IS 807 (2006): Design, erection and testing (structural portion) of cranes and hoists - Code of practice [MED 14: Cranes, Lifting Chains and Related Equipment]

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भारतीय मानक

क्रेन और उच्चालकों के डिजाइन, स्थापना और परीक्षण (संरचनात्मक भाग) — रीति संहिता

(दूसरा पुनरीक्षण)

Indian Standard

DESIGN, ERECTION AND TESTING (STRUCTURAL PORTION) OF CRANES AND HOISTS — CODE OF PRACTICE

(Second Revision)

ICS 53.020.20

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

April 2006

Price Group 15

Cranes, Lifting Chains and Its Related Equipment Sectional Committee, ME 14

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Cranes, Lifting Chains and Its Related Equipment Sectional Committee had been approved by the Mechanical Engineering Division Council.

This standard covers design of structural portion of cranes and hoists and specifies permissible stresses and other details of design. In order to ensure economy in design in reliability in operation. To deal with the subject conventionally, cranes have been broadly classified into eight classes depending upon their duty and number of hours in service per year. The correct classification of a crane is important and should be joint responsibility of the producer and the manufacturer.

This standard was first published in 1963. In the first revision the permissible stresses for members subjected to fluctuations of stress have been aligned with IS 1024 : 1999 'Code of practice for use of welding in bridges and structures subject to dynamic loading', and AWS D14.1 introducing the number of cycles of operation for fatigue calculations. The limits of camber have also been specified, in the current revision.

In the current revision, the following points are added:

a) The classifications of the cranes are based on operating time and load spectrum and classification from M1 to M 8,

b) State of loading is based on the hoist spectrum,

c) The various loads have been explained elaborately and notch effect,

d) The fatigue and notch effect have been dealt elaborately,

e) The welding joint design, welding procedures and inspection of welding for industrial cranes have been explained in detail, and

f) The design of bolts, quality of bolts, bolts tightening and effective friction surface has been dealt elaborately.

The composition of the Committee responsible for formulation of this standard is given in Annex C.

This standard is the first in the series of standards relating to cranes and covers the structural design. The other standards covering the mechanical and electrical portion are as follows:

IS 3177 : 1999	Code of practice for overhead travelling cranes and gantry cranes other than steel work cranes (*second revision*)
IS 4137 : 1985	Code of practice for heavy duty electric overhead travelling cranes including special service machines for use in steel work (*first revision*)

CONTENTS

Indian Standard

DESIGN, ERECTION AND TESTING (STRUCTURAL PORTION) OF CRANES AND HOISTS — CODE OF PRACTICE

(Second Revision)

1 SCOPE

This standard covers the code of practice for design, manufacture, erection and testing (structure) of EOT cranes, goliath, shear legs and derricks.

2 REFERENCES

The following standards contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
800 : 1984	Code of practice for general construction in steel (*second revision*)
875	Code of practice for design loads (other than earthquake) for buildings and structures:
(Part 1) : 1987	Dead loads — Unit weights of building material and stored materials (*second revision*)
(Part 2) : 1987	Imposed loads (*second revision*)
(Part 3) : 1987	Wind loads (*second revision*)
(Part 4) : 1987	Snow loads (*second revision*)
(Part 5) : 1987	Special loads and load combinations (*second revision*)
961 : 1975	Structural steel (high tensile) (*second revision*)
1363	Hexagon head bolts, screws and nuts of product grade 'C':
(Part 1) : 2002	Hexagon head bolts (size range M 5 to M 64) (*fourth revision*)
(Part 2) : 2002	Hexagon head screws (size range M 5 to M 64) (*fourth revision*)
(Part 3) : 1992	Hexagon nuts (size range M 5 to M 64) (*third revision*)
1364	Hexagon head bolts, screws and nuts of product grades A and B:
(Part 1) : 2002	Hexagon head bolts (size range M 1.5 to M 64) (*third revision*)
(Part 2) : 2002	Hexagon head screws (size range M 1.5 to M 4) (*third revision*)
(Part 3) : 2002	Hexagon nuts (size range M 1.5 to M 64) (*third revision*)
(Part 4) : 2002	Hexagon thin nuts (chamfered) (size range M 1.5 to M 64) (*third revision*)
(Part 5) : 2002	Hexagon thin nuts (unchamfered) (size range M 1.5 to M 64) (*third revision*)
1367	Technical supply conditions for threaded steel fasteners:
(Part 1) : 2002	General requirements for bolts, screws and studs (*third revision*)
(Part 2) : 2002	Tolerances for fasteners – Bolts, screws, studs and nuts – Product grades A, B and C (*third revision*)
(Part 3) : 2002	Mechanical properties of fasteners made of carbon steel and alloy steel — Bolts, screws and studs (*fourth revision*)
(Part 5) : 2002	Mechanical properties of fasteners made of carbon steel and alloy steel — Set screws and similar threaded fasteners not under tensile stresses (*third revision*)
(Part 6) : 1994	Mechanical properties and test methods for nuts with specified proof loads (*third revision*)
(Part 7) : 1980	Mechanical properties and test methods for nuts without specified proof loads (*second revision*)

IS No.	*Title*
(Part 8) : 2002	Prevailing torque type steel hexagon nuts — Mechanical and performance properties (*third revision*)
(Part 9/Sec 1) : 1993	Surface discontinuities, Section 1 Bolts, screws and studs for general applications (*third revision*)
(Part 9/Sec 2) : 1993	Surface discontinuities, Section 2 Bolts, screws and studs for special applications (*third revision*)
(Part 10) : 2002	Surface discontinuities — Nuts (*third revision*)
(Part 11) : 2002	Electroplated coatings (*third revision*)
(Part 12) : 1981	Phosphate coatings on threaded fasteners (*second revision*)
(Part 13) : 1983	Hot-dip galvanized coatings on threaded fasteners (*second revision*)
(Part 14) : 1984	Stainless steel threaded fasteners (*second revision*)
(Part 14/Sec 1) : 2002	Mechanical properties of corrosion-resistant stainless steel fasteners, Section 1 Bolts, screws and studs (*third revision*)
(Part 14/Sec 2) : 2002	Mechanical properties of corrosion-resistant stainless steel fasteners, Section 2 Nuts (*third revision*)
(Part 14/Sec 3) : 2002	Mechanical properties of corrosion-resistant stainless steel fasteners, Section 3 Set screws and similar fasteners not under tensile stress (*third revision*)
(Part 16) : 2002	Designation system for fasteners (*third revision*)
(Part 17) : 1996	Inspection, sampling and acceptance procedure (*third revision*)
(Part 18) : 1996	Packaging (*third revision*)
(Part 19) : 1997	Axial load fatigue testing of bolts, screws and studs
(Part 20) : 1996	Torsional test and minimum torques for bolts and screws with nominal diameters 1 mm to 10 mm
1893 : 1984	Criteria for earthquake resistant design of structures (*fourth revision*)
1929 : 1982	Specification for hot forged steel rivets for hot closing (12 to 36 mm diameter) (*first revision*)
2062 : 1999	Steel for general structural purposes — Specification (*fifth revision*)
2155 : 1982	Specification for cold forged solid steel rivets for hot closing (6 to 16 mm diameter) (*first revision*)
3138 : 1966	Specification for hexagonal bolts and nuts (M42 to M150)
3737 : 1966	Leather safety boots for workers in heavy metal industries
6610 : 1972	Specification for heavy washers for steel structures
6623 : 1985	Specification for high strength structural nuts (*first revision*)
6639 : 1972	Specification for hexagon bolts for steel structures
6649 : 1985	Specification for hardened and tempered washers for high strength structural bolts and nuts (*first revision*)
8500 : 1991	Structural steel (microalloyed) (medium and high strength qualities) — Specification (*first revision*)

3 TERMINOLOGY

3.1 Bogie — A short end truck attached to the end of one girder (or to a connecting member, if more than one bogie is used per girder). This type of end truck is used when more than four wheels are required on a crane due to the design of the runway.

3.2 Bogie Equalizing — A short end truck which is flexibly connected to one girder (or connecting member) by means of a pin upon which the truck can oscillate to equalize the loading on the two truck wheel.

3.3 Bogie Fixed — A short end truck which is rigidly connected to one girder.

3.4 Bridge — That part of a crane consisting of girders, trucks, end ties, walk way and drive mechanism which carries the trolleys travelling along the runway rails.

3.5 Bumper (Buffer) — An energy absorbing bumper or energy dissipating (buffer) device for reducing impact when a moving bridge or trolley reaches the end of its permitted travel. This device may be attached to the bridge trolley or runway stop.

3.6 Cranes — A specially designed structure equipped with mechanical means for moving a load by raising and lowering by electrical or manual operation and whilst the load is in such a state of motion or suspension transporting it.

3.7 Cab — The operator's compartment on a crane.

3.8 Camber — The slight, upward, vertical curve given to girders partially compensate for deflection due to rated load and weight of the crane parts.

3.9 Clearance — The minimum distance from any part of the crane to the point of nearest obstruction.

3.10 Cover Plate — The top or bottom plate of a box girder.

3.11 Crane, Cab Operated — A crane controlled by an operator in a cab attached to the bridge or trolley.

3.12 Crane, Floor Operated — A crane which is controlled by means of suspension from the crane with the operator on the floor or on an independent platform.

3.13 Crane, Gantry — A crane similar to an overhead crane except that the bridge is rigidly supported in two or more legs.

3.14 Crane, Hot Molten Material Handling (Ladle) — An overhead crane used for transporting or pouring molten material.

3.15 Crane, Manually Operated — A crane whose hoist and travel mechanism are driven by manual operation.

3.16 Crane, Semi-gantry — A gantry crane with one end of the bridge supported on one or more legs and other end of the bridge supported by an end truck connected to the girders and running on an elevated runway.

3.17 Cross Traverse Motion — The motion of the trolley or crab across the crane span is known as cross traverse motion.

3.18 Dead Load — The weight of the crane structured steel work moving on crane runway girder with all material fastened there to and supported permanently.

3.19 Deflection (Dead Load) — The vertical displacement of a bridge girder due to its own weight plus the weight of parts permanently attached thereto, such as foot walk, drive mechanism, motor and control panels. The dead load deflection is fully compensated for in the girder camber.

3.20 Deflection (Live Load) — The vertical displacement of a bridge girder due to the weight of the trolley plus the rated load.

3.21 Diaphragm — A vertical plate (or channel) between the girder webs, which serves to support the top cover plate and bridge and to transfer the forces of the trolley wheel load to the webs rail.

3.22 Dynamic Effect — The effects on the structure caused by inertia or sudden load application such as retardation/acceleration breaking impact due to collision.

3.23 End Tie — A structural member, other than the end truck, which connects the ends of the girders to maintain the squareness of the bridge.

3.24 End Truck (End Carriage) — An assembly consisting of structural members, wheels, bearings, axles, etc, which supports the bridge girders.

3.25 Foot Walk — A walk way with hand rail and toe boards, attached to the bridge or trolley for access purpose.

3.26 Gauge — The horizontal distance between centre-to-centre of the bridge rails.

3.27 Hoist — A machinery unit that is used for lifting and lowering a load.

3.28 Hoist Auxiliary — A supplemental hoisting unit used to handle light loads.

3.29 Hoist Main — The primary hoist mechanism provided for lifting and lowering the rated load of the crane.

3.30 Hook Approached (End) — The minimum horizontal distance, parallel to the runway between the centre line of the hook(s) and the face of the wall (or columns) at the end of the building.

3.31 Hook Approach (Side) — The minimum horizontal distance, perpendicular to the runway, between the centre line of a hook (main or auxiliary) and the centre line of the runway rail.

3.32 Live Load — A load which moves or varies relative to the member being considered. For the trolley, the live load consists of the rated load plus the weight of the block. For the bridge, the live load consists of the rated load plus the weight of the trolley.

3.33 Over Load — Any hook load greater than the rated load.

3.34 Longitudinal Travel Motion — The motion of the whole crane on its gantry or tracks is known as the longitudinal travel motion.

3.35 Rated Lifted Loads — The rated lifted load from the mechanism design consideration shall mean the external load lifted and handled by the crane and shall include in addition the safe working load, lifting tackles such as magnets, grabs, lifting beams, but shall exclude wind load.

3.36 Radius — The horizontal distance from the centre line of the lifting hook before loading to the centre about which the jib slews.

3.37 Reach — The horizontal distance from the centre line of the laden hook to the nearest point of the chassis/ under frame with respect to hook.

3.38 Runway — The assembly of rails, girders, brackets and frame work on which the crane operates.

3.39 Rail Sweep — A mechanical device attached to the end truck of a bridge or trolley.

3.40 Span — The horizontal distance between centre-to-centre of the runway rails.

3.41 Stability Base — The effective span of the supporting base.

3.42 Stability Reach — The distance of the jib head pin from the point of intersection of the nearest base line and vertical plane passing through the center line of the jib.

3.43 Stop — A member to physically limit the travel of the trolley or bridge. This member is rigidly attached to a fixed structure and normally does not have energy absorbing ability.

3.44 Web Plate — The critical plates, connecting the upper and lower flanges or cover plate of a girder.

3.45 Wheel Base — The distance from centre-to-centre of the outer most wheels of the bridge or trolley, measured parallel to the rail.

3.46 Wind Load — The forces produced by the velocity of the wind which is assumed to act horizontally.

3.47 Wheel Load Bridge — The vertical force (without impact) produced on any bridge wheel by the sum of the rated load, trolley weight and bridge weight, with the trolley so positioned on the bridge as to give maximum loading.

3.48 Wheel Load Trolley — The vertical force (without impact) produced on any trolley wheel by the sum of the rated load and trolley weight.

4 MATERIALS

4.1 The material of structures shall be in the form of plate, sheet and rolled sections.

4.2 Structural steel shall conform to IS 2062 or IS 8500 as per designers suitability or as mutually agreed to between the purchaser and the manufacturer permissible stress shall be related to yield stress of the material used.

4.3 Materials for pins, rivets and bolts including high strength bolts and nuts shall be as given in Table 1.

4.4 Material characteristics shown in Table 2 may be used for design purpose.

4.5 Table 1 contains the different material grade for principal load bearing members and also rivets, pins and bolts, high strength bolts and nuts. The physical characteristics of steel are given in Table 2.

NOTE — No black bolts shall be used for the principal load bearing members in the crane.

Table 1 Rivet and Bolts

(*Clauses* 4.3 *and* 4.5)

Sl No.	Product	Ref to Indian Standard
(1)	(2)	(3)
i)	Rivets	2155 1929
ii)	Pins and bolts	1364 (Parts 1 to 5) 3138
iii)	High strength bolts and nuts	6639 6623 6649 3757

Table 2 Physical Properties of Steel

(*Clauses* 4.4 *and* 4.5)

Sl No.	Parameter	Values
(1)	(2)	(3)
i)	Modulus of longitudinal elasticity (E), in N/mm^2	2.1×10^5
ii)	Modulus of elasticity in shear (G), in N/mm^2	8.1×10^4
iii)	Poisson's ratio (1/m)	0.3
iv)	Co-efficient of linear expansion (α)	1.2×10^{-5}
v)	Specific gravity (γ)	7.85

5 CLASSIFICATION OF CRANES

There are two factors to be taken into consideration for the purpose of determining the group to which the cranes belong are the class of utilization and the state of loading, that is:

a) Class of operating time; and

b) Load spectrum.

5.1 Class of Operating Time

a) Class of operating time indicates the average period per day;

b) Two hundred fifty working days per year shall be considered; and

c) Higher classes of operating time for more than one shift per day.

5.1.1 Class of utilization takes account of the frequency of one of the cranes as a whole when in service. This concept could be represented by the number of working cycles, which the crane would accomplish during its life (*see* Table 3). The classes of utilization are used as a basis for the design of the structure.

5.2 Load Spectrum

5.2.1 *State of Hoist Loading — Hoist Load Spectrum*

The state of hoist loading determines the extent to which the crane lifts the maximum load, L_{Max} or only a lesser load, L. This idea is illustrated by a spectrum of hoist loads showing the number of cycles of operation during which a certain fraction of the maximum load is reached or exceeded. It is one of the important factors determining the severity of the duty of the cranes.

