on sub-clause 209.1.

(b) For effective spans of over 7.5 m but not exceeding 30 m, the intensity of load shall be determined according to the equation :

$$P = P' - \left(\frac{40L - 300}{9}\right)$$

(c) For effective spans of over 30 m, the intensity of load shall be determined according to the equation :

$$P = \left(P' - 260 + \frac{4800}{L}\right)\left(\frac{16.5 - W}{15}\right)$$

where P' = 400 kg/m^2 or 500 kg/m^2 as the case may be, based on sub-clause 209.1.

P = the live load in kg/m^2,

L = the effective span of the main girder, truss or arch in m, and

W = width of the footway in m.

209.5. Each part of the footway shall be capable of carrying a wheel load of 4 tonne, which shall be deemed to include impact, distributed over a contact area 300 mm in diameter; the permissible working stresses shall be increased by 25 per cent to meet this provision. This provision need not be made where vehicles cannot mount the footway as in the case of a footway separated from the roadway by means of an insurmountable obstacle, such as truss or a main girder.

Note : A footway kerb shall be considered mountable by vehicles.

209.6. **The Pedestrian/Bicycle Railings/Parapets**

The pedestrian/bicycle railings/parapets can be of a large variety of construction. The design loads for two basic types are given below:

i) Type: Solid/partially filled in parapet continuously cantilevering along full length from deck level.

Loading: Horizontal and vertical load of 150 kg/m. acting simultaneously on the top level of the parapet.

ii) Type: Frame type with discrete vertical posts cantilevering from the curb/deck with minimum two rows of horizontal rails (third row bring the curb itself, or curb replaced by a low level 3rd rail). The rails may be simply supported or continuous over the posts.

Loading: Each horizontal railing designed for horizontal and vertical load of 150 kg/m, acting simultaneously over the rail. The filler portion, supported between any two horizontal rails and vertical rails should be designed to resist horizontal load of 150 kg/m^2. The posts to resist horizontal load of 150 kg x spacing between posts in metre acting on top of the post.

209.7. **Crash Barriers**

Crash barriers are designed to withstand the impact of vehicles of certain weights at certain angle while travelling at the specified speed. They are expected to guide the vehicle back on the road while keeping the level of damage to vehicle as well as to the barriers within acceptable limits.

Following are the three categories for different applications:

Category	Application	Containment for
P-1: Normal Containment	Bridges carrying Expressway, or equivalent impact	1.5 Ton vehicle at 110 km/h, and 20° angle of
P-2: Low Containment	All other bridges except bridge over railways.	1.5 Ton vehicle at 80 km/hr and 20° angle of impact
P-3: High Containment	At hazardous and high risk locations, over busy railway lines, complex interchanges, etc.	30 Ton vehicle at 60 km/hr and 20° angle of impact.

The barriers can be of rigid type, using cast-in-situ/precast reinforced concrete panels, or of flexible type, constructed using metallic cold-rolled and/or hot-rolled sections. The metallic type, called semi-rigid type, suffer large dynamic deflection of the order of 0.9 to 1.2m, on impact, whereas the 'rigid' concrete type suffer comparatively negligible deflection. The efficacy of the two types of barriers is established on the basis of full size tests carried out by the laboratories specialising in such testing. Due to the complexities of the structural action, the value of impact force cannot be quantified.

A certificate from such laboratory can be the only basis of acceptance of the semi-rigid type, in which case all the design details and construction details tested by the laboratory are to be followed in toto without modifications, and without changing relative strengths and positions of any of the connections and elements.

For the rigid type of barrier, the same method is acceptable. However, in absence of testing/test certificate, the minimum design resistance shown in Table 3 should be built into the section.

Table 3. Minimum Design Resistance

Item	Requirement	Parapet Type		
		P1 Insitu/ Precast	**P2 Insitu/ Precast**	**P3 Insitu**
1	Shape	Shape on traffic side to be as per IRC-5, or New Jersey (NJ) Type of 'F' Shape designated thus by AASHTO		
2	Minimum grade of concrete	M-40	M-40	M-40
3	Minimum thickness of R C wall (at top)	180mm	150mm	250mm
4	Minimum moment of resistance at base of the wall [(see note (i)] for bending in vertical plane with reinforcement adjacent to the traffic face [see note (ii)].	15 kNm/m	7.5 kNm/m	100 kNm/m for end section and 75 kNm/m for intermediate section [see note (iii)]
5	Minimum moment of resistance for bending in horizontal plane with reinforcement adjacent to outer face [see note (ii)]	7.5 kNm/m	3.75 kNm/m	40 kNm/mm
6	Minimum moment of resistance of anchorage at the base of a precast reinforced concrete panel.	22.5 kNm/m	11.25 kNm/m	
7	Minimum transverse shear resistance at vertical joints between precast panels, or at vertical joints made between lengths of in-situ parapet.	44 kNm/m of joint	22.5 kNm/m	
8	Minimum height	800 mm	800 mm	1500 mm

Note :

i) The base of wall refers to horizontal sections of the parapet within 300mm above the adjoining paved surface level. The minimum moments of resistance shall reduce linearly from the base of wall value to zero at top of the parapet.

ii) In addition to the main reinforcement, in items 4 and 5 above, distribution steel equal to 50% of the main reinforcement shall be provided in the respective faces.

iii) For design purpose the parapet shall be divided into end sections extending a distance not greater than 3.0m from ends of the parapet and intermediate sections extending along remainder of the parapet.

iv) If concrete barrier is used as a median divider, the steel is required to be placed on both sides.

v) In case of P-3 in-situ type, minimum horizontal transverse shear resistance of 135 kNm/m shall be provided.

209.8. **Vehicle Barriers/Pedestrian Railing between Foot-path and Carriageway**

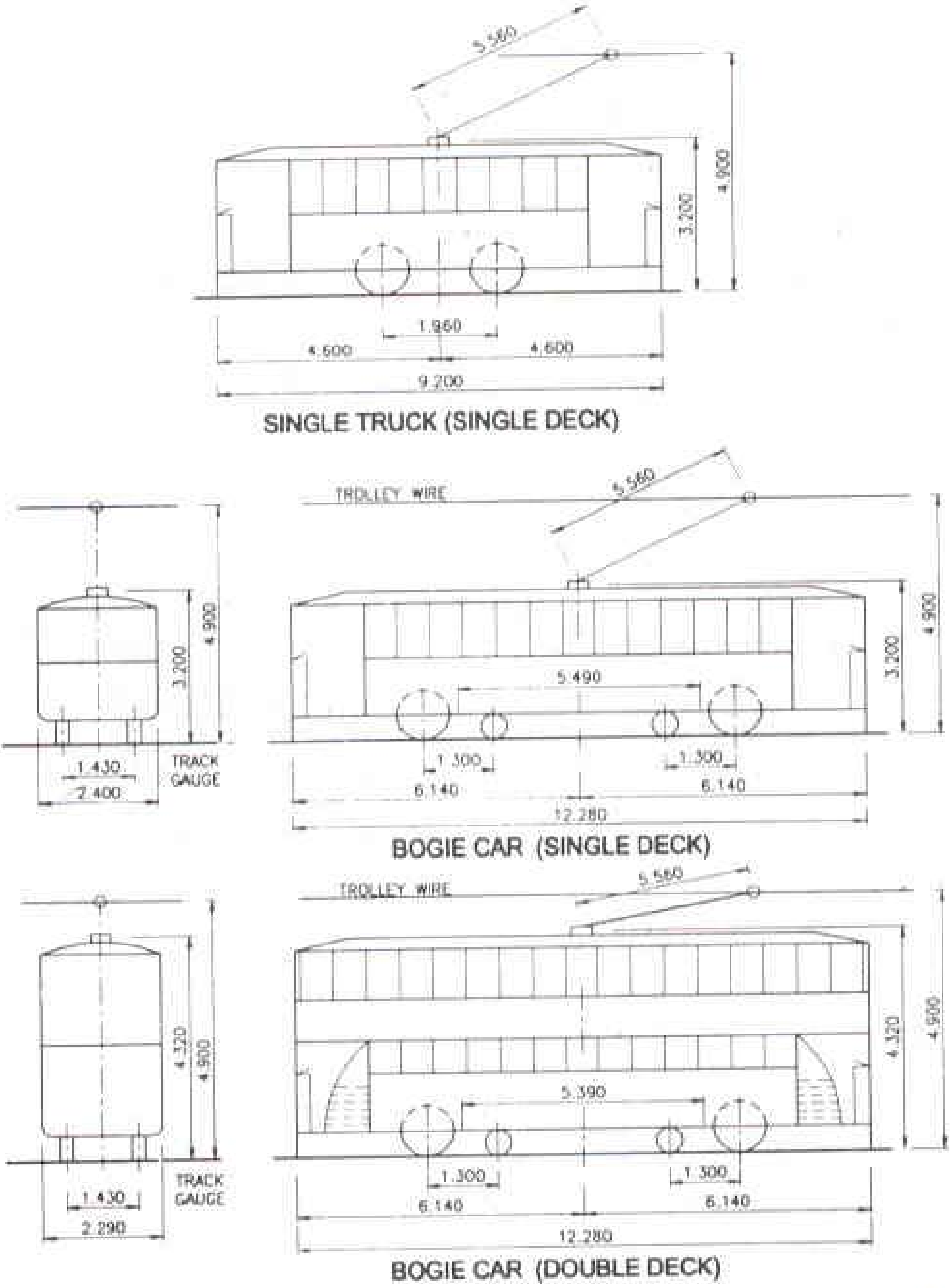
Where considerable pedestrian traffic is expected, such as in/near townships, rigid type of reinforced concrete crash barrier should be provided separating the vehicular traffic from the same. The design and construction details should be as per Clause 209.7. For any other type of rigid barrier, the strength should be equivalent to that of rigid RCC type.

For areas of low intensity of pedestrian traffic, semi-rigid type of barrier, which suffers large deflections can be adopted.

210. TRAMWAY LOADING

210.1. When a road bridge carries tram lines, the live load due to the type of tram cars sketched in Fig. 4 shall be computed and shall be considered to occupy a 3 m width of roadway.

210.2. A nose to tail sequence of the tram cars or any other sequence which produces the heaviest stresses shall be considered in the design.



Notes :

1. Clearance between passing single deck bogie cars on straight tracks laid at standard 2.75m track centres shall be 300 mm.
2. Clearance between passing double bogie cars on straight tracks laid at standard 2.75 m track centres shall be 450 mm.
3. Linear dimensions in metre.

ROLLING STOCK WEIGHT

Description	Loaded weight tonne	Unloaded weight tonne
Single truck (single deck)	9.6	7.9
Bogie car (Single deck)	15.3	12.2
Bogie car (Double deck)	21.5	16.0

Fig. 4. Average dimension of tramway rolling stock (Clause 210.1)

210.3. Stresses shall be calculated for the following two conditions and the maximum thereof considered in the design :

(a) Tram loading, followed and preceded by the appropriate standard loading specified in Clause 207.1 together with that standard loading on the traffic lanes not occupied by the tram car lines.

(b) The appropriate standard loading specified in Clause 207.1 without any tram cars.

211. IMPACT

211.1. Provision for impact or dynamic action shall be made by an increment of the live load by an impact allowance expressed as a fraction or a percentage of the applied live load.

211.2. **For Class A or Class B Loading :** In the members of any bridge designed either for Class A or Class B loading (vide Clause 207.1), this impact percentage shall be determined from the curves indicated in Fig. 5. The impact fraction shall be determined from the following equations which are applicable for spans between 3m and 45 m.

(i) Impact factor fraction for reinforced concrete bridges = $\frac{4.5}{6+L}$

(ii) Impact factor fraction for steel bridges = $\frac{9}{13.5+L}$

where L is length in metres of the span as specified in Clause 211.5.

211.3. **For Class AA Loading and Class 70 R Loading:** The value of the impact percentage shall be taken as follows :

(a) For spans less than 9 m :

(i) for tracked vehicles	:	25 per cent for spans upto 5 m linearly reducing to 10 per cent for spans of 9 m
(ii) For wheeled vehicles	:	25 per cent

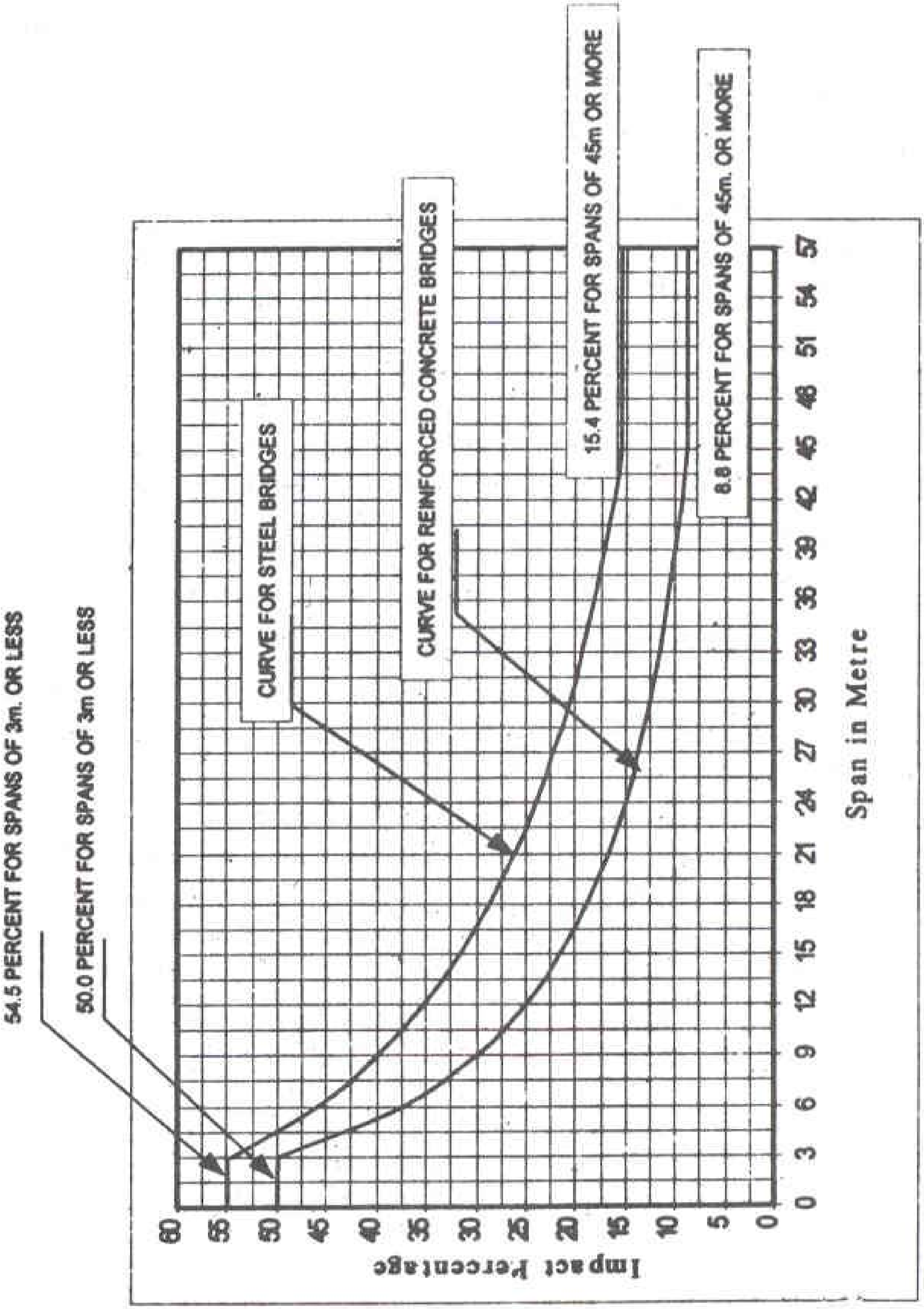


Fig. 5. Impact percentage for highway bridges for Class A and Class B loading (Clause 211.2)

(b) For spans of 9 m or more :

(i) Reinforced concrete bridges

Tracked vehicles	:	10 per cent upto a span of 40 m and in accordance with the curve in Fig. 5 for spans in excess of 40 m.
Wheeled vehicles	:	25 per cent for spans upto 12 m and in accordance with the curve in Fig. 5 for spans in excess of 12 m

(ii) Steel bridges

Tracked vehicles	:	10 per cent for all spans
Wheeled vehicles	:	25 per cent for spans upto 23 m and in accordance with the curve indicated in Fig. 5 for spans in excess of 23 m.

211.4. No impact allowance shall be added to the footway loading specified in Clause 209.

211.5. The span length to be considered for arriving at the impact percentages specified in Clauses 211.2 and 211.3 shall be as follows :

(a) For spans simply supported or continuous or for arches .... the effective span on which the load is placed.

(b) For bridges having cantilever arms without suspended spans .... the effective overhang of the cantilever arms reduced by 25 per cent for loads on the cantilever arm and the effective span between supports for loads on the main span.

(c) For bridges having cantilever arms with suspended span .... the effective overhang of the cantilever arm plus half the length of the suspended span for loads on the cantilever arm, the effective length of the suspended span for loads on the suspended span and the effective span between supports for loads on the main span.

Note : "For individual members of a bridge such as a cross girder or deck slab etc. the value of L mentioned in 211.2 or the spans mentioned in 211.3 shall be the effective span of the member under consideration".

211.6. In any bridge structure where there is a filling of not less than 0.6 m including the road crust, the impact percentage to be allowed in the design shall be assumed to be one-half of what is specified in Clauses 211.2 and 211.3.

211.7. For calculating the pressure on the bearings and on the top surface of the bed blocks, full value of the appropriate impact percentage shall be allowed. But, for the design of piers; abutments and structures, generally below the level of the top of the bed block, the appropriate impact percentage shall be multiplied by the factor given below :

(a)	For calculating the pressure at the bottom surface of the bed block	... 0.5
(b)	For calculating the pressure on the top 3 m of the structure below the bed block	... 0.5 decreasing uniformly to zero
(c)	For calculating the pressure on the portion of the structure more than 3m below the bed block	zero

211.8. In the design of members subject, among other stresses, to direct tension, such as hangers in a bowstring girder bridge, and in the design of members subject to direct compression, such as spandrel columns or walls in an open spandrel arch, the impact percentage shall be taken the same as that applicable to the design of the corresponding member or members of the floor system which transfer loads to the tensile or compressive members in question.

211.9. These Clauses on Impact do not apply to the design of suspension bridges.

212. WIND LOAD

212.1. All structures shall be designed for the following lateral wind forces. These forces shall be considered to act horizontally and in such a direction that the resultant stresses in the member under consideration are the maximum.

212.2. The wind force on a structure shall be assumed as a horizontal force of the intensity specified in Clause 212.3 and acting on an area calculated as follows :

(a) For a deck structure :
The area of the structure as seen in elevation including the floor system and railing, less area of perforations in the hand railing or parapet walls.