There are four states of loading, designated by the values $P = 1$, $P = 2/3$, $P = 1/3$ and $P = 0$ are shown on the curves. These curves represent the four sets of conventional spectra corresponding to the number of cycles to class of utilization are shown in Table 4.

5.3 State of Stress — Stress Spectrum

The state of stress are defined in the same manner on those of the hoisted loads with same spectra according to Table 5, Table 6 and Table 7.

6 STATE OF LOADING

6.1 Loads to be Considered

The following loads shall be considered in the calculation of the steel structural parts of the cranes.

6.1.1 *Principal Loads Exerted on the Structure*

6.1.1.1 The loads due to the dead weight of the components (crane girders, end carriage, plate forms, LT machinery and electrical items panel, resistance boxes).

6.1.2 *Lifted Loads*

The lifted loads (hook loads) comprise the useful load and the self weights of members designed to carry the useful load, for example, the bottom block spreader bar, the grab, the lifting magnet and also a proportion of the carrying means such as ropes.

Table 3 Classes of Utilization

(*Clause* 5.1.1)

Sl No.	Class of Utilization	Frequency of Utilization of the Hoisting Motion	Conventional Number of Hoisting Cycles
(1)	(2)	(3)	(4)
i)	A	Irregular occasional use followed by long idle periods	6.3×10^4
ii)	B	Regular use on intermittent duty	2×10^5
iii)	C	Regular use on intensive duty	6.3×10^5
iv)	D	Intensive, heavy duty more than one shift/day	2×10^6

Table 4 State of Loading

(*Clause* 5.2.1)

Sl No.	State of Loading	Definition	Corresponding Spectrum
(1)	(2)	(3)	(4)
i)	Very light	Cranes which hoist SWL exceptionally and, normally, very light loads	$P = 0$
ii)	Light	Cranes which only hoist the SWL and normally loaded about one-third of SWL	$P = 1/3$
iii)	Moderate	Cranes which hoist the SWL fairly frequently and normally loads between 1/3 to 2/3 of SWL	$P = 2/3$
iv)	Heavy	Cranes which are regularly loaded close to the SWL	$P = 1$

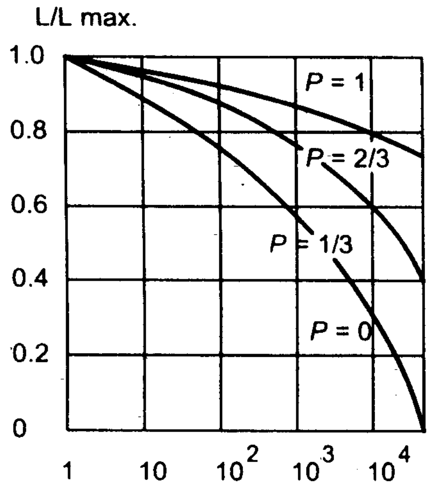


FIG. 1 GRAPHICAL REPRESENTATION OF CLASS OF UTILIZATION A 6.3×10^4 CYCLES

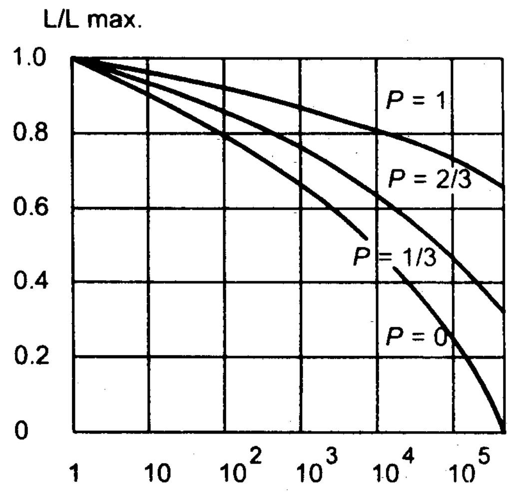


FIG. 2 GRAPHICAL REPRESENTATION OF CLASS OF UTILIZATION B 2×10^5 CYCLES

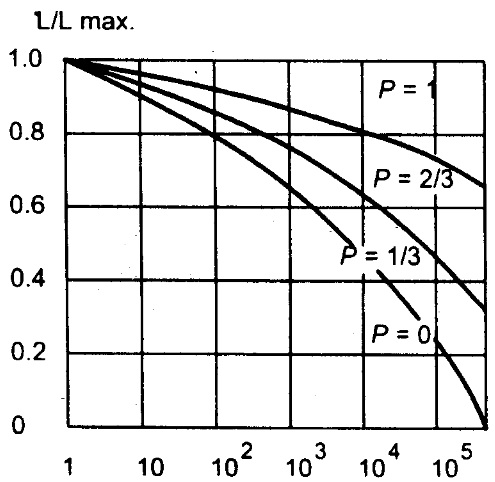


FIG. 3 GRAPHICAL REPRESENTATION OF CLASS OF UTILIZATION C 6.3×10^5 CYCLES

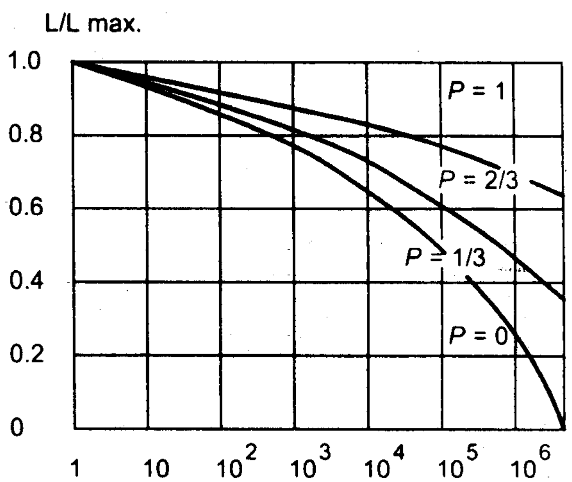


FIG. 4 GRAPHICAL REPRESENTATION OF CLASS OF UTILIZATION D 2×10^6 CYCLES

Table 5 States of Stress

(*Clause* 5.3)

Sl No.	State of Loading	Definition	Spectrum
(1)	(2)	(3)	(4)
i)	Very light	Components subjected exceptionally to its maximum stress and normally to light	$P = 0$
ii)	Light	Components rarely subjected to its maximum stress but normally about 1/3 of maximum stress	$P = 1/3$
iii)	Moderate	Components frequently subjected to its maximum stress and normally stress vary from 1/3 to 2/3 of the maximum stress	$P = 2/3$
iv)	Heavy	Components regularly subjected to its maximum stress	$P = 1$

Table 6 Group Classification of Cranes

(*Clause* 5.3)

Sl No.	State of Hoist Loading or State of Stress	Class Utilization and Number of Hoisting Cycles			
		A 6.3×10^4	B 2×10^5	C 6.3×10^5	D 2×10^6
(1)	(2)	(3)	(4)	(5)	(6)
i)	Very light, $P = 0$	M1	M2, M3	M4	M5
ii)	Light, $P = 1/3$	M2	M3, M4	M5	M6
iii)	Moderate, $P = 2/3$	M3	M4, M5	M6, M7	M8
iv)	Heavy, $P = 1$	M4	M5	M6, M7	M8

Table 7 Examples of Classification of Cranes

(*Clause* 5.3)

Sl No. (1)	Type of Cranes (2)	Applications (3)	Class of Utilization (4)	State of Loading (5)	Group (6)
i)	Over head travelling cranes	1. Hot cranes, cranes for power station, cranes for repair shops	A	0-1	M1-M2
		2. Cranes for warehouse, stocking yard, machine and assembly shop and cranes for general use	A	1-2	M2-M3-M4
		3. Store room cranes, workshop cranes	B-C	1-2	M4-M5-M6
		4. Grabbing over head travelling cranes, magnet cranes	C-D	3	M6-M7-M8
		5. Cranes for steel works	C-D	3	M6-M7-M8
		6. Ladle cranes	C-D	3	M7-M8
		7. Stripper cranes, soaking pit cranes	D	3	M7-M8
		8. Charging cranes	C-D	3	M7-M8
		9. Forging cranes	D	3	M7-M8
ii)	Gantry cranes	1. Cranes for power station and cranes for repair shop	A	0-1	M1-M2
		2. Cranes for stocking yard	B-C	1-2	M3-M4
iii)	Gantry cranes	1. Cranes for container handling	B-C	2	M4-M5-M6
		2. Cranes with grab, magnets	B-C-D	3	M7-M8
iv)	Jib cranes	1. Stocking yard cranes, repair shop, assembling shop	A-B	1-2	M1-M3
		2. Wharf cranes	B-C	2-3	M3-M4-M5
		3. Grabbing and magnet cranes	C-D	2-3	M5-M6-M7
		4. Unloaders	D	3	M7-M8
		5. Cranes for building construction	B	1-2	M1-M3
v)	Derrick	1. Derrick for heavy load	A-B	0-1	M1-M2
		2. Derrick for construction and building	B	2-3	M3-M4
		3. Floating cargo crane	A-B	2	M5-M6
		4. Floating grabbing crane	A-B	3	M5-M6-M7

6.1.3 The loads due to horizontal motion are as follows:

a) Inertia effects due to acceleration (or deceleration) of the traverse, travel, slewing or luffing motions. These effects can be calculated in terms of the value of acceleration (or deceleration) and its values are given in Table 8;
b) Effects of centrifugal force;
c) Transverse horizontal reaction resulting from rolling action; and
d) Buffet effects.

6.1.3.1 *Inertia force*

The forces of inertia resulted from the acceleration and deceleration of the traverse motion, travel motion, level luffing motion and slewing motion of the crane shall generally be considered as β times of the weight of the moving parts and the hoisting load, and be given by the following formula:

For level luffing motion, $\beta = 0.1\sqrt{v}$

For transverse travel motion, $\beta = 0.01\sqrt{v}$

For slewing motion, $\beta = 0.006\sqrt{v}$

where v is the speed of respective motion, in m/min.

However, in case of traverse motion and travel motion by the wheel drive, it shall be taken as 15 percent of the load of the driving wheel at maximum.

Moreover, for the slewing motion, it shall be considered that the load is acting at the end point of the jib.

NOTE — If the speed and acceleration values are not specified by the user, acceleration times corresponding to the speeds to be reached may be chosen according to the three following working conditions:

a) Cranes of low and moderate speed with great length of travel;
b) Cranes of moderate and high speed for normal application; and
c) High speed cranes with high acceleration.

6.1.3.2 *Force due to slewing and luffing motion*

For slewing and luffing motions the calculation shall be based on the acceleration (or deceleration) torque applied to the motor shaft of the mechanism. The rates of acceleration shall depend upon the cranes. For a normal crane a value between 0.1 m/s² and 0.6 m/s², according to the speed and radius, may be chosen for the acceleration at the jib head so that an acceleration time of 5 to 10 second is achieved.

6.1.3.3 *Effects of centrifugal force*

The centrifugal force shall be the force, which is acting outwards in the direction of slewing radius, resulted from the slewing radius and slewing motion and shall be obtained from the following formula:

$$F = \frac{WV^2}{gR}$$

where

F = centrifugal force, in kgf or N;

W = hoisting load, in kgf or N;

g = acceleration of free fall, in m/s²;

R = slewing radius, in m; and

V = peripheral speed, in m/s.

Table 8 Acceleration Time and Acceleration Value

(*Clause* 6.1.3)

Sl No.	Speed to be Reached, in m/s	Low and Moderate Speed with Long Travel		Moderate and High Speed (Normal Applications)		High Speed with High Acceleration	
		Acceleration Time, in s	Acceleration, in m/s²	Acceleration Time, in s	Acceleration, in m/s²	Acceleration Time, in s	Acceleration, in m/s²
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	4.00	—	—	8.0	0.50	6.0	0.67
ii)	3.15	—	—	7.1	0.44	5.4	0.58
iii)	2.5	—	—	6.3	0.39	4.8	0.52
iv)	2.0	9.1	0.22	5.6	0.35	4.2	0.47
v)	1.50	8.3	0.19	5.0	0.32	3.7	0.43
vi)	1.00	6.6	0.15	4.0	0.25	3.0	0.33
vii)	0.63	5.2	0.12	3.2	0.19	—	—
viii)	0.40	4.1	0.098	2.5	0.16	—	—
ix)	0.25	3.2	0.078	—	—	—	—
x)	0.16	2.5	0.064	—	—	—	—

6.1.3.4 *Transverse reactions due to rolling action*

The lateral force on wheel shall be the horizontal force acting at right angles with the travelling direction of the wheels and shall be given from Fig. 5 by the ratio of the span and the effective wheel base.

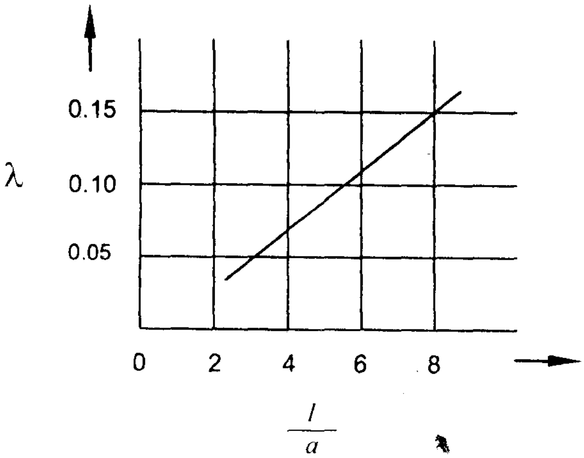


FIG. 5 RATIO OF SPAN AND EFFECTIVE WHEEL BASE *versus* SIDE FORCE CONSTANT ON WHEELS

$$S_F = \lambda . R$$

where

S_F = lateral force on wheels, in kgf or N;

λ = side force constant on wheel;

R = wheel load, in kgf or N;

l = span, in m; and

a = wheel base, in m.

The effective wheel base shall be taken from Fig. 6A, Fig. 6B and Fig. 6C. Moreover, when the horizontal guide rollers are provided, the centre distance between the outer two guide rollers shall be taken as the effective wheel base.

6.1.3.5 *Buffer effects*

The impact due to collision with buffers may be applied on the structure or on the suspended load.

A distinction may be drawn between:

a) The case in which the suspended load can swing; and

b) That in which rigid guides prevent swing.

For **6.1.3.5**(a) the following rules shall be applied:

For horizontal speed below 0.7 m/s, no account shall be taken of buffer effect.

For speed exceeding 0.7m/s, account shall be taken of reactions set up in the structure by collisions with buffers. However, for higher speed (greater than 1 m/s) the use of decelerating device which act upon approach to the ends of the track is permitted provided the action of these devices is automatic and they produce an effective deceleration on the cranes which always reduces the speed to the predetermined lower value before the buffers are reached.

6.1.3.6 *Collision effects on the suspended load*

Impacts due to collision between the load and fixed obstructions are taken into account only for cranes when the load is rigidly guided.

The loads can be computed by considering that horizontal force applied at the level of the load is capable of causing two of the crab wheels to lift.