(b) For a through or half-through structure :
The area of the elevation of the windward truss as specified at (a) above plus half the area of elevation above the deck level of all other trusses or girders.

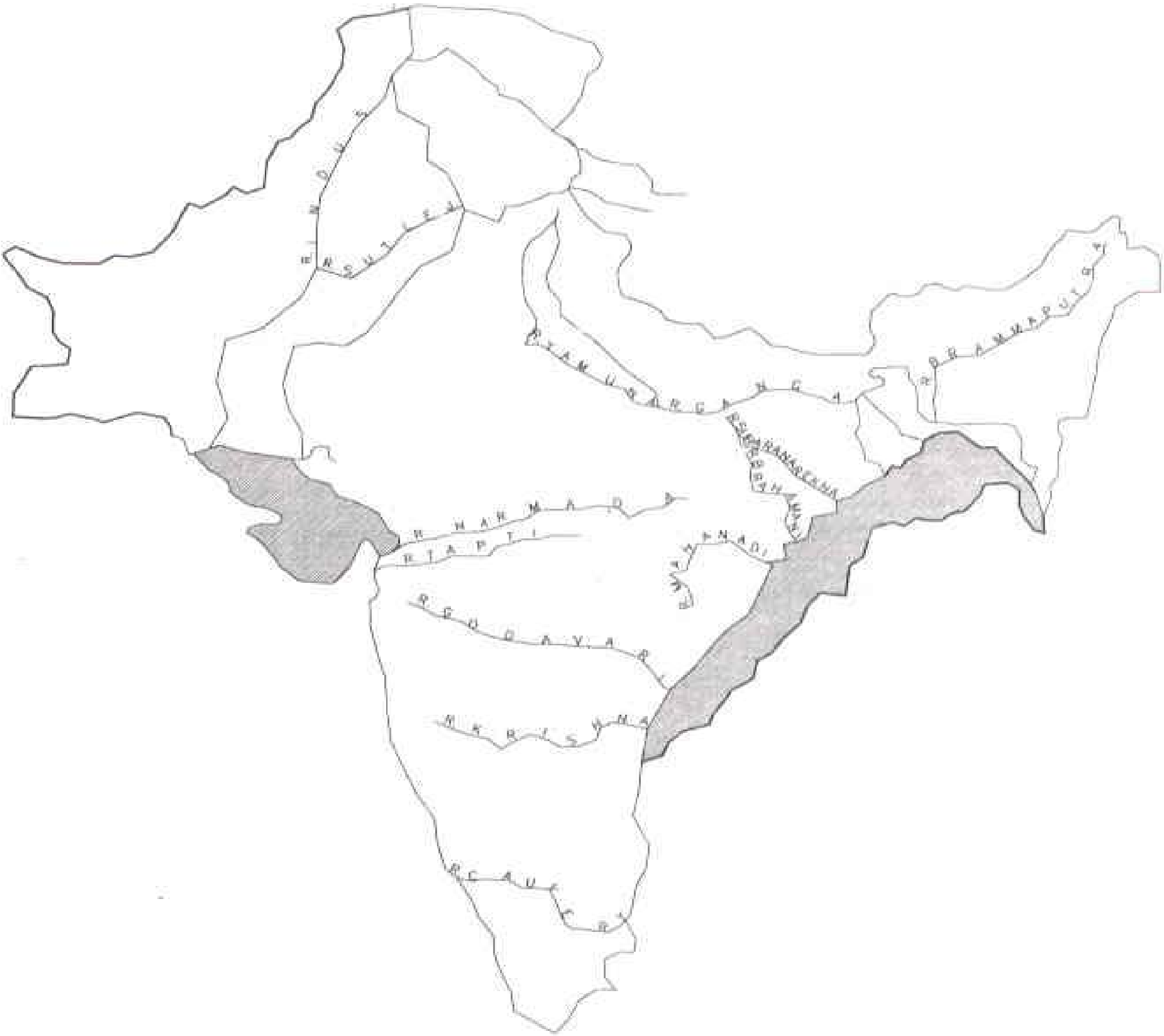
212.3. The intensity of the wind force shall be based on wind pressures and wind velocities shown in Table 4 and shall be allowed for in the design. The pressures given therein shall however, be doubled for bridges situated in areas such as the Kathiawar Peninsula and the Bengal and Orissa coasts shown hatched in Fig. 6.

212.4. The lateral wind force against any exposed moving live load shall be considered as acting at 1.5m above the roadway and shall be assumed to have the following values :

Highway bridges, ordinary	300 kg/linear m
Highway bridges, carrying tramway	450 kg/linear m

While calculating the wind force on live load, the clear distance between the trailers of a train of vehicles shall not be omitted.

INTENSITY OF WIND PRESSURE



As given in the Table in Clause 212.3

Double the values in the Table in Clause 212.3

Fig. 6.

Table 4. Wind Pressures and Wind Velocities

H.	V.	P.	H.	V.	P.
0	80	40	30	147	141
2	91	52	40	155	157
4	100	63	50	162	171
6	107	73	60	168	183
8	113	82	70	173	193
10	118	91	80	177	202
15	128	107	90	180	210
20	136	119	100	183	217
25	142	130	110	186	224

where, H = the average height in metre of the exposed surface above the mean retarding surface (ground or bed level or water level).

V = horizontal velocity of wind in kilometre per hour at height H.

P = horizontal wind pressure in kg/m^2 at height H.

212.5. The bridges shall not be considered to be carrying any live load when the wind velocity at deck level exceeds 130 km per hour.

212.6. The total assumed wind force as calculated according to Clauses 212.2, 212.3, 212.4 and 212.5 shall, however, not be less than 450 kg per linear metre in the plane of the loaded chord and 225 kg per linear metre in the plane of unloaded chord on through or half-through truss, latticed or other similar spans, and not less than 450 kg per linear metre on deck spans.

212.7. A wind pressure of 240 kg/m^2 on the unloaded structure, applied as specified in Clauses 212.2 and 212.3 shall be used if it produces greater stresses than those produced by the combined wind forces as per Clauses 212.2 and 212.3, 212.4, 212.5 or by the wind force as per Clause 212.6.

212.8. In calculating the uplift in the posts and anchorages of high latticed towers due to the above mentioned lateral forces, stresses shall also be investigated for the condition of decking being loaded on a traffic lane or lanes on the leward side only.

213. HORIZONTAL FORCES DUE TO WATER CURRENTS

213.1. Any part of a road bridge which may be submerged in running water shall be designed to sustain safely the horizontal pressure due to the force of the current.

213.2. On piers parallel to the direction of the water current, the intensity of pressure shall be calculated from the following equation :

$$P = 52\, KV^2$$

where P = intensity of pressure due to water current, in kg/m^2

V = the velocity of the current at the point where the pressure intensity is being calculated, in metre per second, and

K = a constant having the following values for different shapes of piers illustrated in Fig. 7 :

(i)	Square ended piers (and for the superstructure) :	1.50
(ii)	Circular piers or piers with semi-circular ends :	0.66
(iii)	Piers with triangular cut and ease waters, the angle included between the faces being 30 degrees or less:	0.50
(iv)	Piers with triangular cut and ease waters, the angle included between the faces being more than 30 degrees but less than 60 degrees:	0.50 to 0.70
(v)	- do - 60 to 90 degrees :	0.70 to 0.90

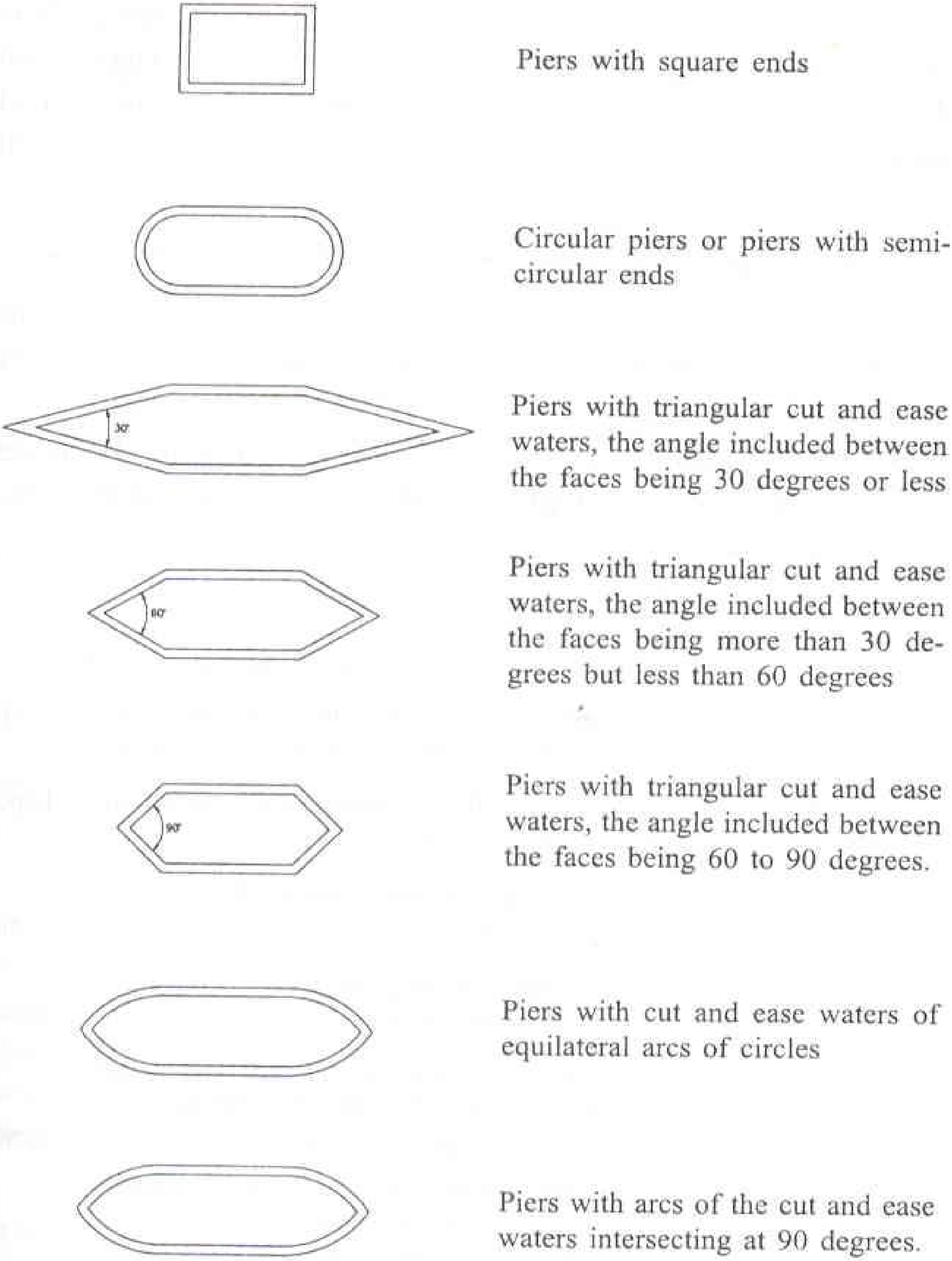
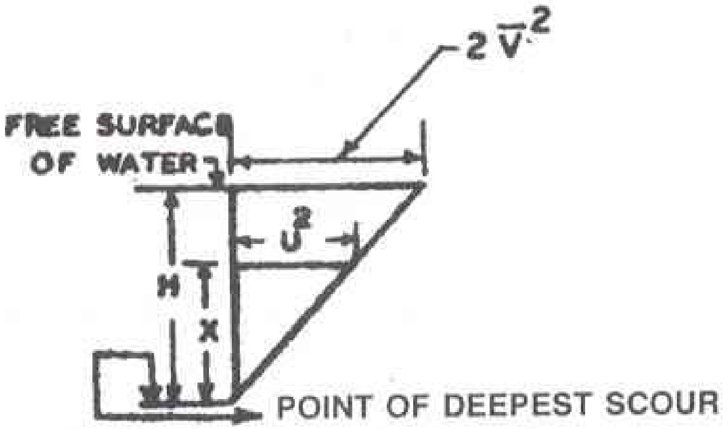


Fig. 7. Shapes of Bridge Piers
(Clause 213.2)

(vi)	Piers with cut and ease waters of equilateral arcs of circles :	0.45
(vii)	Piers with arcs of the cut and ease waters intersecting at 90 degrees :	0.50

213.3. The value of V^2 in the equation given in Clause 213.2 shall be assumed to vary linearly from zero at the point of deepest scour to the square of the maximum velocity at the free surface of water. The maximum velocity for the purpose of this sub-clause shall be assumed to be $\sqrt{2}$ times the maximum mean velocity of the current.



Square of velocity at a height X from the point of deepest

scour $= U^2 = 2\frac{\bar{V}^2 X}{H}$

where $\bar{V}$ is the maximum mean velocity.

213.4. When the current strikes the pier at an angle, the velocity of the current shall be resolved into two components - one parallel and the other normal to the pier.

(a) The pressure parallel to the pier shall be determined as indicated in Clause 213.2 taking the velocity as the component of the velocity of the current in a direction parallel to the pier.

(b) The pressure of the current, normal to the pier and acting on the area of the side elevation of the pier, shall be calculated similarly taking the velocity as the component of the velocity of the current in a direction normal to the pier, and the constant K as 1.5, except in the case of circular piers where the constant shall be taken as 0.66.

213.5. To provide against possible variation of the direction of the current from the direction assumed in the design, allowance shall be made in the design of piers for an extra variation in the current direction of 20 degrees; that is to say, piers intended to be parallel to the direction of current shall be designed for a variation of 20 degrees from the normal direction of the current and piers originally intended to be inclined at θ degrees to the direction of the current shall be designed for a current direction inclined at $(20 \pm \theta)$ degrees to the length of the pier.

213.6. In case of a bridge having a pucca floor or having an inerodible bed, the effect of cross-currents shall in no case be taken as less than that of a static force due to a difference of head of 250 mm between the opposite faces of a pier.

213.7. When supports are made with two or more piles or trestle columns, the group shall be treated as a solid rectangular pier of the same overall length and width and the value of K taken as 1.25 for calculating pressures due to water currents both parallel and normal to the pier.

213.8. The effects of the force of water currents shall be duly considered upto the level indicated in Clause 214.7.

214. LONGITUDINAL FORCES

214.1. In all road bridges, provision shall be made for longitudinal forces arising from any one or more of the following causes:

(a) Tractive-effort caused through acceleration of the driving wheels;

(b) Braking effect resulting from the application of the brakes to braked wheels; and

(c) Frictional resistance offered to the movement of free bearings due to change of temperature or any other cause.

Note : Braking effect is invariably greater than the tractive-effort.

214.2. The braking effect on a simply supported span or a continuous unit of spans or on any other type of bridge unit shall be assumed to have the following value :

(a) In the case of a single-lane or a two-lane bridge : twenty per cent of the first train load plus ten per cent of the load of the succeeding trains or part thereof, the train loads in one-lane only being considered for the purposes of this sub-clause. Where the entire first train is not on the full span, the braking force shall be taken as equal to twenty per cent of the loads actually on the span.

(b) In the case of bridges having more than two-lanes: as in (a) above for the first two-lanes plus five per cent of the loads on the lanes in excess of two.

Note : The loads in this Clause shall not be increased on account of impact.

214.3. The force due to braking effect shall be assumed to act along a line parallel to the roadway and 1.2 m above it. While transferring the force to the bearings, the change in the vertical reaction at the bearings should be taken into account.

214.4. The distribution of longitudinal horizontal forces among bridge supports is effected by the horizontal deformation of bridges, flexing of the supports and rotation of the foundations. For spans resting on stiff supports, the distribution may be assumed as given in Clause 214.5 below. For spans resting on flexible supports, distribution of horizontal forces may be carried out according to procedure given in Clause 214.6 below.

214.5. **Simply Supported and Continuous Spans on Unyielding Supports**

214.5.1. **Simply supported spans on unyielding supports**

214.5.1.1. For a simply supported span with fixed and free bearings (other than elastomeric type) on stiff supports, horizontal forces at the bearing level in the longitudinal direction shall be greater of the two values given below:

		Fixed bearing	Free bearing
	(i)	$Fh - \mu(Rg+Rq)$	$\mu\ (Rq + Rg)$
or	*(ii)*	$\frac{Fh}{2} + \mu(Rg + Rq)$	$\mu\ (Rg + Rq)$

Where,

Fh = Applied horizontal force

Rg = Reaction at the free end due to dead load

Rq = Reaction at free end due to live load

μ = Coefficient of friction at the movable bearing which shall be assumed to have the following values:

(i) For steel roller bearings	0.03	
(ii) For concrete roller bearings	0.05	
(iii) For sliding bearings:		
(a) Steel on cast iron or steel on steel		0.4
(b) Gray cast iron Gray cast iron (Mechanite)	0.3	
(c) Concrete over concrete with bitumen layer in between	0.5	
(d) Teflon on stainless steel	.03 and .05 whichever is governing	

Note: Unbalanced dead loads shall be accounted for properly. In seismic areas, the fixed bearing shall also be checked for full seismic and braking/tractive force.

214.5.1.2. For simply supported reinforced concrete and prestressed concrete superstructure, the span upto which plate bearings can be used shall be limited to 15 metre.

214.5.1.3. In case of simply supported small spans upto 10 metres resting on unyielding supports and where no bearings are provided, horizontal force in the longitudinal direction at the bearing level shall be

$$\frac{F_h}{2} \text{ or } \mu\ R_g \text{ whichever is greater}$$

214.5.1.4. For a simply supported span siting on identical elastomeric bearings at each end resting on unyielding supports. Force at each end

$$= \frac{F_h}{2} + \text{Vr } l_{tc}$$

V_r = shear rating of the elastomer bearings

l_{tc} = movement of deck above bearing, other than that due to applied forces.

214.5.1.5. The substructure and foundation shall also be designed for 10 per cent variation in movement of the span on either side.

214.5.2. For continuous bridge with one fixed bearing and other free bearings:

Fixed bearing	Free bearing
Case-I	
(μR-μL) +ve Fh acting in +ve direction	
(a) If Fh > 2μR	μRx
Fh-(μR+μL)	
(b) If Fh<2μR	
$\frac{Fh}{1 + \Sigma n_R} + (\mu R - \mu L)$	
Case-II	
(μR-μL) +ve and Fh acting in -ve direction	
(a) If Fh > 2μL	μRx
Fh-(μR+μL)	
(b) If Fh<2μL	
$\frac{Fh}{1 + \Sigma n_L} - (\mu R - \mu L)$	

Whichever is greater.

Where:

n_L or n_R = number of free bearings to the left or right of fixed bearings, respectively.

μL or μR = the total horizontal force developed at the free bearings to the left or right of the fixed bearing respectively

μRx = the net horizontal force developed at any one of the free bearings considered to the left or right of the fixed bearings.

Note: In seismic areas, the fixed bearing shall also be checked for full seismic force and braking/tractive force.