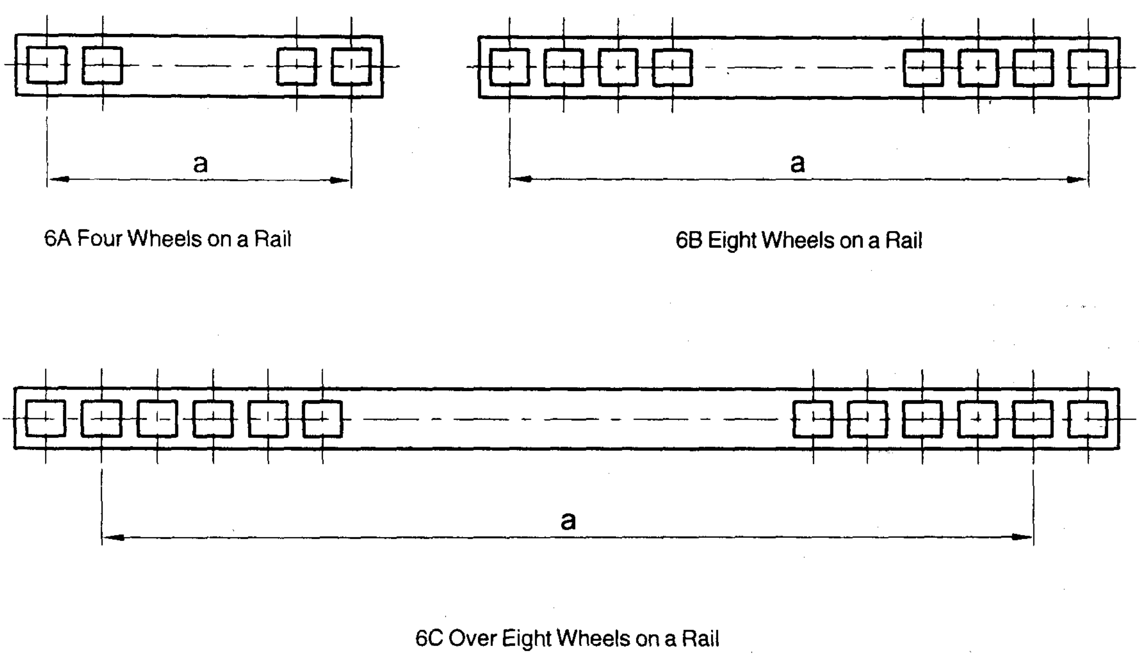


FIG. 6 METHOD FOR TAKING EFFECTIVE WHEEL BASE

7 LOADS DUE TO CLIMATIC EFFECTS

7.1 The loads due to climatic effects are those resulting from the action of the wind, from snow loads and from temperature variations.

7.1.1 *Wind Action*

a) It shall be assumed that the wind can blow horizontally in all directions. The action of the wind will depend essentially upon the shape of the cranes; and

b) It results in increased and reduced pressure whose magnitude are proportional to the aerodynamics pressure.

7.1.2 *Wind Pressure*

The aerodynamic pressure, q is given by the general formula:

$$q = \frac{V_w^2 \cdot \rho}{16g}$$

where

ρ = density, in kg/m^3;

q = pressure, in kgf/m^2;

V_w = wind velocity, in m/s; and

g = gravitational acceleration, in m/s^2.

The values of wind velocity and pressure are given in Table 9.

7.1.3 *Calculating Wind Effects*

The wind exerts a force against a girder, and the component of this force resolved along the direction of the wind is given by the relation:

$$P = A.q.C$$

where

P = resultant load, in kgf;

A = area presented to the wind by girder (in m^2) that is, the projected area of the component parts of the girder on a plane perpendicular to the direction of the wind;

q = aerodynamic pressure, in kgf/m^2; and

C = aerodynamic coefficient which takes the increased and reduced pressure on the various surface and depends upon the configuration of the girder. The values of C are given in Table 10.

7.1.4 *Case of Several Girders Located Behind One Another*

When a girder or part of a girder is protected from the wind by the presence of another girder, the wind force on the protected part of the girder is determined by applying a reducing coefficient 'η' to the force calculated in accordance with the formula $P = \eta.A.q.C$. The value of this coefficient 'η' is depends upon 'b' and 'h' and on the ratio of A/A_e (*see* Fig. 7).

where

A = visible area (area of solid portions);

A_e = enveloped area (solid portion + voids);

h = depth of the girder;

b = distance between the surfaces facing each other; and

q = aerodynamic pressure, in kg/m^2.

In case of lattice girders, the ratio $Q = A/A_e$ is greater than 0.6, the reducing coefficient shall be the same as that for a solid girder. The configuration of girders is given in Fig. 7 and values of coefficient are given in Table 11.

7.2 Values of the Reducing Coefficient (η)

7.2.1 *Wind Load for Suspended Load*

7.2.1.1 The wind action on the suspended load shall be determined by taking account of the greatest area which can face the wind and its values given in Fig. 8.

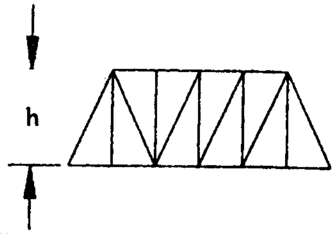
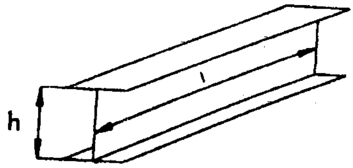
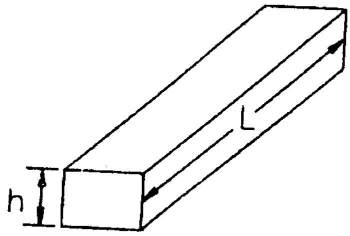
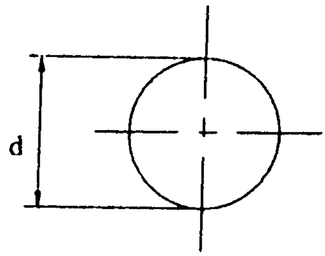
Table 9 Wind Velocity and Pressure

(*Clause* 7.1.2)

Sl No.	Height of Member Above Ground	Limiting Working Wind			Maximum Wind (Crane Out of Service)		
	m	Velocity, V_w		Aerodynamic Pressure, q	Velocity, V_w		Aerodynamic Pressure, q
		m/s	km/h	kgf/m^2 or N/m^2	m/s	km/h	kgf/m^2 or N/m^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	0 to 20	20	72	25	36	130	80
ii)	20 to 100	do	do	do	42	150	110
iii)	Over 100	do	do	do	46	165	130

Table 10 Values of the Aerodynamic Coefficient *C*

(*Clause* 7.1.3)

Sl No. (1)	Type of Girder (2)	Type of Girder (3)	Variable (4)	*C* (5)
i)	Truss of rolled sections		—	1.6
ii)	Plate girder or box girder	 	20 } 10 } For l/h 5 } 2 }	1.6 1.4 1.3 1.2
iii)	Cylindrical member or truss of cylindrical member	*d* in m where *q* in kgf/m^2 	$d\sqrt{q} < 1$ $d\sqrt{q} > 1$	1.2 0.7

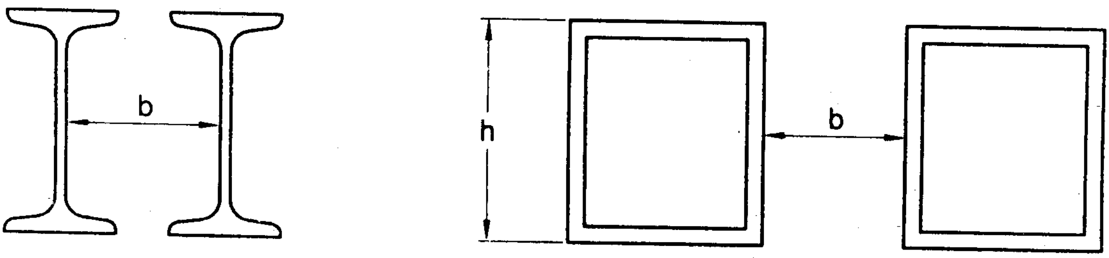


FIG. 7 DISTANCE OF CONFORMITY GIRDERS

The resulting force shall be calculated taking $C = 1$ for the value of aerodynamic coefficient.

However, for the handling of miscellaneous loads less than 25 t, where the wind facing area cannot be precisely determined by the user, the values may be assumed as $1 m^2$ per t for the part up to 5 t, $0.5 m^2$ per t for that part from 5 t to 25 t. The basic wind pressures for different regions in India shall be taken from IS 875 (Part 3).

Table 11 Values of Coefficient η in Terms of $Q = A/A_e$ and b/h

(*Clause* 7.1.4)

$Q = A/A_e$ (1)	0.1 (2)	0.2 (3)	0.3 (4)	0.4 (5)	0.5 (6)	0.6 (7)	0.8 (8)	1.0 (9)
$b/h = 0.5$	0.75	0.4	0.32	0.21	0.15	0.05	0.05	0.05
$b/h = 1$	0.92	0.75	0.59	0.43	0.25	0.1	0.1	0.1
$b/h = 2$	0.95	0.8	0.63	0.5	0.33	0.2	0.2	0.2
$b/h = 4$	1	0.88	0.76	0.66	0.55	0.45	0.45	0.45
$b/h = 5$	1	0.95	0.88	0.81	0.75	0.68	0.68	0.68

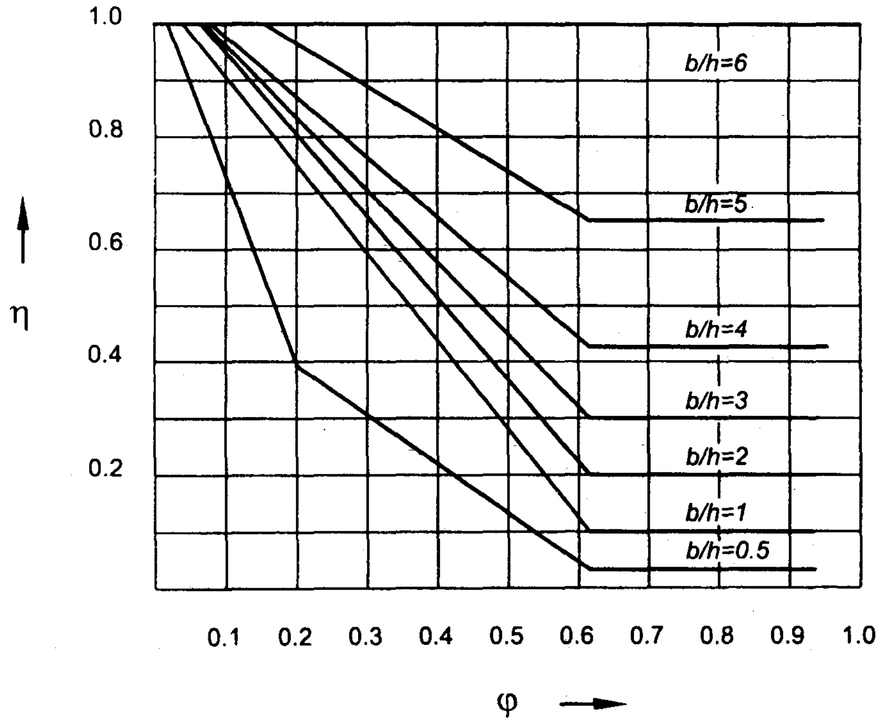


FIG. 8 RELATION DIAGRAM BETWEEN φ AND η

7.2.2 *Snow Load*

Snow load shall be neglected in the design calculations for over head travelling cranes, bridge cranes and jib cranes.

7.2.3 *Temperature Variation*

Stresses due to temperature variation shall be considered only in special cranes such as when members are not free to expand.

In such cases, the maximum temperature fluctuation shall be taken to be – 20°C to + 45°C.

8 MISCELLANEOUS LOADS

8.1 Loads Carried by Platforms

Access gangways, driver's cabins and platforms shall be designed to carry the following concentrated loads:

a) 300 kg for maintenance gang ways and platform where materials may be placed.

b) 150 kg for gangways and platforms intended only for access of personnel.

c) 30 kg as the horizontal force, which may be, exerted on hand rails and toe-guards.

NOTE — These loads are not used in the calculations for girders.

8.2 Seismic Load

The horizontal load of 20 percent of the self-weight shall be taken as seismic load irrespective to types, such as travelling or fixed cranes. However, the horizontal load of the hoisting load suspended by the rope may be neglected.

The seismic load coefficient in some important town in India and map of India showing seismic load are given in IS 1893.

8.3 Amplification of Load

8.3.1 *Impact Factors (Ψ)*

The impact loads caused in the hoisting operation are different in value according to the hoisting speed, deflection of the girder, rope length, and are given by multiplying the impact factor specified in Table 12, to the hoisting loads.

For a structural member, the stress caused from the hoisting load is different in sign, from that of the self-weight, a load multiplied by (1 – Ψ)/2 to the hoisting load shall be taken into consideration of the impact load caused by setting the load down on the ground.

8.3.2 *Choosing the Amplification Coefficient (M) or Duty Factors*

The value of the amplifying co-efficient *M* depends upon the group classification of the cranes. The main loads shall be multiplied by the duty factors given in Table 13 considering the working conditions and the importance of the duty.

8.4 Case Loading (Combination of Loads)

In the calculation of stresses, the most unfavourable combination shall be applied. The three different cases of loading are to be considered:

a) Working without wind;
b) Working with limiting working wind; and
c) For exceptional loadings.

8.4.1 *Cranes Working Without Wind*

The following shall be taken into consideration [(static load due to dead weight) + (working load) × (dynamic coefficient, Ψ)].

8.4.2 *Cranes Working with Wind*

M [(self weight) + Ψ (hoisting load) + (horizontal load)] + (wind load in services) + (load due to heat), where *M* is the duty factor, Ψ is the impact factor.

8.4.3 *Cranes Subjected to Exceptional Loadings*

Exceptional loading occurs in the following cases:

a) Cranes out-of-service with maximum wind,
b) Cranes undergoing static as well as dynamic tests, and
c) Cranes working and subjected to a buffer effect.

The height of the following combination shall be considered:

a) Loads due to the dead weight plus the load due to the maximum wind;
b) Loads due to dead weight and working load due to the service load plus the greatest buffer effect; and
c) Loads S_G due to the dead weight plus the highest of the two loads $\Psi P_1 S_L$ *and* $P_2 S_L$.

where

P_1 = coefficients by which the safe working load is multiplied for the dynamic test;

P_2 = coefficients which the safe working load is multiplied for the static test;

S_L = safe working load; and

S_G = maximum permissible load.

Table 12 Impact Factor, Ψ

(*Clause* 8.3.1)

Group of Cranes	M1	M2	M3	M4	M5	M6	M7	M8
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ψ	1.06	1.12	1.18	1.25	1.32	1.4	1.40	1.5

Table 13 Duty Factor

(*Clause* 8.3.2)

Group of Classification	M1	M2	M3	M4	M5	M6	M7	M8
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
M	1	1	1	1.05	1.06	1.1	1.12	1.2

NOTES

1 All the loads are to be selected in the most unfavourable position and magnitude for the member under consideration. For instance, if the value not multiplied by Ψ is larger than multiplied by Ψ, the value of Ψ should be taken as 1.

2 The horizontal loads shall be considered over the worst combination of loads which may happen simultaneously of the loads. However if it is clear that the horizontal motions do not occur at the same time with the hoisting motions, the value of Ψ may be taken as 1.

3 When the crane is out of service, the trolley shall be placed at a determined position with no load.

4 In case of the slewing crane, the jib shall be placed at a designated position with no load when out of service.

5 The application of load due to temperature and seismic load shall be referred to **7.2.3** and **8.2**.

8.5 Transportation and Erection

Concentrated and uniformly distributed load imposed by the dead weight, if crane structures in the course of transportation and erection at the site. To take care of the above condition the load factor as given in Table 14 is to be considered. If this cannot be determined, it shall be assumed that the trolley is placed at the most unfavourable position.

Table 14 Load Factor

Sl No. (1)	Type (2)	Factor (3)
i)	Erection loads	1.2
ii)	Transportation by road	1.3
iii)	Transportation by rail and ship	1.1

NOTES

1 In the case of the slewing crane the jib shall be placed at a designated position with no load when out of service. If there is no designation, it shall be assumed that the jib is located at the most unfavourable position.

If it is clear that the job is unable to be slewed by the wind, it shall be assumed that the jib is against the wind in its most unfavourable direction.

2 The application of load due to heat and seismic load shall be applied respectively (*see* **7.2.3** and **8.2**).

9 ALLOWABLE STRESS

9.1 Fundamental Allowable Stress

The stresses set up in the various structural members are determined for the case of loading (the working case without wind, the working case with limiting working wind, the case of exceptional loading) and a check is made to ensure that there is a sufficient safety coefficient 'γ' in respect of the critical stresses, considering the following three possible causes of failure:

a) Exceeding the elastic limit;

b) Exceeding the critical cripping or buckling load; and

c) Exceeding the limit of endurance to fatigue.

The fundamental allowable stress, σ_a shall be taken as the value obtained by dividing either the yield point (or yield strength at 0.2 percent strain) or the tensile strength of the material by safety factor as per Table 15, depending upon the respective loading condition mentioned in the combination of loads, whichever is the smaller.