214.6. Simply Supported and Continuous Spans on Flexible Supports

214.6.1. Shear rating of a support is the horizontal force required to move the top of the support through a unit distance taking into account horizontal deformation of the bridges, flexibility of the support and rotation of the foundation. The distribution of 'applied' logitudinal horizontal forces (e.g., braking, seismic, wind etc.) depends solely on shear ratings of the supports and may be estimated in proportion to the ratio of individual shear ratings of a support to the sum of the shear ratings of all the supports.

214.6.2. The distribution of self-induced horizontal force caused by deck movement (owing to temperature, shrinkage, creep, elastic shortening, etc.) depends not only on shear ratings of the supports but also on the location of the 'zero' movement point in the deck. The shear rating of the supports, the distribution of applied and self-induced horizontal force and the determination of the point of zero movement may be made as per recognised theory for which reference may be made to publications on the subjects.

214.7. The effects of braking force on bridge structures without bearings, such as arches, rigid frames, etc., shall be calculated in accordance with approved methods of analysis of indeterminate structures.

214.8. The effects of the longitudinal forces and all other horizontal forces should be calculated upto a level where the resultant passive earth resistance of the soil below the deepest scour level (floor level in case of a bridge having pucca floor) balances these forces.

215. CENTRIFUGAL FORCES

215.1. Where a road bridge is situated on a curve, all portions of the structure affected by the centrifugal action of moving vehicles are to be proportioned to carry safely the stress induced by this action in addition to all other stress to which they may be subjected.

215.2. The centrifugal force shall be determined from the following equation :

$$C = \frac{WV^2}{127\,R}$$

Where C = centrifugal force acting normally to the traffic (1) at the point of action of the wheel loads or (2) uniformly distributed over every metre length on which a uniformly distributed load acts, in tonnes.

W = live load (1) in case of wheel loads, each wheel load being considered as acting over the ground contact length specified in Clause 207, in tonnes, and (2) in case of a uniformly distributed live load, in tonnes per linear metre.

V = the design speed of the vehicles using the bridge in km per hour, and

R = the radius of curvature in metres.

215.3. The centrifugal force shall be considered to act at a height of 1.2m above the level of the carriageway.

215.4. No increase for impact effect shall be made on the stress due to centrifugal action.

215.5. The overturning effect of the centrifugal force on the structure as a whole shall also be duly considered.

216. BUOYANCY

*216.1. **Deleted**

216.2. In the design of abutments, especially those of submersible bridges, the effects of buoyancy shall also be considered assuming that the fill behind the abutments has been removed by scour.

* 216.3. **Deleted**

216.4. To allow for full buoyancy a reduction is made in the gross weight of the member affected, in the following manner :

(a) When the member under consideration displaces water only, *e.g.*, a shallow pier or abutment pier founded at or near the bed level, the reduction in weight ,shall be equal to that of the volume of the displaced water.

(b) When the member under consideration displaces water and also silt or sand, *e.g.*, a deep pier or abutment pier passing through strata of sand and silt and founded on similar material, the upward pressure causing the reduction in weight shall be considered as made up of two factors :

(i) Full hydrostatic pressure due to a depth of water equal to the difference in levels between the free surface of water and the foundation of the member under consideration, the free surface being taken for the worst condition; and

(ii) Upward pressure due to the submerged weight of the silt or sand calculated in accordance with Rankine's theory for the appropriate angle of internal friction.

216.5. In the design of submerged masonry or concrete structures, the buoyancy effect through pore pressure may be

*Refer Clause 202.3

limited to 15 per cent of full buoyancy.

216.6. In case of submersible bridges, the full buoyancy effect on the superstructure shall be taken into consideration.

217. EARTH PRESSURE

217.1. Structures designed to retain earth fills shall be proportioned to withstand pressure calculated in accordance with any rational theory. Coulomb's theory shall be acceptable, subject to the modification that the centre of pressure exerted by the backfill, when considered dry, is located at an elevation of 0.42 of the height of the wall above the base instead of 0.33 of that height. No structure shall, however, be designed to withstand a horizontal pressure less than that exerted by a fluid weighing 480 kg/m^3. All abutments and return walls shall be designed for a live load surcharge equivalent to 1.2m earth fill.

217.2. **Deleted**

217.3. Reinforced concrete approach slab with 12mm dia 150mm c/c in each direction both at top and bottom as reinforcement in M30 grade concrete covering the entire width of the roadway, with one end resting on the structure designed to retain earth and extending for a length of not less than 3.5 m into the approach shall be provided.

217.4. All designs shall provide for the thorough drainage of back-filling materials by means of weep holes and crushed rock or gravel drains, or pipe drains, or perforated drains.

217.5. The pressure of submerged soils (not provided with drainage arrangements) shall be considered as made up of two components :

(a) Pressure due to the earth calculated in accordance with the method laid down in Clause 217.1, the unit weight of earth being reduced for buoyancy, and

(b) full hydrostatic pressure of water.

217.6. **Deleted**

218. TEMPERATURE

218.1. **General** : Daily and seasonal fluctuations in shade air temperature, solar radiation, etc. cause the following:

a) Changes in the overall temperature of the bridge, referred to as the effective bridge temperature. Over a prescribed period there will be a minimum and a maximum, together with a range of effective bridge temperature, resulting in loads and/or load effects within the bridge due to:

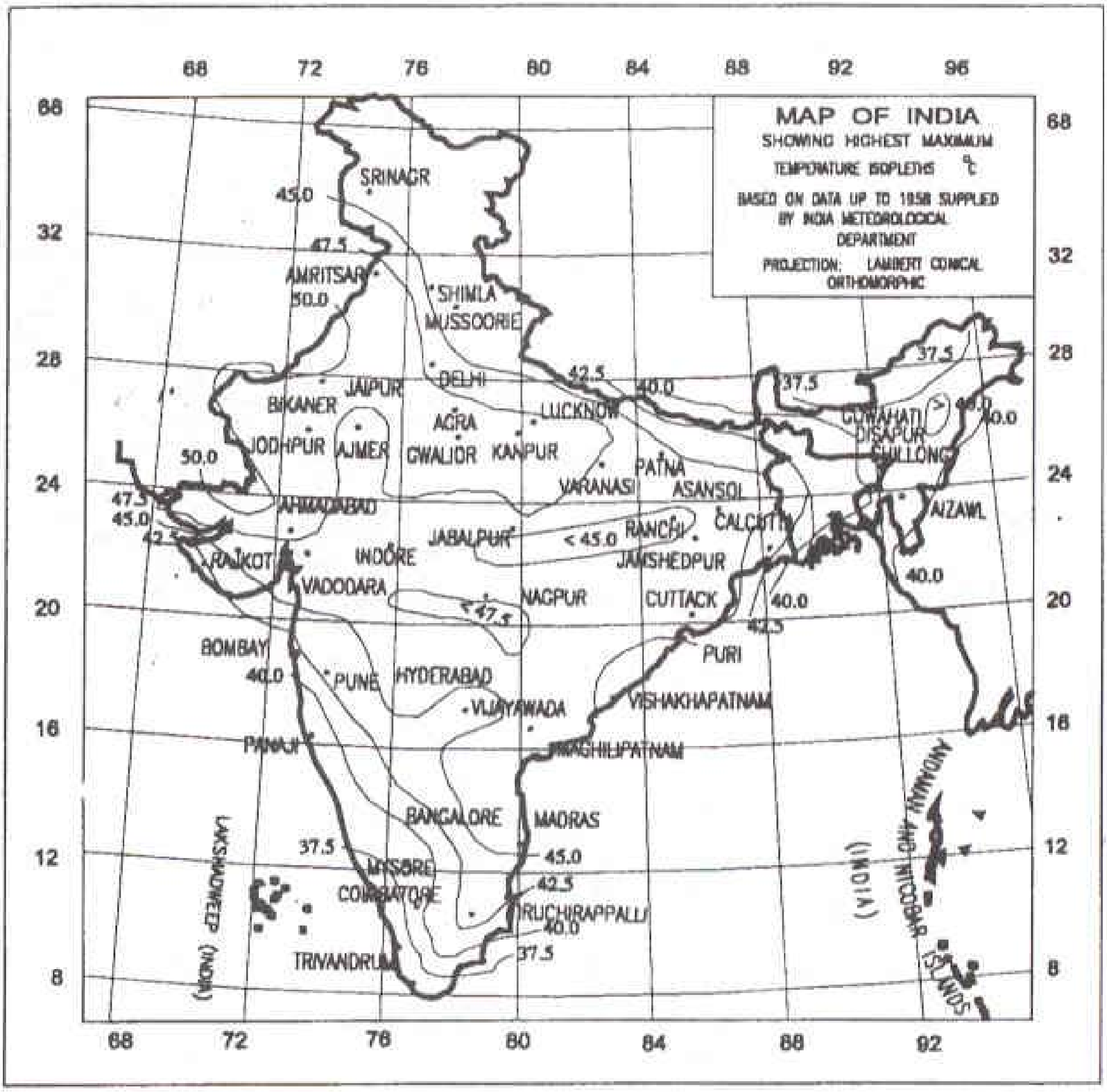
   i) Restraint offered to the associated expansion/contraction by the form of construction (e.g., portal frame, arch, flexible pier, elastomeric bearings) referred to as temperature restraint; and

   ii) Friction at roller or sliding bearings referred to as frictional bearing restraint;

b) Differences in temperature between the top surface and other levels through the depth of the superstructure, referred to as temperature difference and resulting in associated loads and/or load effects within the structure.

Provisions shall be made for stresses or movements resulting from variations in the temperature.