Table 15 Safety Factor

Sl No.	Loading Conditions	Safety Factor	
		For Yield Point	For Tensile Strength
i)	I	1.5	1.8
ii)	II	1.3	1.5
iii)	III	1.15	1.4

NOTES

1 Only tested quality materials (plates, beam, channels, angles and rails) shall be used for the principal loading members.

2 The quality of steels used shall be stated and the physical properties, chemical composition and welding qualities shall be guaranteed by the manufacturer of the material.

9.2 Structural Members and Welds

Allowable stresses for structural members and welds are given in Table 16.

9.3 Rivets, Bolts and Pins

The allowable stresses for rivets, bolts and pins shall conform to the specification as given in Table 17.

9.4 Conventional Number of Cycles and Stress Spectrum

The number of cycles of variation of loading and the spectrum of stresses to be taken into consideration for fatigue stresses. Suitable provision shall be made in the design of the structural member to the protection against cause of the following fatigue failure:

a) Failure due to maximum tensile stress of sufficiently high value;

b) A large enough variation or fluctuation in the applied stress;

c) A sufficiently large number of cycles of the applied stress; and

d) Protection against stress concentration, corrosion, temperature, over load, metallurgical structure, residual stress and combined stress.

Table 16 Allowable Stresses for Structural Members and Welds

(*Clause* 9.2)

		Kind of Stresses	Allowable Stresses	Section for Calculation
Structural members		Tension	σ_a	Gross
		Compression	$\sigma_a/1.15$	Gross
		Buckling	As given in **12**	
		Shear	$\sigma_a/\sqrt{3}$	Gross
		Bending	As given in **13.1**	Gross and net
Welds	Butt weld	Tension	σ_a	
		Compression	σ_a	
		Shear	$\sigma_a/\sqrt{2}$	
	Fillet weld	Tension in the direction of bead, compression	σ_a	
		Shear	$\sigma_a/\sqrt{2}$	Throat

NOTES

1 Net section shall be located at the position of minimum section excluding holes of rivets and bolts.

2 The welds shall conform to the following conditions in the testing methods:

i) The weld shall be free from the defects for class M5 to M8.

ii) In case of presence of defects of class M1 to M4, the allowable value shall not be more than ½ of the allowable value.

Table 17 Allowable Stresses for Rivets, Bolts and Pins

(*Clause* 9.3)

Kind of Joint	Material	Kind of Stresses		Allowable Stresses	Remarks: Diameter Used in Calculation, etc
Rivet	IS 1363 IS 1364 IS 1367 IS 1929	Shop	Shear	$\sigma_a/\sqrt{3}$	Diameter of rivet hole
			Bearing pressure	$1.4\ \sigma_a$	
		Fields	Shear	80% of the above	
			Bearing pressure		
High tensile bolt	IS 2155	Apparent shear		$0.21\sigma_a$	Diameter of bolt stem
High tensile grip bolt	IS 3138	Apparent shear		$0.21\sigma_a$	Diameter of bolt stem
Reamed bolt	IS 3737	Shear		$\sigma_a/\sqrt{3}$	Diameter of bolt stem
	IS 6610	Bearing pressure		$1.4\ \sigma_a$	Diameter of bolt stem
Pin joint	IS 6623	Shear		$\sigma_a/\sqrt{3}$	Diameter of pin when the pin slides slightly only the allowable stress for bearing pressure shall be given as 50 percent of the left described
	IS 6639	Bearing pressure		$1.4\ \sigma_a$	
	IS 6649	Bending		σ_a	
Anchor bolt		Tension		$0.6\ \sigma_a$	Diameter of bottom screw
		Shear		$0.35\ \sigma_a$	

9.4.1 *Fatigue Curve for Ferrous Metal*

The basic method of presenting engineering fatigue data is by means of $S-N$ curve, a plot of stress 'S' against the number of cycles 'N'.

$S-N$ curve is concerned chiefly in the fatigue failure at high number of cycles ($N > 10^5$cycles).

S – N curve becomes horizontal at a certain limiting stress; below this limiting stress (fatigue limit or endurance limit) the material can endure an infinite number of cycles without failure. The failure is at high stress in a short number of cycles.

While designing the structural member, due consideration shall be given to fatigue limit, high stress, high number of cycles and load spectrum. Representation is given graphically in Fig. 9.

9.4.2 *Material Used and Notch Effect*

The fatigue strength of member depends upon the quality of the material used. The fatigue ratio for steel shall be around 0.2 to 0.3. The fatigue strength of the structural members depends upon the shape and the method of making the joints. The shapes of the parts joined and the means of doing it have the effect of producing stress concentration (notch effect) which considerably reduces the fatigue strength of the member. Representation is given graphically in Table 18 and Fig. 10. Classification of various joints to their degree of stress concentration (or notch effect) is given in Annex A.

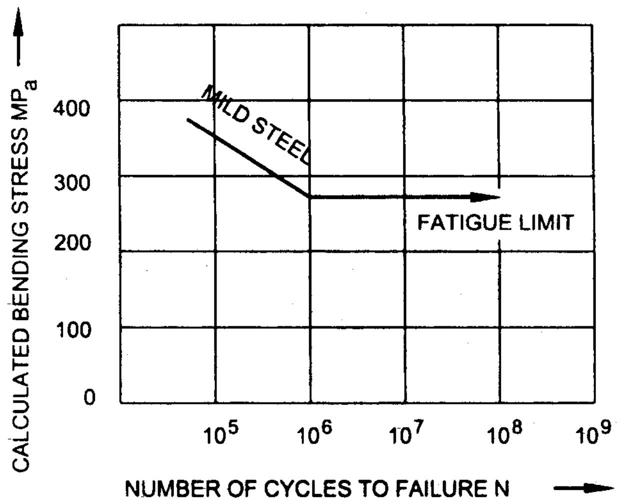


FIG. 9 FATIGUE CYCLES

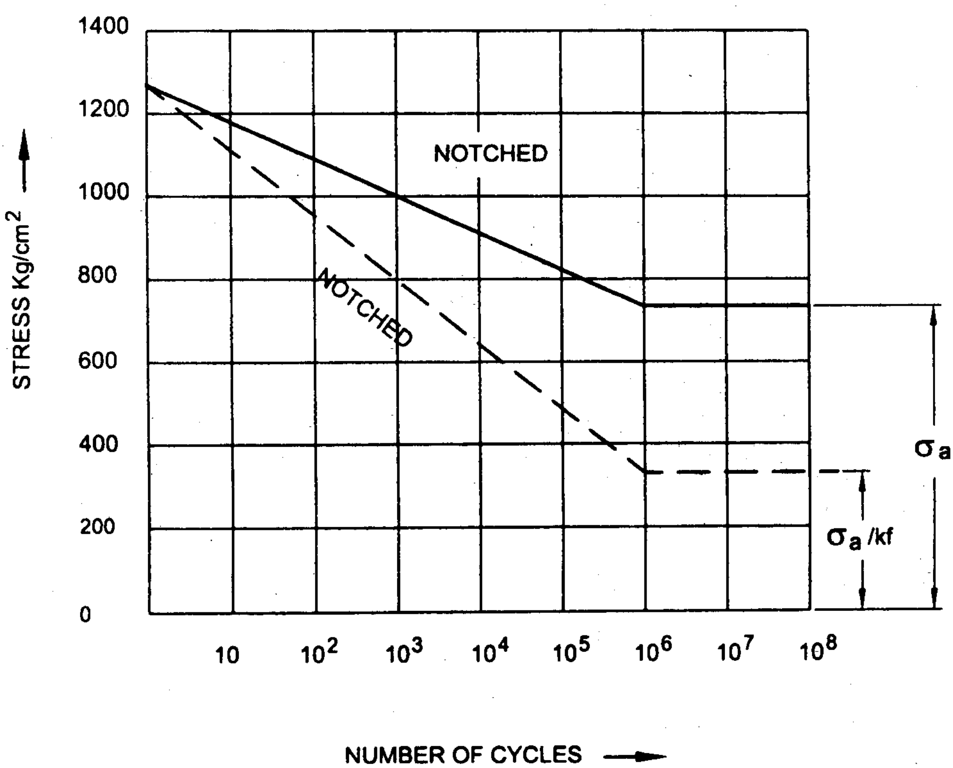


FIG. 10 NOTCH EFFECT

Table 18 Classification by Notch Strength

(*Clause* 9.4.2)

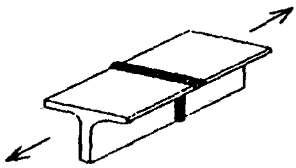
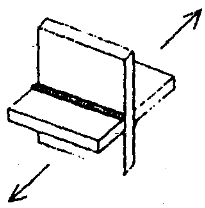
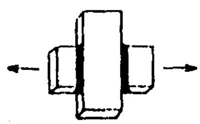
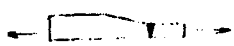
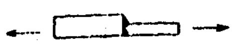
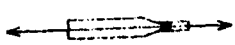
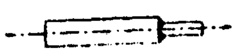
Sl No.	Explanation	Figure	Classification by Notch Strength		Remarks
			As Welded	Bead Finished	
(1)	(2)	(3)	(4)	(5)	(6)
	Parent metal		*a*		
i)	Butt joint at right angles to the force	Butt joint of flat plates 	*c*	*a*	Taken as *d*. when a backing strip is used
		Butt joint of shapes 	*c*	*b*	Confirm absence of lamination
		Cruciform joint 			
			*d*	*c*	
ii)	Butt joint of plates of different thickness at right angles to the force	Asymmetrical slope 	*c*	*d*	
		Asymmetrical joint 	*d*	*c*	
		Symmetrical slope 	*c*	*b*	
		Symmetrical joint 	*d*	*c*	

Table 18 (*Continued*)

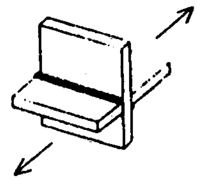
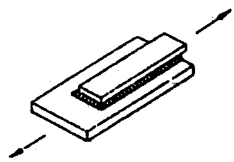
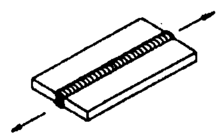
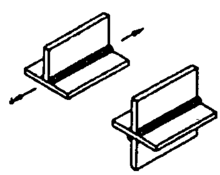
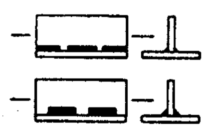
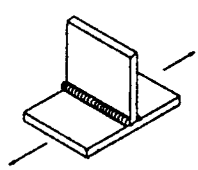
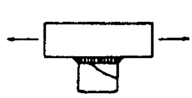
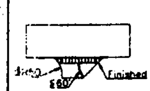
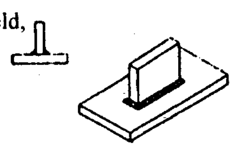
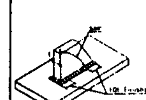
Sl No.	Explanation	Figure	Classification by Notch Strength		Remarks
			As Welded	Bead Finished	
(1)	(2)	(3)	(4)	(5)	(6)
iii)	Fillet weld at right angles to the force		*d*	*c*	Confirm absence of lamination
					
iv)	Continuous butt weld and fillet weld parallel to the force	Butt weld 	*b*	*b*	
		Fillet weld 			
v)	Discontinuous		*c*	*c*	
vi)	With necessary member joint	Fillet weld, fillet weld (spot) 	*c*	*b*	
		Butt Weld 	*d*	*c*	
vii)	With necessary member joint	Fillet weld, 	*d*	*c*	

Table 18 (*Continued*)

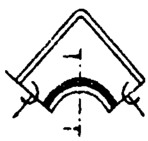
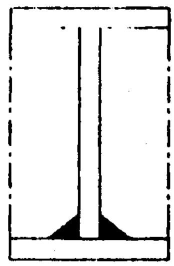
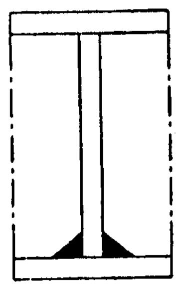
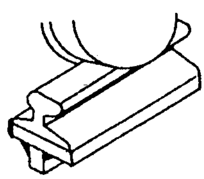
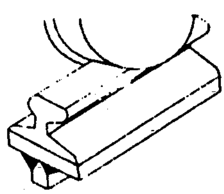
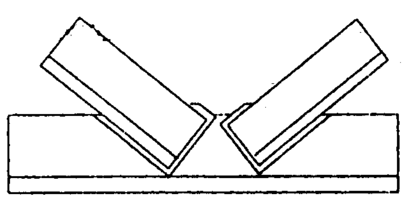
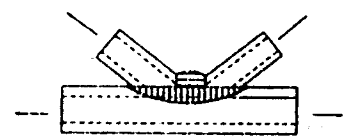
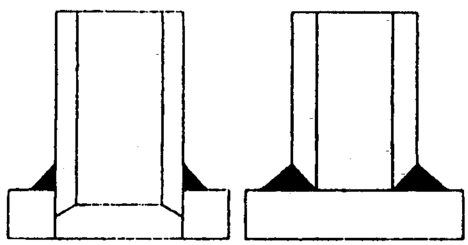
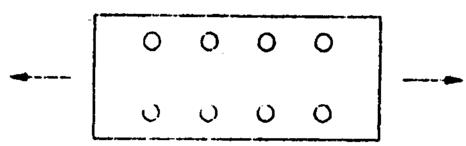
Sl No. (1)	Explanation (2)	Figure (3)		Classification by Notch Strength		Remarks (6)
				As Welded (4)	Bead Finished (5)	
viii)	Joint of curved flange and web		Fillet weld 	*c*	*c*	
			Fillet weld (perfect) 	*b*	*b*	
ix)	Beneath rail	Fillet weld 		*d*	*d*	
		Fillet weld (perfect) 		*c*	*b*	
x)	Truss	Fillet weld 		*d*	*c*	

Table 18 (*Concluded*)

Sl No.	Explanation	Figure	Classification by Notch Strength		Remarks
			As Welded	Bead Finished	
(1)	(2)	(3)	(4)	(5)	(6)
xi)	Pipe	Fillet weld  Fillet weld *V*-groove 	*d*	*c*	
xii)	Perforated member		*c*		

9.4.3 *Determination of the Maximum Stress,* σ_{Max}

Maximum stress σ_{Max}, is the highest stress in absolute value that is, it may be tension or compression which occurs in the member in loading case, without the application of amplifying coefficients, *M*.

9.4.4 *Ratio (K) between the Extreme Stresses*

This ratio is determined by calculating the extremes values of the stresses to which the component is subjected according to loading condition.

The ratio may vary depending upon the operating cycles but it depends on the safe side. To determine this ratio '*K*' by taking two extreme values which can occur during possible operation.

If σ_{Max} and σ_{Min} are the algebraic values of these extreme stresses, σ_{Max} being the extreme stress having higher absolute valve, the ratio may be written:

$K = \sigma_{Min} / \sigma_{Max}$ or $\sigma_{Max} / \sigma_{Min}$ in case of shear

where

σ_{Min} = minimum direct stress, and

σ_{Max} = maximum direct stress.

This ratio, which varies from +1 to −1, is positive if the extreme stresses are both of the same sense (fluctuating stresses) and negative when the extreme stresses are one of the opposite sense (alternating stresses).

9.4.5 *Amplitude Method*

The amplitude of the variable stresses (σ_{Max}, σ_{Min}) shall not exceed the allowable stress and also shall satisfy the following three formulae:

$(\sigma_{Max} - \sigma_{Min}) \leq F_J . F_L . \sigma_d$ with respect to the direct stress for parent metals,

$(\tau_{Max} - \tau_{Min}) \leq F_J . F_L . \sigma_d / \sqrt{3}$

For welds,

$(\tau_{Max} - \tau_{Min}) \leq F_J . F_L . \sigma_d / \sqrt{2}$ with respect to the shear stress for welds shall be applied. F_J, F_L are to be taken from the notch '*a*' (*see* **9.4.2**).

where

σ_{Max} = maximum direct stress, in kgf/cm² or N/mm²;

σ_{Min} = minimum direct stress, in kgf/cm² or N/mm²;

τ_{Max} = maximum shear stress, in kgf/cm² or N/mm²;

τ_{Min} = minimum shear stress, in kgf/cm² or N/mm²;

F_J = joint factor given in Table 19;

F_L = life factor given in Table 20; and

σ_d = allowable fatigue stress. This should be taken as 1 000 kgf/cm² or 100 N/mm². However, each stress shall not exceed the allowable stress.