218.2. **Range of Effective Bridge Temperature** : Effective bridge temperature for the location of the bridge shall be estimated from the isotherms of shade air temperature given in Figs. 8 and 9. Minimum and maximum effective bridge temperatures would be lesser or more respectively than the corresponding minimum and maximum shade air temperatures. In determining load effects due to temperature restraint, the effective bridge temperature when the structure is effectively restrained shall be taken as datum in calculating expansion up to the maximum effective bridge temperature and contraction



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

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Fig. 8. Chart Showing Highest Maximum Temperature

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

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Responsibility for the correctness of internal details rests with the publishers.

Fig. 9. Chart Showing Lowest Minimum Temperature

down to the minimum effective bridge temperature. Given below are the extreme ranges of effective bridge temperatures:

(a) Metal structures :
from -35°C to 50°C

(b) Concrete structures :

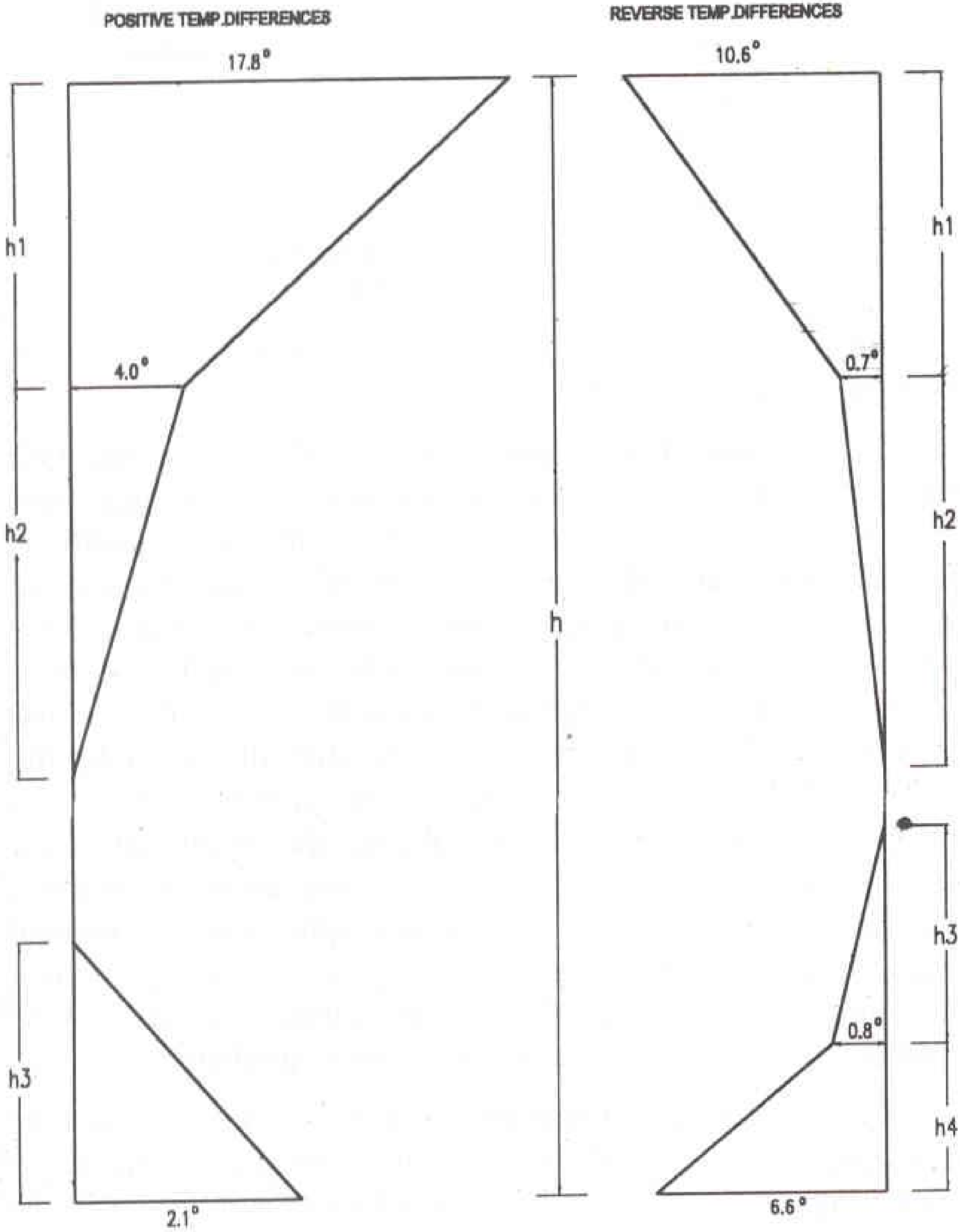
Temperature rise	Temperature fall
25°C	25°C

But in both cases, i.e., (a) and (b) intermediate values may be assessed based on Figs. 8 and 9.

218.3. **Temperature Differences** : Effect of temperature difference within the superstructure shall be derived from positive temperature differences which occur when conditions are such that solar radiation and other effects cause a gain in heat through the top surface of the superstructure. Conversely, reverse temperature differences are such that heat is lost from the top surface of the bridge deck as a result of re-radiation and other effects. Positive and reverse temperature difference for the purpose of design shall be assumed as shown in Fig. 10. Design temperature loads shall be reviewed after the in-situ data from bridges located in different parts of the country becomes available. These design provisions are applicable to concrete bridge decks with about 50mm wearing surface. So far as steel and composite decks are concerned specialised literature may be referred for assessing effect of temperature gradient.

218.4. **Material Properties** : For the purpose of calculating temperature effects, the coefficient of thermal expansion for reinforcing steel and for concrete may be taken as 11.7×10^{-6}/ degree centigrade.

218.5. **Permissible Increase in Stresses and Load Combinations** : Tensile stresses resulting from temperature effects



h1 = 0.3h ɛ 0.15m
h2 = 0.3h · 0.10m
ɛ 0.25m
h3 = 0.3h ɛ 0.15m

h1 = h4 = 0.2h ɛ 0.25m
h2 = h3 = 0.25h ɛ 0.20m

Fig. 10. Design Temperature Differences

not exceeding in the value of two third of the modulus of rupture may be permitted in prestressed concrete bridges. Sufficient amount of non-tensioned steel shall however be provided to control the thermal cracking. Increase in stresses shall be allowed for calculating load effects due to temperature restraint under load combinations.

219. DEFORMATION STRESSES
(for steel bridges only)

219.1. A deformation stress is defined as the bending stress in any member of an open web-girder caused by the vertical deflection of the girder combined with the rigidity of the joints. No other stresses are included in this definition.

219.2. All steel bridges shall be designed, manufactured and erected in a manner such that the deformation stresses are reduced to a minimum. In the absence of calulations, deformation stresses shall be assumed to be not less than 16 per cent of the dead and live loads stresses.

219.3. In prestressed girders of steel, deformation stresses may be ignored.

220. SECONDARY STRESSES

220.1. (a) **Steel structures :** Secondary stresses are additional stresses brought into play due to the eccentricity of connections, floor beam loads applied at intermediate points in a panel, cross girders being connected away from panel points, lateral wind loads on the end-posts of through girders, etc., and stresses due to the movement of supports.

(b) **Reinforced concrete structures :** Secondary stresses are additional stresses brought into play due either to the movement of supports or to the deformations in the geometrical shape of the structure or its member, resulting from causes such as rigidity of end connection or loads applied at intermediate points of trusses or restrictive shrinkage of concrete floor beams.

220.2. All bridges shall be designed and constructed in a manner such that the secondary stresses are reduced to a minimum and they shall be allowed for in the design.

220.3. For reinforced concrete members, the shrinkage co-effecient for purposes of design may be taken as 2×10^{-4}

221. ERECTION STRESSES AND CONSTRUCTION LOADS

221.1. The effects of erection as per actual loads based on the construction programme shall be accounted for in the design. This shall also include the condition of one span being completed in all respects and the adjacent span not in position. However, one span dislodged condition need not be considered in the case of slab bridges not provided with bearings.

221.2. Construction loads are those which are incident upon a structure or any of its constituent components during the construction of the structures.

A detailed construction procedure associated with a method statement shall be drawn up during design and considered in the design to ensure that all aspects of stability and strength of the structure are satisfied.

221.3. Examples of Typical Construction Loadings are given below. However, each individual case shall be investigated in complete detail.

Examples:

a) Loads of plant and equipment including the weight handled that might be incident on the structure during construction.

b) Temporary superimposed loading caused by storage of construction material on a partially completed a bridge deck.

c) Unbalanced effect of a temporary structure, if any, and unbalanced effect of modules that may be required for cantilever segmental construction of a bridge.

d) Loading on individual beams and/or completed deck system due to travelling of a launching truss over such beams/deck system.

e) Thermal effects during construction due to temporary restraints.

f) Secondary effects, if any, emanating from the system and procedure of construction.

g) Loading due to any anticipated soil settlement.

h) Wind load during construction as per Clause 212. For special effects such as unequal gust load and for special type of construction such as long span bridges specialist literature may be referred to.

i) Seismic effects on partially constructed structure as per Clause 222.

222. SEISMIC FORCE

222.1. All bridges shall be designed for seismic forces in Zone V. Major bridges i.e. with total lengths of more than 60 m in Zones III and IV shall be designed for seismic forces. Bridges on Zones I and II need not be designed for seismic forces.

222.2. For the purpose of determining the seismic forces, the country is classified into five zones as shown in Fig. 11.

222.3. The vertical seismic coefficient shall be considered in the case of structures built in Zones IV and V in which stability is a criterion for design or for overall stability analysis for structures except as otherwise stated in the relevant clauses.

The vertical seismic coefficient where applicable may be taken as half of the horizontal seismic coefficient.

Both horizontal and vertical seismic forces may also be taken into account to be acting simultaneously.

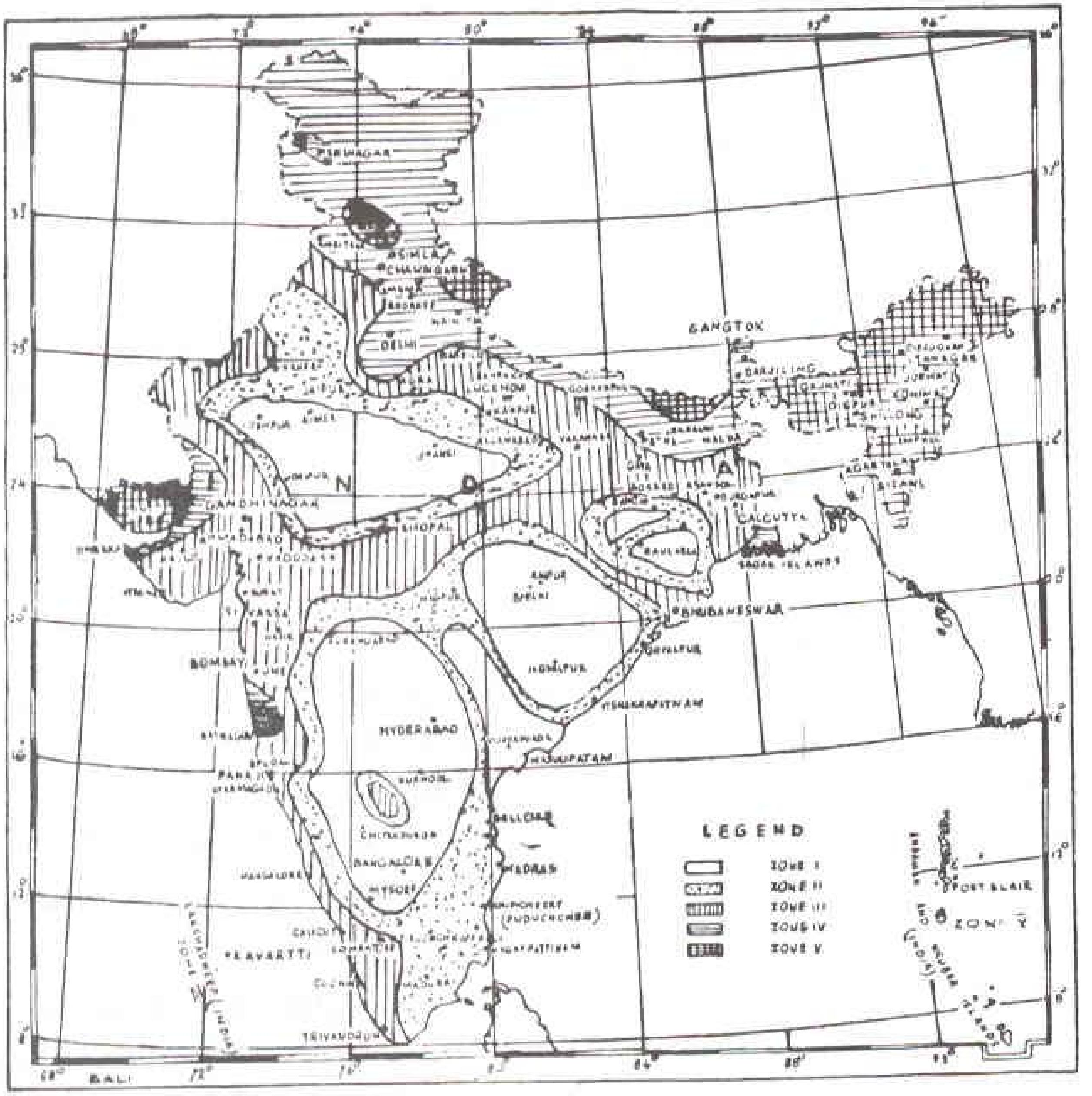


Fig. 11. Map showing the seismic zones of India

222.4. The scour to be considered for design shall be based on mean design flood. In the absence of detailed data the scour to be considered for design shall be 0.9 times the maximum design scour depth.

222.5. **Horizontal Seismic Force** : The horizontal seismic forces to be resisted shall be computed as follows except in the case of long span bridges with spans greater than 150 m where special studies have to be undertaken based on dynamic approach :

$$F_{eq} = \alpha\beta\lambda G$$

Where

F_{eq} = Seismic force to be resisted

α = Horizontal seismic coefficient depending on location (for portion below scour depth this is zero) as given in Table 5.

β = A coefficient depending upon the soil foundation system as given in Table 6.

λ = A coefficient depending upon the importance of the bridge as given below :

Important bridges 1.5

Other bridges 1.0

Note : The importance of a bridge shall be decided on local conditions considering the various issues like the type of structure, strategic importance, vital communication links, etc.

Table 5. Horizontal Seismic Co-efficient

Zone No.	Horizontal Seismic Co-efficient, α
V	0.08
IV	0.05
III	0.04
II	0.02
I	0.01

Table 6. Values of β for Different Soil and Foundation System

Type of Soil mainly constituting the founda-tion	Values of β for			
	Bearing piles resting on soil type I or raft foundations	Bearing piles resting on soil type II & III, friction piles, com-bined or isolated RCC footings with beams	Isolated RCC footings with-out the beams or un-reinforced strip founda-tions	Well founda-tions
Type I Rock or Hard soils (For N 30)	1.0	1.0	1.0	1.0
Type II Medium Soils N between (10 and 30)	1.0	1.0	1.2	1.2
Type III soft soils (N 10)	1.0	1.2	1.5	1.5

Note : N stands for the standard Penetration Test value.

222.6. These horizontal forces due to the seismic effect shall be taken to act through the centre of gravity of all the loads under consideration. The direction of these forces should be such that the resultant stresses in the member under consideration are the maximum.

222.7. The seismic force due to live load shall not be considered when acting in the direction of traffic, but shall be considered in the direction perpendicular to traffic.

222.8. In loose sands or poorly graded sands with little or no fines the vibrations due to earthquake may cause liquefaction or excessive total and differential settlements. In

Zone III, IV and V, the founding of bridges on such sands be avoided unless appropriate methods of compaction or stabilisation are adopted.

222.9. Use of unreinforced masonry or concrete arches shall be avoided in Zone V.

222.10. Parts of the structure embedded in soil shall not be considered to produce any seismic forces.

223. SHIP/BARGE IMPACT ON BRIDGES

223.1. The bridge portion located in navigable water (as well as other portions where possibility of vessels reaching the same exists) shall be designed for ship/barge impact.

223.2. The ship impact forces and their points of application to the piers shall be assessed on the basis of design vessels and their speeds. Specialist literature may be referred for assessment of these forces. For larger ships in navigable waterways, piers shall be protected by building independently supported energy absorbing structures adjacent to the piers of sufficient capacity to absorb the energy before the vessel hits the pier. Other suitable protection measures, such as fenders, sacrificial caissons, islanding etc. can also be adopted. The design impact forces shall be established for the collision with bridge piers and pier shafts head on by the vessel bow or sideways by the vessel head. The design impact force shall atleast be 100 t acting at a height of 1 m above HTL/HFL, inspite of fenders being provided.

224. SNOW LOAD

The snow load of 900 Kg/m^3 where applicable on the bridge deck shall be taken in the following three conditions to be checked independently.

(i) A snow accumulation of 25 cm over the deck shall be taken into consideration while designing the structure for wheeled vehicles.

(ii) A snow accumulation of 50 cm over the deck shall be taken into consideration while designing the structure for tracked vehicle.

(iii) In case of snow accumulation exceeding 50 cm maximum snow accumulation based on actual site observation shall be considered without live load.

225. VEHICLE COLLISION LOADS ON BRIDGE AND FLYOVER SUPPORTS

225.1. General

225.1.1. Bridge piers of wall type, columns or the frames built in the median or in the vicinity of the carriageway supporting the superstructure shall be designed to withstand vehicle collision loads. The effect of collision load shall also be considered on the supporting elements, such as foundations and bearings. For multilevel carriageways, the collision loads shall be considered separately for each level.

225.1.2. The effect of collision load shall not be considered on abutments or on the structures separated from the edge of the carriageway by a minimum distance of 4.5m and shall also not be combined with principal live loads on the carriageway supported by the structural members subjected to such collision loads, as well as wind or seismic load.

225.2. Increase in Permissible Stress

The permissible stresses in both steel and concrete shall be increased by 50 per cent and the safe bearing capacity of the founding strata increased by 25 per cent when considering the effect of collision loads.

225.3. **Collision Load**

225.3.1. The nominal loads given in Table 7 shall be considered to act horizontally as Vehicle Collision Loads. Supports shall be capable of resisting the main and residual load component acting simultaneously. Loads normal to the carriage-way below and loads parallel to the carriageway below shall be considered to act separately and shall not be combined.

Table 7. Nominal Vehicle Collision Loads on Supports of Bridges

	Load normal to the carriageway below	Load parallel to the carriageway below	Point of application on bridge support
	Ton	Ton	
Main load component	50	100	At the most severe point between 0.75 m and 1.5 m above carriageway level
Residual load component	25	50	At the most severe point between 1 m and 3 m above carriageway level

225.3.2. The loads indicated in Clause 225.3.1, are assumed for vehicles plying at velocity of about 60 Km/hr. In case of vehicles travelling at lesser velocity, the loads may be reduced in proportion to the square of the velocity but not less than 50 per cent.