Table 19 Joint Factors (F_J)

Notches (1)	*a* (2)	*b* (3)	*c* (4)	*d* (5)
Joint factors, F_J	1.5	1.3	1.0	0.7

Table 20 Life Factors (F_L)

(*Clause* 9.4.5)

Group of Cranes	M1	M2	M3	M4	M5	M6	M7	M8
Notches (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
a.b	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.0
c.d	1.7	1.4	1.4	1.2	1.2	1.0	1.0	1.0

9.4.6 *Checking the Members Subjected to Fatigue*

The permissible stress for fatigue is derived from the critical stress defined as being the stress which on the basis of test made with test pieces, corresponds to a 90 percent probability of survival to which a coefficient of safety of 4/3 is applied thus: σ_d of fatigue = $0.75\sigma_a$ at 90 percent survival. Graphical representation is given in Fig. 11.

Practical indications based on the results of research in this field is given in Annex A on the determination of permissible stresses for steel grade st-37, st-42, st-52 according to the various group in which the components are classified and notch effects of the main types of joints used.

10 STABILITY AGAINST OVERTURNING

Stability against overturning shall be checked by calculation, assuming the tipping point to have been reached by increasing the working load and the dynamic and weather effects by the factors specified in Table 21, the rail track or the base of the appliance being assumed to be horizontal and rigid. Typical diagram are shown in Fig. 12 to 16.

In case of floating cranes, due accounts shall be taken of the inclination imparted to the crane as a whole.

10.1 Special Measures

Supplementary means of mooring may be provided to ensure stability when out of service.

Further more, it is permissible to impose definite positions of the cranes or of certain of it's components when out of services or alternatively to allow freedom of movements of the latter (crane jib for example). Such measures should only be adopted after agreement between the user and the manufacturer as they impose conditions on operation.

10.2 Safety against Movement by the Wind

Independently of the stability against overturning, a check should be made that the cranes shall not be set in motion if maximum wind increased by 10 percent. This check shall be carried out assuming a coefficient of friction equal to 0.14 for braked wheels and a resistance to rolling of 10 kgf/t for unbraked wheels mounted on anti-friction bearing or of 15 kgf/t for bushed wheels.

Where there is danger of movement a mooring device such as a chains, clamps, manual or automatic locking pin, etc, shall be provided. For the design of clamps, the coefficient of friction between the clamps and the rail shall be taken as 0.25.

11 CALCULATION OF TENSION MEMBERS

The tension stress shall be calculated by the net sectional area excluding the holes of the bolts and the rivets from the following formula:

$$\sigma_t = \frac{N}{A_n} < \sigma_{ta}$$

where

N = tensile force in axial direction, in kgf or N;

A_n = net sectional area, in cm² or mm²;

σ_t = tensile stress, in kgf/cm² or N/mm²; and

σ_{ta} = allowable tensile stress.

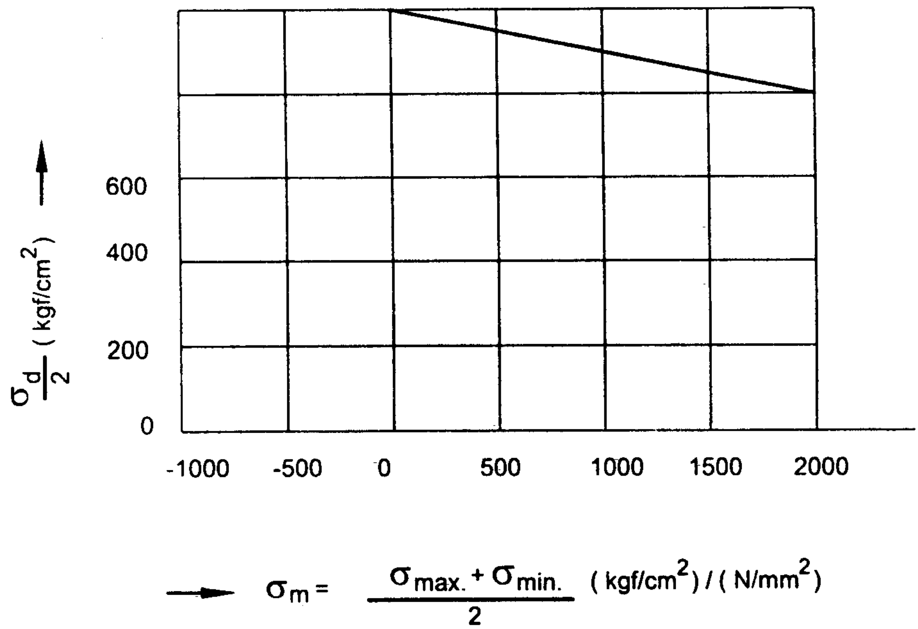


FIG. 11 ALLOWABLE FATIGUE STRENGTH

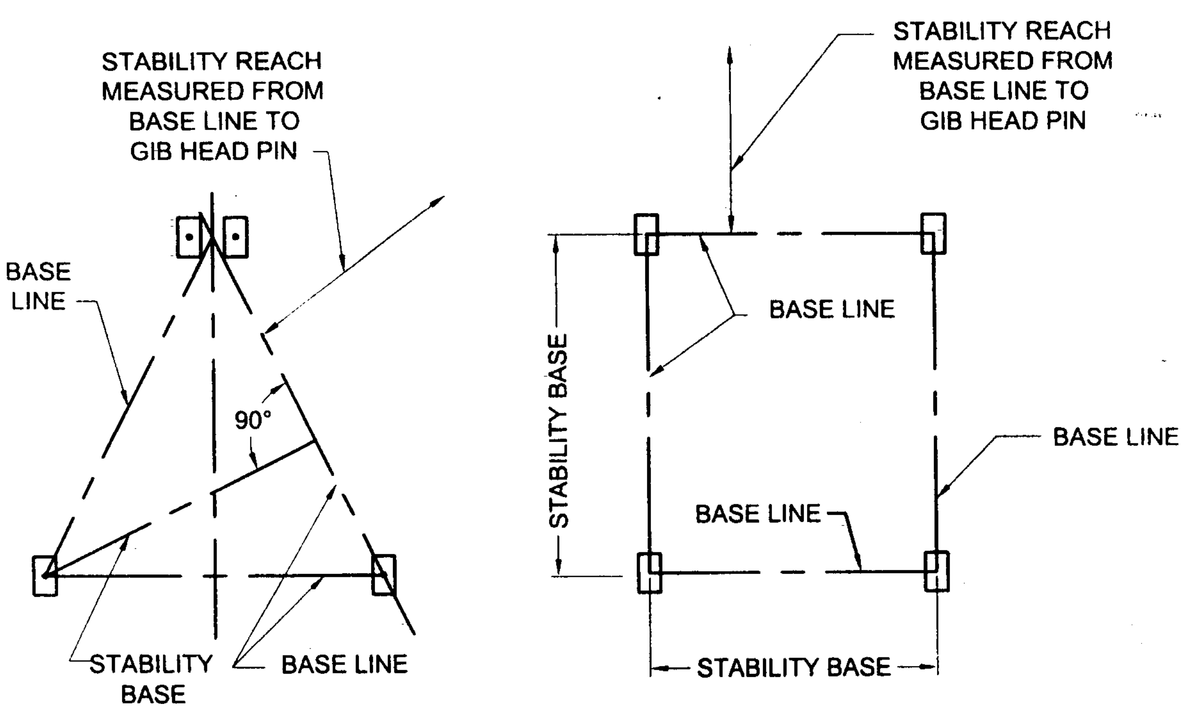


FIG. 12 ILLUSTRATION OF STABILITY BASE STABILITY REACH AND REACH FOR NON-SLEWING 3 OR 4 POINT SUSPENSION CRANES

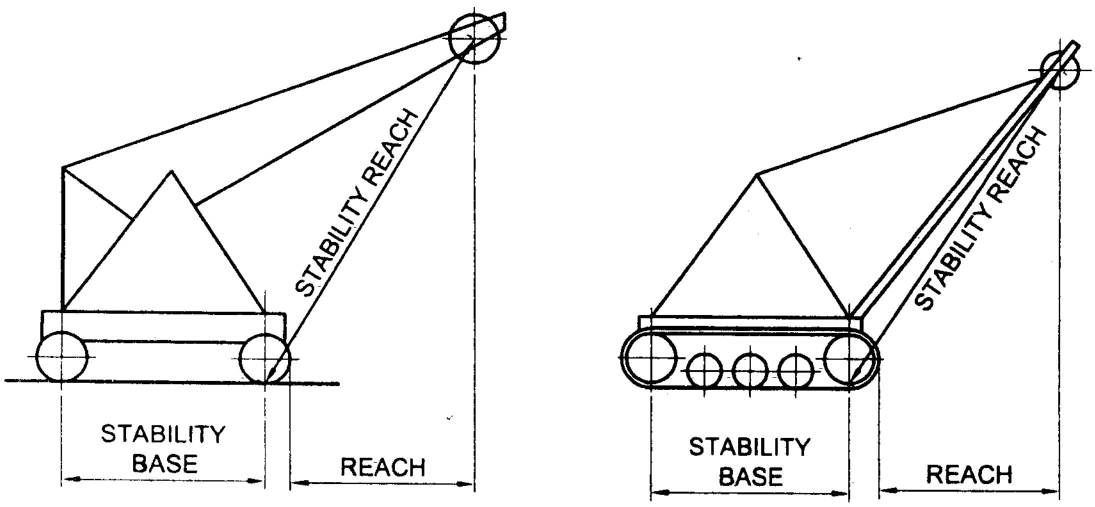


FIG. 13 TYPE MOUNTED MOBILE CRANE

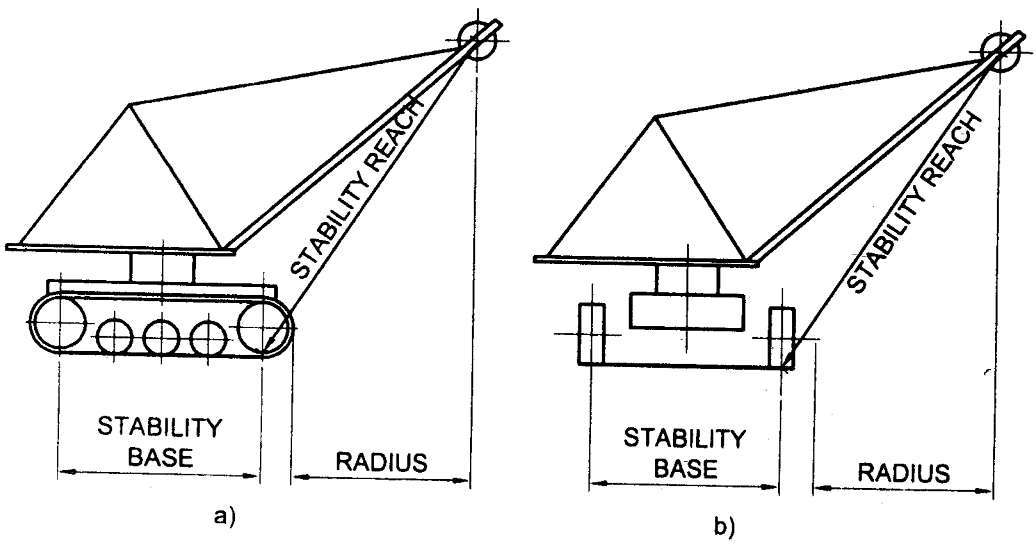


FIG. 14 TRAWLER TYPE MOBILE CRANE

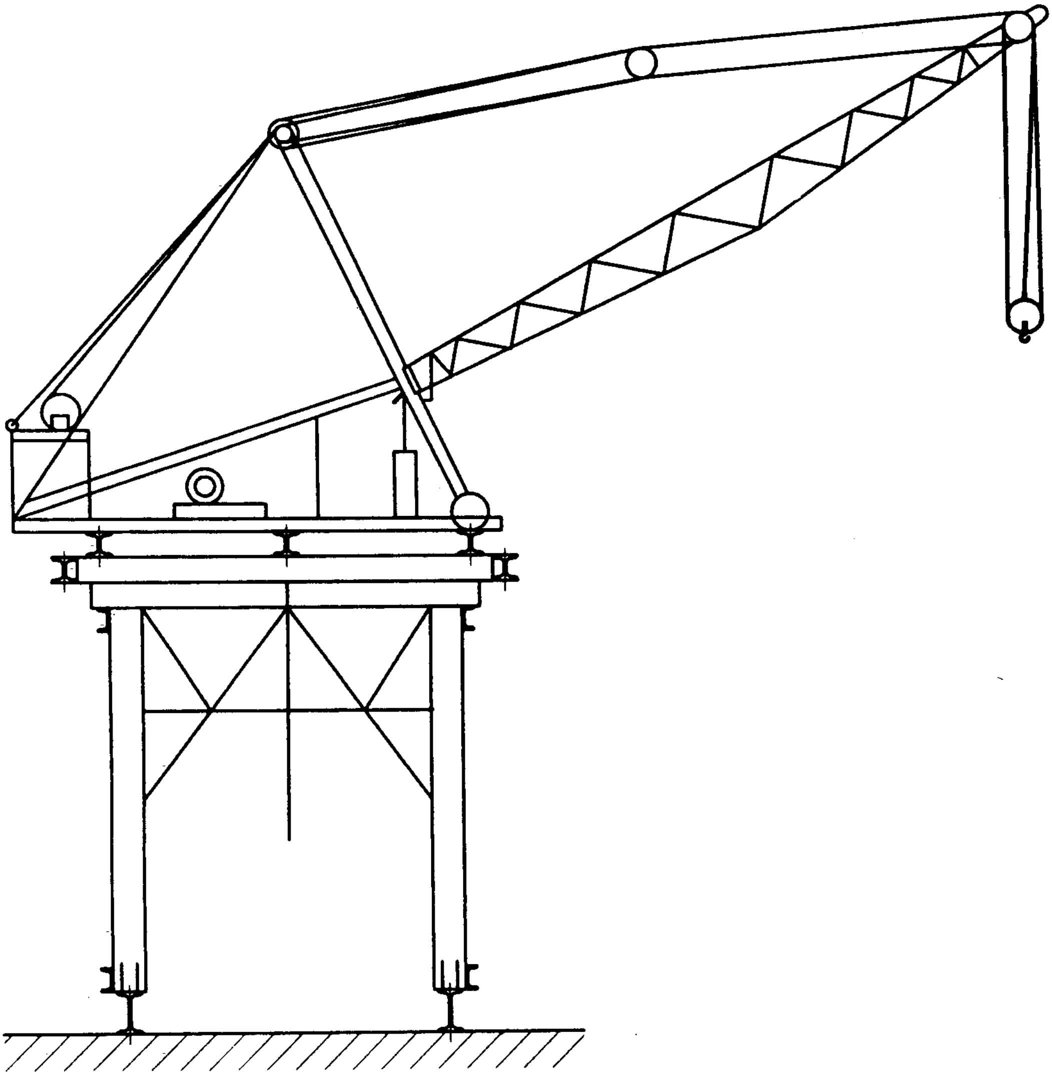


FIG. 15 PORTAL JIB CRANE

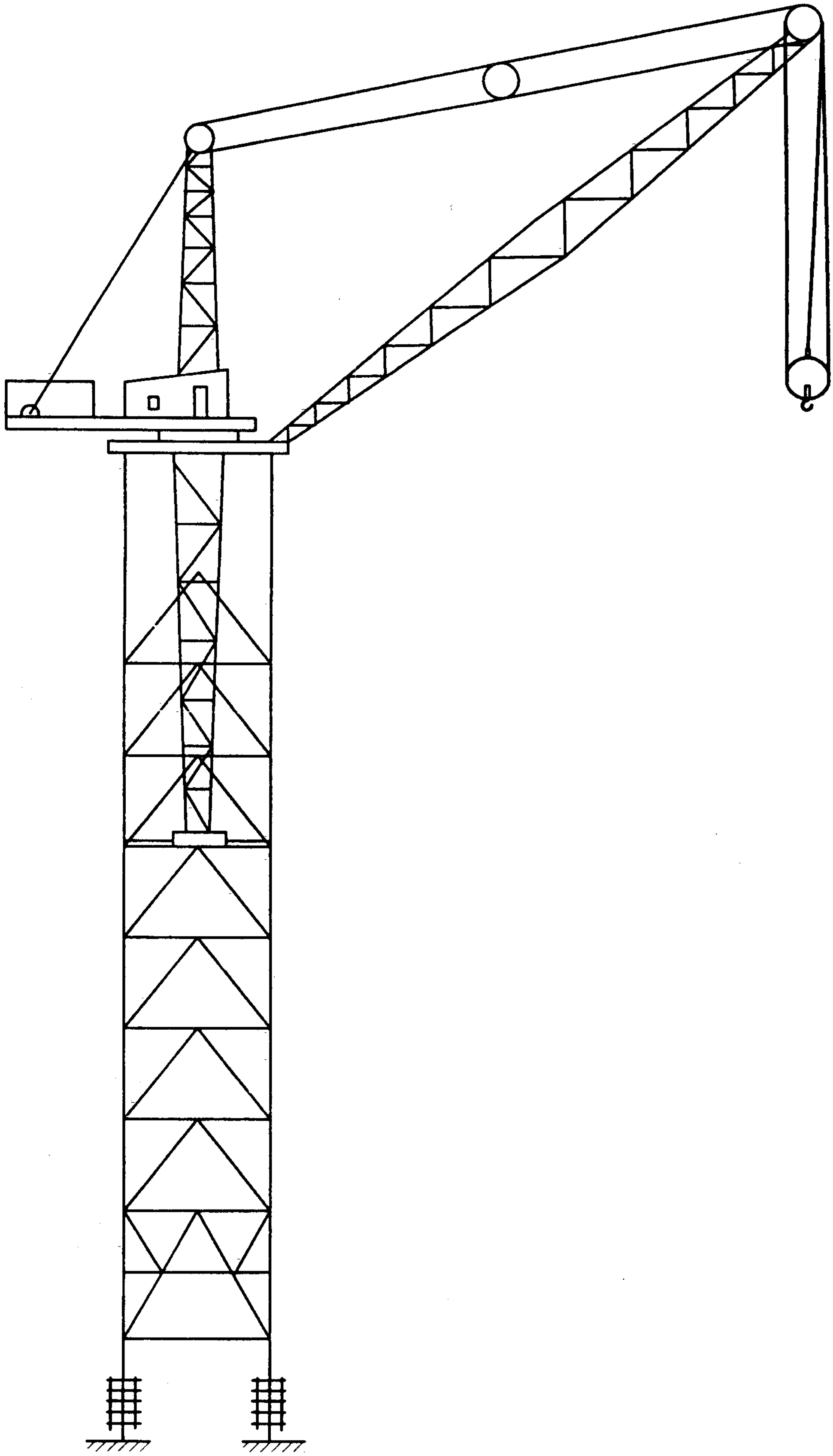


FIG. 16 TOWER CRANE OR TOWER DERIRC CRANE

Table 21 Stability Requirements

(*Clause* 10)

Checks to be Made (1)		Loads to be Considered (2)	Amplifying (3)
Static check		a) Safety working load	1.5
		b) Horizontal effects	0
		c) Wind	0
Dynamic check	Cranes under load	a) Safe working load	1.35
		b) Two horizontal effects	1
		c) Limiting working wind	1
Dynamic check	Cranes under no-load	a) Safe working load	– 0.1
		b) Two horizontal effects	1
		c) Limiting working wind	1
Checking for maximum wind (Storm wind)		a) Safe working load	0
		b) Horizontal effects	0
		c) Maximum wind	1.1
Check for breakage of sling		a) Safe working load	– 0.3
		b) Two horizontal effect with no load	1
		c) Limiting working wind	1

NOTES

1 Limiting working wind in the most unfavourable direction.

2 Travel motion used for positioning only and shall be made separately.

3 Unless calculation justify a lower value.

12 CALCULATION OF COMPRESSION MEMBERS

The compressive stress shall be calculated by the gross sectional area not excluding the holes of the bolts or the rivets from the following formula:

$$\sigma_c = \frac{wN}{A} < \sigma_{ca}$$

where

N = compression force in axial direction, in kgf or N;

A = gross sectional area, in cm^2 or mm^2;

w = buckling coefficient;

σ_c = compressive stress, in kgf/cm^2 or N/mm^2; and

σ_{ca} = allowable compressive stress.

The ratio of the effective length l to the least radius of gyration for compression members shall not exceed 180 for main member and 240 for wind bracing and subsidiary members.

The actual values shall be taken from IS 800.

13 CALCULATION OF BOX GIRDER SUBJECTED TO BENDING AND TORSIONAL STRESSES

The bending stress and torsional stress for the box girder subjected to bending and torsional stresses shall be respectively calculated as follows. However, in the case of the cranes when the ratio (span/width) of the girder is not more than 40, the lateral buckling due to the bending is not considered.

13.1 Bending

$$\sigma_t = \frac{M}{I} \cdot \frac{M}{A_n} \leq \sigma_{ta}$$

$$\sigma_c = \frac{M}{I} \cdot \leq \sigma_{ca}$$

$$\tau = \frac{F}{A_n'} \cdot < \tau_a$$

where

σ_t = tensile stress along edge, in kgf/cm^2 or N/mm^2;

σ_c = compressive stress along edge, in kgf/cm^2 or N/mm^2;

σ_{ta} = allowable tensile stress;

τ = shear stress, in kgf/cm^2 or N/mm^2;

τ_a = allowable shear stress;

M = bending moment, in kgfcm or Nmm;

I = geometrical moment of inertia, in cm^4 or mm^4;

A = gross sectional area of tension flanges, in cm^2 or mm^2;

A_n = net sectional area of tension flanges, in cm^2 or mm^2;

e = distance between the neutral axis to tension edge or compression edge, in cm or mm;

F = shear force, in kgf or N; and

A_n' = net sectional area of web subjected to shear, in cm^2 or mm^2.

13.2 Torsion

$$\tau_t = \frac{M_t}{2.A.t} \le \tau_a$$

where

τ_t = shear stress due to torsional moment in kgf/cm^2;

τ_a = allowable shear stress;

M_t = torsional moment around the shearing centre in kgf cm or N mm;

A = area surrounded with centre lines of webs and flanges in cm^2 or mm^2; and

t = thickness of web or flange in cm or mm.

14 CALCULATION OF MEMBERS SUBJECTED TO BENDING BY FORCE IN THE DIRECTION OF AXIS

Stress of the members subjected to bending by force in the axial direction shall be calculated from the following formulae or a precise buckling calculation shall be carried out considering the deformation of the members as required:

$$\sigma_t = \frac{N}{A_n} + \frac{M}{I} \cdot \frac{A}{A_n} .e \le \sigma_{ta}$$

$$\sigma_c = \frac{N}{A} .w + 0.9 \frac{M}{I} .e \le \sigma_{ta}$$

where

σ_t = tensile stress along edge, in kgf/cm^2 or N/mm^2;

σ_c = compressive stress along edge, in kgf/cm^2 or N/mm^2;

σ_{ta} = allowable tensile stress;

N = force in axial direction, in kgf or N;

M = bending moment, in kgf-cm or N-mm;

I = geometrical moment of inertia, in cm^4 or mm^4;

A = gross sectional area of member, in cm^2 or mm^2;

A_n = net section area of member, in cm^2 or mm^2; and

e = distance between the neutral axis and the edge of section, in cm or mm.

Moreover, open section such as I section member shall be checked about lateral buckling.

15 CALCULATION OF WELDED JOINTS

15.1 Stresses on Joints under Tension, Compression or Shearing Force

Stresses at the butt weld or the fillet weld shall be calculated from the following formulae:

$$\sigma = \frac{P}{\Sigma a.l}$$

$$\tau = \frac{P}{\Sigma a.l}$$

where

σ = tensile or compressive stress at the weld, in kgf/cm^2 or N/mm^2;

τ = shear stress at the weld, in kgf/cm^2 or N/mm^2;

P = force acting on the joint, in kgf or N;

a = throat of the weld, in cm or mm; and

l = effective length of the weld, in cm or mm.

15.2 Combined Stresses on Joints under Bending and Shear Moment

Composite stress shall be calculated from the following formula for joints on which the bending moment and the shear force act simultaneously, such as the continuous weld connecting a web plate and flange, vertical or horizontal butt weld of web plates and fillet weld connecting I-shape girder to wall surface:

$$\sqrt{\sigma^2 + 2\tau^2} \le \sigma_a$$

where

σ = tensile or compressive stress at the weld, in kgf/cm^2 or N/mm^2;

σ_a = bending stress in kgf/cm^2 or N/mm^2; and

τ = shearing stress in kgf/cm^2 or N/mm^2.

15.2.1 *Stress Due to Bending Moment*

$$\sigma = \frac{M}{I} \cdot y$$

where

σ = tensile or compressive stress at the weld, in kgf/cm^2 or N/mm^2;

M = bending moment acting at the joint, in kgf-cm;

I = moment of inertia of the throat around the neutral axis and in the case of fillet weld, the moment of inertia of expansion effective section as shown in Fig. 17 in which the throat is expanded on the joining surface, in cm^4 or mm^4; and

y = distance from the neutral axis to a point under consideration, in cm or mm.

15.2.2 *Shear Stress*

$$\tau = \frac{P \cdot M_G}{I \cdot a}$$

where

τ = shear stress, in kgf/cm^2 or N/cm^2;

P = shear force at the joint, in kgf or N;

M_G = geometrical moment of the area of a section outside of the weld line under consideration about the neutral axis, in cm^3 or mm^3;

I = moment of inertia, in cm^4 or mm^4; and

a = throat, in cm or mm.

16 CALCULATION OF LOCAL BUCKLING OF PLATES

Local buckling strength of the plates shall be calculated on both the buckling of a partial panel surrounded by the stiffeners and the buckling of the whole panel including stiffeners where the load acting on the plate shall be multiplied by the impact factor (ψ) and the duty factor, M.

16.1 Compressive Stress or Shear Stress Acts Independently

16.1.1 In such case where σ_{lki}, $\sqrt{3}t_{ki}$ exceeds the elastic limit of the material, the allowance stress shall be reduced accordingly

$$\sigma_l \leq \frac{\sigma_{lki}}{s}$$

$$\tau \leq \frac{\tau_{ki}}{s}$$

where

σ_l = absolute value of the maximum compressive stress in kgf/cm^2 or N/cm^2;

σ_{lki} = local ideal buckling stress given from the formula $\sigma_l = \sigma_c.k$;

τ_{ki} = local ideal buckling given from the formula $\tau_{ki} = \sigma_c k$;

τ = shear stress in kgf/cm^2 or N/mm^2;

s = safety factor for local buckling (*see* Table 22);

σ_c = fundamental buckling stress given from the following formula:

$$\sigma_c = \frac{\pi^2 . E . t^2}{12 b^2 (1 - \mu^2)} = (1\,378 . \frac{t}{b})^2, \text{ kgf/cm}^2 \text{ or N/mm}^2$$

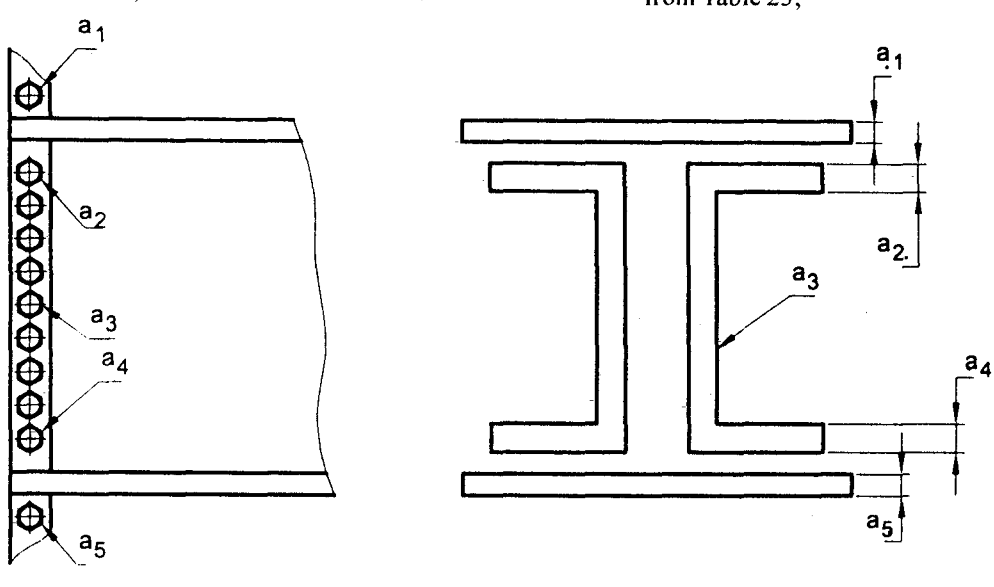
E = modulus of longitudinal elasticity, in kgf/cm^2 or N/mm^2;

μ = poisson's ratio;

t = thickness of the plate, in cm or mm;

b = width of the panel, in cm or mm;

k = local buckling coefficient and concerning the partial panel it shall be in accordance with Table 23. Concerning the whole surface including stiffeners, it shall be obtained according to the condition of each stress from Table 23;



a = THROAT

FIG. 17 EXPANSION OF THROAT

a = length of the panel, in cm or mm;

α = ratio of length to width of the panel;

$$\alpha = \frac{a}{b}$$

γ = stiffeners ratio of the stiffener;

$$\gamma = \frac{J}{0.092\, bt^3}$$

J = geometrical moment of inertia about the centre line of the plate to calculate the local buckling for the gross section of the stiffeners, in cm^4 or mm^4;

S = ratio of area of the stiffener;

$$s = \frac{F}{bt}$$

F = gross sectional area of the stiffeners in cm^2 or mm^2.

NOTE — The values of buckling coefficient shall be taken from Tables 23 to 27.

16.2 Normal Stress and Shear Stress Acts Simultaneously

The two local buckling stress, σ_{lki} and τ_{lki} are separately calculated and the local combined stress, σ_{vki} shall be obtained from the following formula:

$$\sigma_{vki} = \frac{\sqrt{\sigma_l^2 + 3\tau^2}}{\frac{1+\phi}{4}\,\frac{\sigma_l}{\sigma_{lki}} + \sqrt{\left(\frac{3-\phi}{4}\cdot\frac{\sigma}{\sigma_{lki}}\right)^2 + \left(\frac{\tau}{\tau_{ki}}\right)^2}}$$

where

ϕ = ratio of maximum to minimum stress acting perpendicular to a plate.

In special case when $\tau = 0$, $\sigma_{vki} = \sigma_{lki}$

when $\sigma = 0$, $\sigma_{vki} = \sqrt{3}\,\tau_{ki}$

In case where ideal combined stress σ_{vki} exceeds the elastic limit of the material the allowable stress shall be determined by the reduced combined stress σ_{vk}

$$\sigma_{vk} = \sqrt{\sigma_l^2 + 3\tau^2} = \frac{\sigma_{vk}}{s}\ l, \text{ in kgf/cm}^2 \text{ or N/mm}^2$$

where

σ_l = absolute value of the maximum compressive stress in kgf/cm^2 or N/cm^2,

s = safety factor for local buckling,

σ_{vk} = reduced combined stress,

σ_{vki} = ideal combined stress, and

σ_v = allowable reduced stress.

17 DESIGNS OF STRUCTURAL MEMBERS SUBJECT TO AXIAL FORCES

The structural members and joints shall be of the structure free from eccentricity and special stress concentration, and in the inevitable case, these shall be designed taking into consideration the effect.