225.3.3. The bridge supports shall be designed for the residual load component only, if protected with suitably de-signed fencing system taking into account its flexibility, having a minimum height of 1.5 m above the carriageway level.

226. INDETERMINATE STRUCTURES AND COMPOSITE STRUCTURES

Stresses due to creep, shrinkage and temperature, etc. should be considered for statically indeterminate structures or composite members consisting of steel or concrete prefabricated elements and cast-in-situ components for which specialist literature may be referred to. Creep and shrinkage produce permanent stresses and hence no relaxation in permissible stresses shall be allowed.

TRACKED VEHICLES				WHEELED VEHICLES												
Class		Width of track	Width over track	Four wheelers	Max. single axle load	Six wheelers	Max. single axle load	Max. bogie load	Minimum wheel spacing and tyre sizes of critical (Heaviest)) axles.				Max.tyre load on min.tyre size.	Max.tyre pressure	Remarks
a	b	c	d	e	f	g	h	j	k	l	m	n	o	p	q
3				1.8t; 0.7, 1.1; 610 1980 910	1.1 t	2.42t; 0.6 0.98 0.84; 610 1980 2590 910	1.0t		370; SA. 150 x 410				0.55 t on col. (k) 150x410	2.46 kg/cm^2	
5R	5.5t; 1990; Nose to tail Length 3660	230	1980	5.5 t; 2.1 3.4; 610 3050 910	3.4 t	5.4t; 1.0 2.2 2.2; 610 3200 1220 910	2.2t	4.5t	SA. for (f) 220x510; 1780; SA. 190 x 410; BA. 190 x 410	360/360; 1780; SA.150 x410 (f)&(h); BA. 150 x 410			1.7 t on col. (k) 220x410	4.218 kg/cm^2	
9R	9.5t; 2740; Nose to tail Length 4270	300	2130	9.2 t; 3.4 5.8; 610 3960 910	5.8 t	10t; 3.0 3.5 3.5; 610 3200 1220 910	3.5t	7.0t	SA. for (f) 300x510; 1910; SA. 230 x 510; BA. 230 x 510	480/360; 1910; SA.220 x510 for (f); SA.150 x510; BA.150 x 510			2.9 t on col. (k) 250x510	5.273 kg/cm^2	
12R	12.5t; 2740; Nose to tail Length 4880	300	2290	12t; 4.5 7.5; 610 3960 910	7.5 t	12t; 2.4 4.8 4.8; 610 3200 1220 910	4.8t	9.6t	SA. for (f) 360x510; 2060; SA. 250 x 510; BA. 250 x 510	510/430; 2060; SA.230 x510 for (f); SA.190 x510; BA.190 x 510			3.75t on col. (k) 360x610	5.273 kg/cm^2	
18R	19t; 3050; Nose to tail Length 5490	360	2360	15.5 t; 5.5 10.0; 610 4270 910	10.0 t	18.7tt; 3.5 7.6 7.6; 610 3960 1220 910	7.6t	15.2t	SA. for (f) 410x610; 2130; SA. 360 x 510; BA. 360 x 510	510/480; 2130; SA.230 x510 for (f); SA.220 x510; BA.220 x 510			5.00t on col. (k) 410x610	5.273 kg/cm^2	
24R	25t; 3660; Nose to tail Length 5490	360	2440	20t; 8.0 12.0; 610 4270 910	12.0t	21.2t; 4.2 8.5 8.5; 610 3960 1220 910	8.5t	17.0t	SA. for (f) 410x610; 2210; SA. 410 x 610; BA. 410 x 610	660/510; 2210; SA.300 x510 for (f); SA.230 x510; BA.230 x 510	2210; 250; SA.300 x510 for (f); SA.230 x510; BA.230 x 510		6.00t on col. (k) 410x610	5.273 kg/cm^2	
30R	30t; 3660; Nose to tail Length 6440	410	2590	38 t; 4.0 10.0 10.0 14.0; 610 3660 1220 4880 910			14.0 t	20 t Axle spacing 1220	2440; SA. 530 x 610; BA. 460 x 610	760/510; 2440; SA.360 x510; BA.230 x 510	2440; 300; SA.360 x510; BA.230 x 510	2440; 200; SA.190 x510; BA.190 x 510	7.00t on col. (k) 530x610	5.273 kg/cm^2	
40R	40t; 3660; Nose to tail Length 7320	560	2740	55 t; 5.0 7.0 7.0 12.0 12.0 12.0; 610 3660 1220 3050 4270 1070 910			16.0 t	26 t Axle spacing 1070	2510; SA. 530 x 610; BA. 460 x 610	760/660; 2510; SA.360 x610; BA.300 x 510	2510; 330; SA.360 x610; BA.300 x 510	2510; 200; SA.190 x510; BA.190 x 510	8.00t on 530x610 single axle col.(k) for wind effect. The length of vehicle may be assumed 2440	5.273 kg/cm^2	
50R	50t; 4270; Nose to tail Length 7540	610	2790	65.5 t; 5.0 7.0 7.0 15.5 15.5 5.5; 610 3660 1220 3050 4270 1070 910			17.5 t	32 t Axle spacing 1070		860/760; 2590; SA.410 x610; BA.300 x 610	2590; 360; SA.410 x610; BA.360 x 610	2590; 200; SA.190 x510; BA.190 x 510	DIT TO	5.273 kg/cm^2	Actual max. tyre load 4.38 t on 410x610
60R	60t; 4570; Nose to tail Length 7920	760	2840	74 t; 5.0 7.5 7.5 18.0 18.0 18.0; 610 3660 1220 3050 4270 1070 910			19.0 t	36 t Axle spacing 1070		860; 2670; SA.410 x610; BA.410 x 610	2670; 380; SA.410 x610; BA.410 x 610	2670; 230; SA. 220 x510; BA. 220 x 510	DIT TO	5.273 kg/cm^2	Actual max. tyre load 4.75 t on 410x610
70R	70t; 4570; Nose to tail Length 7920	840	2900	100 t; 8.0 12.0 12.0 17.0 17.0 17.0 17.0; 610 3960 1520 2130 1370 3050 1370 910			20 t; 1220	40 t; 20.0 20.0; 1830 1220 1830		860; 2790; SA.410 x610; BA.410 x 610	2790; 380; SA.410 x610; BA.410 x 610	2790; 510 250; SA. 230 x510; BA. 230 x 510	DIT TO	5.273 kg/cm^2	Actual max. tyre load 5.0 t on 410x610

Appendix 1

HYPOTHETICAL VEHICLES FOR CLASSIFICATION OF VEHICLES AND BRIDGES (REVISED)

NOTES FOR LOAD CLASSIFICATION CHART

1. The possible variations in the wheel spacings and tyre sizes, for the heaviest single axles - cols. (f) and (h), the heaviest bogie axles - col. (j) and also for the heaviest axles of the train vehicle of cols. (e) and (g) are given in cols. (k), (l), (m) and (n). The same pattern of wheel arrangement may be assumed for all axles of the wheel train shown in cols. (e) and (g) as for the heaviest axles. The overall width of tyre in mm may be taken as equal to [150+(p-1) 57], where "p" represents the load on tyre in tonnes, wherever the tyre sizes are not specified on the chart.
2. Contact areas of tyres on the deck may be obtained from the corresponding tyre loads, max. tyre pressures col. (p) and width of tyre treads.
3. The first dimension of tyre size refers to the overall width of tyre and second dimension to the rim diameter of the tyre. Tyre tread width may be taken as overall tyre width minus 25 mm for tyres upto 225 mm width, and minus 50 mm for tyres over 225 mm width.
4. The spacing between successive vehicles will be 30 m. This spacing will be measured from the rear-most point of ground contact of the leading vehicles to the forward-most point of ground contact of the following vehicle in case of tracked vehicles; for wheeled vehicles, it measured from the centre of the rear-most axle of the leading vehicle to the centre of the first axle of the following vehicle.
5. The classification of the bridge shall be determined by the safe load carying capacity of the weakest of all the structural members including the main girders, stringers (or road bearers), the decking, cross bearers (or transome) bearings, piers and abutments, investigated under the track, wheel axle and bogie loads shown for the various classes. Any bridge upto and including class 40 will be marked with a single class number - the highest tracked or wheel standard load class which the bridge can safely withstand. Any bridge over class 40 will be marked with a single class number if the wheeled and tracked classes are the same, and with dual classification sign showing both T and W load classes if the T and W classes are different.
6. The calculations determining the safe load carrying capacity shall also allow for the effects due to impact, wind pressure, longitudinal forces, etc., as described in the relevant Clauses of this Code.
7. The distribution of load between the main girders of a bridge is not necessarily equal, and shall be assessed from considerations of the spacing of the main girders, their torsional stiffness, flexibility of the cross bearers, the width of roadway and the width of the vehicles, etc., by any rational method of calculations.
8. The maximum single axle loads shown in columns (f) and (h) and the bogie axle loads shown in column (j) correspond to the heaviest axles of the trains, shown in columns (e) and (g) in load-classes upto and including class 30-R. In the case of higher load classes, the single axle loads and bogie axle loads shall be assumed to belong to some other hypothetical vehicles and their effects worked out separately on the components of bridge deck.
9. The minimum clearance between the road face of the kerb and the outer edge of wheel or track for any of the hypothetical vehicles shall be the same as for Class AA vehicles, when there is only one-lane of traffic moving on a bridge. If a bridge is to be designed for two-lanes of traffic for any type of vehicles given in the Chart, the clearance may be decided in each case depending upon the circumstances.