17.1 Net Sectional Area of Tension Member

In order to obtain the effective net sectional area of the tension member, the areas of the rivet or the bolt holes shall be reduced adequately according to the position of the rivets or the bolts. In Fig. 17, if the section *a-c-c-a* is smaller than that of *a-a*, four rivets or bolt holes shall be reduced from the sectional area of the member.

17.2 Slenderness Ratio

The slenderness ratio λ of the member shall be calculated from the following formula:

$$\lambda = l_k / k$$

where

l_k = buckling length, in cm or mm; and

k = minimum radius of gyration relating to buckling axis, in cm or mm.

The buckling length l_k shall be obtained as follows:

As to the buckling in a plane of a truss, the buckling length is taken as l_k, which is the distance between the centre of gravity of the joining bolts (including rivets) at the ends of the member. When a member intersects the other members, the intersecting part may be regarded as rigid in the plane of the truss.

The bend buckling vertical to the plane of the truss shall be as follows:

a) The distance of nodal points may be taken as l_k, if the both ends of the member are supported not to permit displacement.

b) In the case where one end of the member is joined rigidly to a lateral member having bend rigidity not to displace laterally, l_k shall be taken as 0.8 l.

c) In the case where both ends are jointed rigidly to the lateral members having bend rigidity not to displace laterally, l_k shall be taken as 0.7 l.

d) In Fig. 18, when the nodal of a and b of both trusses do not displace perpendicularly to the plane of truss and the forces of members N_1, N_2 are different in magnitude and $N_2 < N_1$, it shall taken as

$$l_k = \left(0.75 + 0.25\frac{N_2}{N_1}\right)$$

Table 22 Safety Factors for Local Buckling

(*Clause* 16.1.1)

Sl No.	Loading Condition	Safety Factor for Buckling of the Whole Plane	Safety Factor for Buckling of a Partial Panel Surrounded by Stiffness
(1)	(2)	(3)	(4)
i)	I	$1.71 + 0.180 (\phi - 1)$	$1.5 + 0.075 (\phi - 1)$
ii)	II	$1.50 + 0.125 (\phi - 1)$	$1.35 + 0.05 (\phi - 1)$
iii)	III	$1.35 + 0.075 (\phi - 1)$	$1.25 + 0.025 (\phi - 1)$

Table 23(a) Buckling Coefficient for the Partial Panel *K* (without stiffner)

(*Clause* 16.1.1)

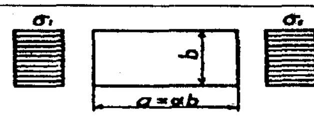
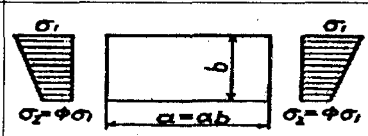
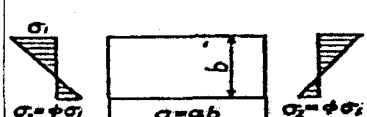
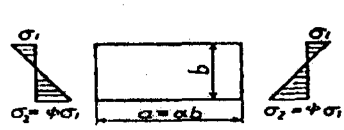
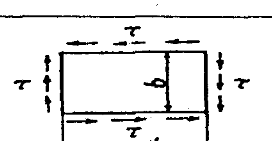
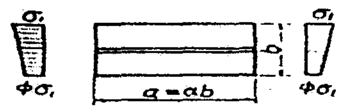
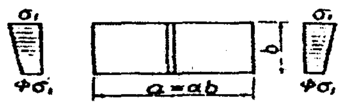
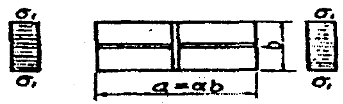
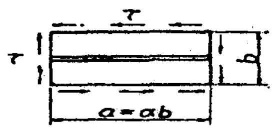
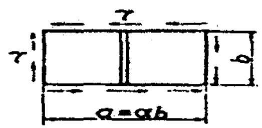
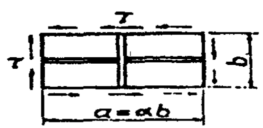
Sl No.	Loading Condition		Range of Application	Buckling Coefficient *K*
i)	Uniformly distributed compressive stress $\phi = 1$		$\alpha \geq 1$	$K = 4$
			$\alpha < 1$	$K = (\alpha + \frac{1}{\alpha})^2$
ii)	Linearly distributed compressive stress $0 \leq \phi < 1$		$\alpha \geq 1$	$K = \frac{8.4}{\phi + 1.1}$
			$\alpha < 1$	$K = \left(\alpha + \frac{1}{\alpha}\right)^2 \cdot \frac{2.1}{\phi + 1.1}$
iii)	Linearly distributed tensile and compressive stresses, where compressive stress is larger $-1 < \phi < 0$			$K = (1 + \phi) K' - \phi K'' + 10\phi (1 + \phi)$ K' = buckling coefficient for $\phi = 0$ (refer to No. ii) K'' = buckling coefficient for $\phi = -1$ (refer to No. iv)
iv)	Linearly distributed tensile and compressive stresses, where compressive stress are equal and tensile stress is larger $\phi \leq -1$		$\alpha \geq 2/3$	$K = 23.9$
			$\alpha < 2/3$	$K = 15.87 + \frac{1.87}{\alpha^2} + 8.6\alpha^2$
v)	Uniformly distributed shear stress		$\alpha \geq 1$	$K = 5.34 + \frac{4.00}{\alpha^2}$
			$\alpha < 1$	$K = 4.00 + \frac{5.34}{\alpha^2}$

Table 23(b) Buckling Coefficient for the Partial Panel K

(*Clause* 16.1.1)

Sl No.	Loading Condition and Arrangement of Stiffness		Range of Application	Buckling Coefficient K
i)	Uniformly distributed compressive stress $0 \leq 1\ \phi \leq 1$ One horizontal stiffener at centre		$\alpha \leq \sqrt[4]{1+2\gamma}$	$K = \dfrac{2}{0.95\,(\phi + 1.1)} \cdot \dfrac{(1+\alpha^2)^2 + 2\gamma}{\alpha^2\,(1+2\delta)}$
			$\alpha > \sqrt[4]{1+2\gamma}$	$K = \dfrac{4}{0.95\,(\phi + 1.1)} \cdot \dfrac{1+\sqrt{1+2\gamma}}{1+2\delta}$
ii)	Uniformly distributed compressive stress $0 \leq \phi \leq 1$ One vertical stiffener at centre		$0.4 \leq \alpha \leq 1.0$	$K = \dfrac{A - \sqrt{A^2 - B}}{1.43\,\alpha^2\,(\phi + 1.1)}$ $A = 1.5\,(1+\alpha^2)^2 + 0.167\,(9+\alpha^2)^2 + 3.3\alpha^2\gamma$ $B = (1+\alpha^2)^2\,(9+\alpha^2)^2 + 2\alpha^2\gamma\,[(1+\alpha^2)^2 + (9+\alpha^2)^2]$
iii)	Uniformly distributed compressive stress. One horizontal stiffener and vertical stiffeners at centre		$0.9 \leq \alpha \leq 1.1$	$K = \dfrac{(1+\alpha^2)^2 + 2\,(\gamma_L + \gamma_Q \cdot \alpha^3)}{\alpha^2\,(1+2\delta_L)}$
iv)	Uniformly distributed shear stress. One horizontal stiffener at centre		$0.5 \leq \alpha \leq 2.0$	$K = \dfrac{4.93\,(1+\alpha^2)}{\alpha^2\sqrt{\tau}}$ $\tau = \dfrac{10.24\,(1+\alpha^2)^2 + 3.16\,(1+9\alpha^2)^2 + 4.05\gamma}{(1+\alpha^2)^2\,(1+9\alpha^2)^2 + 2\gamma\,(1+\alpha^2)^2 + 2\gamma\,(1+9\alpha^2)^2}$ $+ \dfrac{10.24\,(1+\alpha^2)^2 + 0.41\,(9+\alpha^2)^2 + 13.11\gamma}{(1+\alpha^2)^2\,(9+\alpha^2)^2 + 2\gamma\alpha^3\,(9+\alpha^2)^2 + 162\gamma\,(1+\alpha^2)^2}$
v)	Uniformly distributed shear stress. One vertical stiffener at centre		$0.5 \leq \alpha \leq 2.0$	$K = \dfrac{4.93\,(1+\alpha^2)}{\alpha^2\sqrt{\tau}}$ $\tau = \dfrac{10.24\,(1+\alpha^2)^2 + 0.41\,(1+9\alpha^2)^2 + 13.11\gamma\alpha^2}{(1+\alpha^2)^2\,(1+9\alpha^2)^2 + 162\gamma\alpha^3\,(1+\alpha^2)^2 + 2\gamma\alpha^2\,(1+9\alpha^2)^2}$ $+ \dfrac{10.24\,(1+\alpha^2)^2 + 3.16\,(9+\alpha^2)^2 + 4.05\gamma\alpha^3}{(1+\alpha^2)^2\,(9+\alpha^2)^2 + 2\gamma\alpha^3\,(9+\alpha^2)^2 + 2\gamma\alpha^3\,(1+\alpha^2)^2}$
vi)	Uniformly distributed shear stress. One horizontal and one vertical stiffener at centre		$0.5 \leq \alpha \leq 2.0$	$K = 2.60\,\dfrac{1+\alpha^2}{\alpha^3}\,\sqrt{(1+\alpha^2)^2 + 2\,(\gamma_L^2 + \alpha^2\gamma_Q^2)}$

NOTE — Both stiffeners shall cross each other without reduction of bending stiffness or be combined at the same stiffness.

Table 24

(*Clause* 16.1.1)

Buckling Coefficients ω for Steel Members of Yield not more than 24 kgf/mm² (240 N/mm²)

λ	0	1	2	3	4	5	6	7	8	9	λ
20	1.04	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.07	1.08	20
30	1.08	1.09	1.09	1.10	1.10	1.11	1.11	1.12	1.13	1.13	30
40	1.14	1.14	1.15	1.16	1.16	1.17	1.18	1.19	1.19	1.20	40
50	1.21	1.22	1.23	1.23	1.24	1.25	1.26	1.27	1.28	1.29	50
60	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.39	1.40	60
70	1.41	1.42	1.44	1.45	1.46	1.48	1.49	1.50	1.52	1.53	70
80	1.55	1.56	1.58	1.59	1.61	1.62	1.64	1.66	1.68	1.69	80
90	1.71	1.73	1.74	1.76	1.78	1.80	1.82	1.84	1.86	1.88	90
100	1.90	1.92	1.94	1.96	1.98	2.00	2.02	2.05	2.07	2.00	100
110	2.11	2.14	2.16	2.18	2.21	2.23	2.27	2.31	2.35	2.39	110
120	2.43	2.47	2.51	2.55	2.60	2.64	2.63	2.72	2.77	2.81	120
130	2.85	2.90	2.94	2.99	3.03	3.08	3.12	3.17	3.22	3.26	130
140	3.31	3.36	3.41	3.45	3.50	3.55	3.60	3.65	3.70	3.75	140
150	3.80	3.85	3.90	3.95	4.00	4.06	4.11	4.16	4.22	4.27	150
160	4.32	4.38	4.43	4.49	4.54	4.60	4.65	4.71	4.77	4.82	160
170	4.88	4.94	5.00	5.05	5.11	5.17	5.23	5.29	5.35	5.41	170
180	5.47	5.53	5.59	5.66	5.72	5.78	5.84	5.91	5.97	6.03	180
190	6.10	6.16	6.23	6.29	6.36	6.42	6.49	6.55	6.62	6.69	190
200	6.75										200

Buckling Coefficients ω for Cylindrical Steel Members of Yield not more than 24 kgf/mm² (240 N/mm²)

λ	0	1	2	3	4	5	6	7	8	9	λ
20	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.02	20
30	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06	30
40	1.07	1.07	1.08	1.08	1.09	1.09	1.10	1.10	1.11	1.11	40
50	1.12	1.13	1.13	1.14	1.15	1.15	1.16	1.17	1.17	1.18	50
60	1.19	1.20	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	60
70	1.28	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	70
80	1.39	1.40	1.41	1.42	1.44	1.46	1.47	1.48	1.50	1.51	80
90	1.53	1.54	1.56	1.58	1.59	1.61	1.63	1.64	1.66	1.68	90
100	1.70	1.73	1.76	1.79	1.83	1.87	1.90	1.94	1.97	2.01	100
110	2.05	2.08	2.12	2.16	2.20	2.23	2.27	2.31	2.35	2.39	110

NOTE — To cylindrical coefficients, of which ratio of diameter to plate thickness is not more than 6 and λ is equal to 120 or more.

Table 25

(*Clause* 16.1.1)

Buckling Coefficients ω for Steel Members of Yield Point 30 kgf/mm² (300 N/mm²) to 32 kgf/mm² (320 N/mm²)

λ	0	1	2	3	4	.5	6	7	8	9	λ
20	1.05	1.06	1.06	1.07	1.07	1.08	1.08	1.09	1.10	1.10	20
30	1.11	1.11	1.12	1.12	1.13	1.14	1.15	1.16	1.17	1.17	30
40	1.18	1.19	1.20	1.21	1.22	1.23	1.23	1.24	1.25	1.27	40
50	1.28	1.28	1.29	1.31	1.32	1.33	1.35	1.36	1.37	1.38	50
60	1.39	1.41	1.42	1.44	1.45	1.46	1.48	1.50	1.51	1.52	60
70	1.54	1.56	1.58	1.60	1.61	1.63	1.65	1.67	1.69	1.71	70
80	1.73	1.74	1.76	1.79	1.81	1.83	1.85	1.88	1.90	1.93	80
90	1.95	1.98	2.01	2.03	2.05	2.07	2.11	2.15	2.20	2.24	90
100	2.29	2.34	2.39	2.43	2.48	2.53	2.58	2.62	2.67	2.72	100
110	2.77	2.82	2.88	2.93	2.98	3.03	3.09	3.14	3.19	3.24	110
120	3.30	3.35	3.40	3.46	3.52	3.58	3.63	3.69	3.75	3.82	120
130	3.88	3.94	3.00	4.06	4.12	4.18	4.24	4.30	4.37	4.43	130
140	4.49	4.56	4.63	4.69	4.75	4.81	4.88	4.95	5.02	5.09	140
150	5.16	5.22	5.29	5.36	5.43	5.50	5.57	5.64	5.72	5.79	150
160	5.86	5.94	6.02	6.09	6.17	6.25	6.32	6.40	6.48	6.55	160
170	6.62	6.70	6.78	6.86	6.94	7.02	7.10	7.17	7.25	7.34	170
180	7.42	7.51	7.60	7.68	7.76	7.85	7.94	8.02	8.10	8.18	180
190	8.27	8.36	8.45	8.54	8.62	8.70	8.79	8.88	8.98	9.08	190
200	9.18										200

Bucking Coefficients for Cylindrical Steel Members ω of Yield Point 30 kgf/mm² (300 N/mm²) to 32 kgf/mm² (320 N/mm²)

λ	0	1	2	3	4	5	6	7	8	9	λ
20	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	20
30	1.05	1.06	1.06	1.07	1.07	1.08	1.08	1.09	1.09	1.10	30
40	1.10	1.11	1.11	1.12	1.13	1.13	1.14	1.15	1.15	1.16	40
50	1.17	1.18	1.19	1.19	1.20	1.21	1.22	1.23	1.24	1.25	50
60	1.26	1.27	1.28	1.29	1.31	1.32	1.33	1.34	1.36	1.37	60
70	1.38	1.40	1.41	1.43	1.45	1.46	1.48	1.49	1.51	1.53	70
80	1.55	1.57	1.58	1.60	1.62	1.66	1.70	1.73	1.77	1.82	80
90	1.86	1.90	1.94	1.98	2.03	2.07	2.11	2.15	2.20	2.24	90

NOTE — To cylindrical coefficients, of which ratio of diameter to plate thickness is not more than 6 and λ is equal to 100 or more.

Table 26

(*Clause* 16.1.1)

Buckling Coefficients ω for Steel Members of Yield Point 34 kgf/mm^2 (340 N/mm^2) to 36 kgf/mm^2 (360 N/mm^2)

λ	0	1	2	3	4	5	6	7	8	9	λ
20	1.06	1.06	1.07	1.07	1.08	1.08	1.09	1.09	1.10	1.11	20
30	1.11	1.12	1.13	1.14	1.14	1.15	1.15	1.16	1.17	1.18	30
40	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	40
50	1.28	1.29	1.31	1.32	1.33	1.34	1.36	1.37	1.38	1.40	50
60	1.41	1.43	1.44	1.46	1.47	1.49	1.51	1.52	1.54	1.55	60
70	1.58	1.60	1.62	1.64	1.66	1.68	1.70	1.72	1.74	1.76	70
80	1.79	1.81	1.83	1.86	1.88	1.91	1.93	1.96	1.98	2.01	80
90	2.05	2.10	2.14	2.19	2.24	2.29	2.33	2.38	2.43	2.48	90
100	2.53	2.58	2.64	2.69	2.74	2.79	2.85	2.90	2.95	3.01	100
110	3.06	3.12	3.18	3.23	3.29	3.35	3.41	3.47	3.53	3.59	110
120	3.65	3.71	3.77	3.83	3.89	3.96	4.02	4.09	4.15	4.22	120
130	4.96	4.35	4.41	4.48	4.55	4.62	4.69	4.75	4.82	4.89	130
140	4.69	5.04	5.11	5.18	5.25	5.33	5.40	5.47	5.55	5.62	140
150	5.70										150

Buckling Coefficients for Cylindrical Steel Members ω of Yield Point 34 kgf/mm^2 (340 N/mm^2) to 36 kgf/mm^2 (360 N/mm^2)

λ	0	1	2	3	4	5	6	7	8	9	λ
20	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.05	1.05	20
30	1.05	1.06	1.06	1.07	1.07	1.08	1.08	1.09	1.10	1.10	30
40	1.11	1.11	1.12	1.13	1.13	1.14	1.15	1.16	1.16	1.17	40
50	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	50
60	1.28	1.30	1.31	1.32	1.33	1.35	1.36	1.38	1.39	1.41	60
70	1.42	1.44	1.46	1.47	1.49	1.51	1.53	1.55	1.57	1.59	70
80	1.62	1.66	1.71	1.75	1.79	1.83	1.88	1.92	1.97	2.01	80

NOTE — To cylindrical coefficients, of which ratio of diameter to plate thickness is not more than 6 and λ is equal to 90 or more.

Table 27

(*Clause* 16.1.1)

Buckling Coefficients ω for Steel Members of Yield Point 44 kgf/mm² (440 N/mm²) to 46 kgf/mm² (460 N/mm²)

λ	0	1	2	3	4	5	6	7	8	9	λ
20	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.07	1.09	1.09	20
30	1.09	1.10	1.11	1.12	1.13	1.13	1.14	1.15	1.16	1.17	30
40	1.18	1.19	1.20	1.21	1.23	1.24	1.25	1.26	1.28	1.29	40
50	1.30	1.32	1.33	1.35	1.37	1.38	1.40	1.42	1.44	1.46	50
60	1.47	1.49	1.51	1.54	1.56	1.58	1.60	1.62	1.65	1.67	60
70	1.70	1.72	1.75	1.77	1.80	1.83	1.88	1.93	1.98	2.03	70
80	2.08	2.14	2.19	2.24	2.30	2.35	2.41	2.47	2.52	2.58	80
90	2.64	2.70	2.76	2.82	2.88	2.94	3.00	3.06	3.13	3.19	90
100	3.26	3.32	3.39	3.46	3.52	3.59	3.66	3.73	3.80	3.87	100
110	3.94	4.01	4.09	4.16	4.23	4.31	4.38	4.46	4.53	4.61	110
120	4.69	4.77	4.85	4.93	5.01	5.09	5.17	5.25	5.34	5.42	120
130	5.50	5.59	5.67	5.76	5.85	5.94	6.02	6.11	6.20	6.29	130
140	6.32	6.47	6.57	6.66	6.75	6.85	6.94	7.04	7.13	7.23	140
150	7.33										150

Buckling Coefficients for Cylindrical Steel Members ω of Yield Point 44 kgf/mm² (440 N/mm²) to 46 kgf/mm² (460 N/mm²)

λ	0	1	2	3	4	5	6	7	8	9	λ
20	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.03	20
30	1.03	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.09	30
40	1.10	1.11	1.12	1.12	1.13	1.14	1.15	1.16	1.17	1.18	40
50	1.20	1.21	1.22	1.23	1.25	1.26	1.27	1.29	1.30	1.32	50
60	1.34	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.51	1.55	60
70	1.60	1.64	1.67	1.74	1.78	1.83	1.88	1.93	1.98	2.03	70

NOTE — To cylindrical coefficients, of which ratio of diameter to plate thickness is not more than 6 and λ is equal to 80 or more.

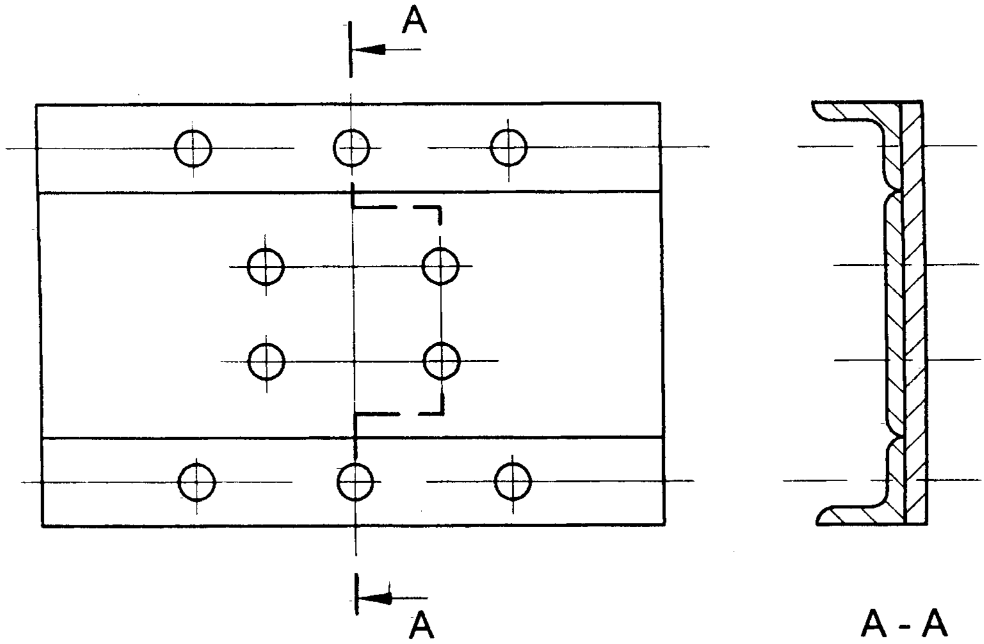
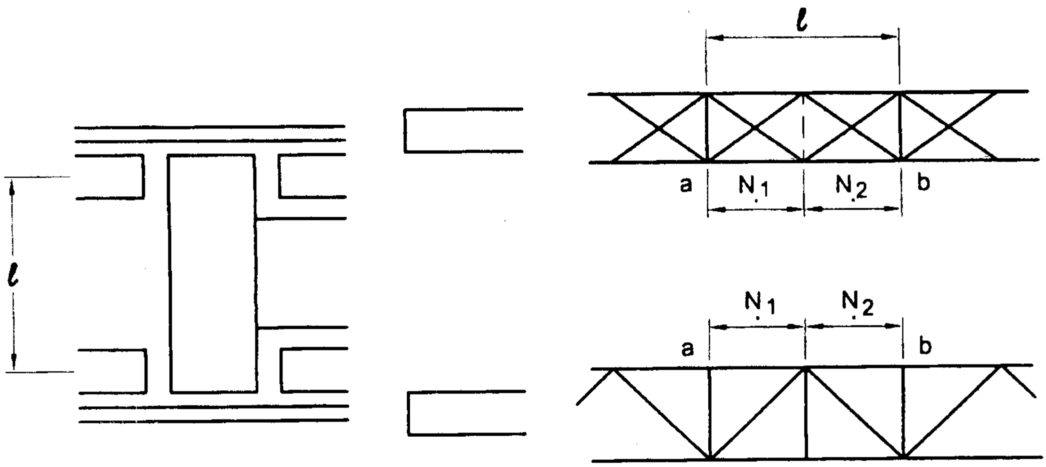


FIG. 18 EFFECTIVE NET SECTIONAL AREA



where *a* and *b* are Nodal points of Trusses and N_1 and N_2 and Forces of members

FIG. 19 BUCKLING LENGTH OUT OF PLATE

17.3 Limit for Slenderness Ratio

The slenderness ratio of the members shall not exceed the values given in Table 28.

Table 28 Limit of Slenderness Ratio Members

Sl No.	Kinds of Members	Slenderness Ratio
(1)	(2)	(3)
i)	Main compressive member	150
ii)	Auxiliary compressive member	240

17.4 Compressive Members with Variable Height

The compressive members having approximately uniform sectional area but having variable height of the member shall have the equivalent geometrical moment of inertia obtained by multiplying the maximum geometrical moment of inertia by the reducing factor *C*, *see* Table 29.

$$I = C \times I_{Max}$$

where

$$r = \frac{I_0}{I_{Max}}$$

These shall be applied only to the bearing member of hinged joint of

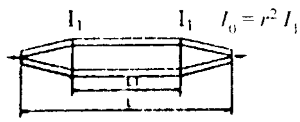
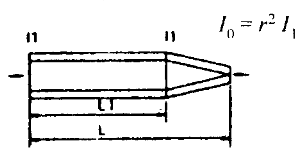
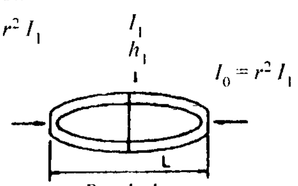
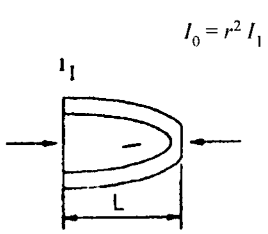
$I_0 > 0.01\ I_{Max}$

$c = 1$ for $l_1 > 0.8l$

c may be interpolated in linear proportion for $0.8l > l_1 > 0.5\ l$

Table 29 Reducing Factor C

(*Clause* 17.4)

Sl No. (1)	Shape of the Member (2)		Reducing Factor (3)
i)	*a*	$I_0 = r^2 I_1$ 	$l \le 0.5l, 0.1 \le r \le l$ $c = (0.17 + 0.33r + 0.5\sqrt{r}) + \frac{\lambda_1}{\lambda}(0.62 + \sqrt{r} - 1.52r)$
ii)	*b*	$I_0 = r^2 I_1$ 	$l_1 \le 0.5l, 0.1 \le r \le l$ $c = (0.08 + 0.92r) + \left(\frac{l_1}{l}\right)^2 (0.32 + 4\sqrt{r} - 4.32r)$
iii)	*c*	$I_0 = r^2 I_1$  Parabola	$0.1 \le r \le l$ $c = 0.48 + 0.02r + 0.5\sqrt{r}$
iv)	*d*	 Parabola	$0.1 \le r \le l$ $c = 0.18 + 0.32r + 0.5\sqrt{r}$

where

I_0 = equivalent geometrical moment of inertia;

I_{Max} = maximum geometrical moment of inertia; and

I = moment of inertia, in cm^4 or mm^4.

17.5 Combined Compressive Members

The combined compressive members are divided into lattice members shown in Fig. 20(a) and rigid frame members shown in Fig. 20(b).

The combined compressive members shall be dealt same as single compressive member the equivalent slenderness ratio is given by the following formula:

$$\lambda_1 = \sqrt{\lambda^2 + \frac{m}{2} \cdot \lambda_1^2}$$

where

λ_1 = equivalent slenderness ratio of a combined compressive member;

λ = slenderness ratio of all members to a principal axis (*see* Fig. 21);

m = number of single members built up into one combined unit by means of horizontal joint as shown in Fig. 21;

λ = slenderness ratio of a single member;

$$\lambda_1 = \frac{\lambda_1}{k_1} \quad \text{for rigid frame member}$$

$$\lambda_1 = \pi\sqrt{\frac{A}{ZA_d} \times \frac{d^2}{\lambda_1 e^2}} \quad \text{for lattice member in cm or mm;}$$

e = distance between the neutral axis to tension edge or compression edge, in cm or mm;

k_1 = radius of gyration of a single member in cm or mm;

d = length of a diagonal member in cm or mm;

A = gross sectional area of a compound member in cm^2 or mm^2;

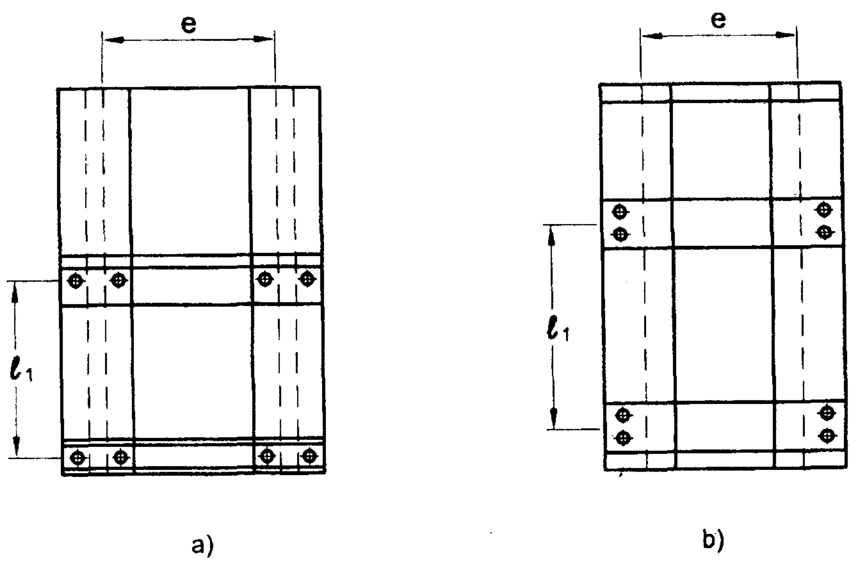


FIG. 20 COMBINED COMPRESSIVE MEMBERS

A_d = sectional area of a lattice member cm^2 or mm^2;

l_1 = buckling length of a single member in cm or mm; and

Z = number of horizontal joints arranged in a parallel plane.

17.6 Shear Stress Acting on Combined Compressive Members

All of the batten plates and parting lathes together with their joints shall not exceed the allowable stresses against the equivalent shear forces shown in the following formula:

$$F_t = \frac{A\,\sigma_{ca}}{80}$$

where

F_t = equivalent stear force in kgf or N;

A = gross sectional area of combined compressive member in cm^2 or mm^2; and

σ_{ca} = allowable comperssive stress in kgf/cm^2 or N/mm^2.

I = geometrical moment of inertia of a girder to the neutral axis of the girder in cm^4 or mm^4;

a) For a rigid frame member, in the case where axial distance of single member exceeds 20 k_1, the equivalent shear force shall be taken as the value shown in the following formula:

$$F_t = \frac{A\,\sigma_{ca}}{80}\left[1 + \frac{5\left(\frac{e}{k_1} - 20\right)}{100}\right] = A\,\frac{\sigma_{ca}}{80}\cdot\frac{\frac{e}{k_1}}{20}$$

where

k_1 = minimum radius of gyration of a single member.

b) In the case of a lattice member constituted of two members, the force D acting on the diagonal members due to F_t is to be given from the following formula:

$$D = \frac{F_t}{Z \sin\alpha}$$

where

α = angle between the main member and the diagonal member.

18 DETAILED DESIGN OF GIRDERS SUBJECTED TO BENDING

18.1 Rivets or Bolts for Joining Girder

The rivets or the bolts for jointing the combined member in the plate girders shall be calculated from the formula:

$$P = \frac{H_a I}{FS}$$

where

P = pitch of rivets or bolts, in cm or mm;

H_a = allowable load for rivet or bolt, in kgf or N;

I = geometrical moment of inertia of a girder to the neutral axis of the girder, in cm^4 or mm^4;

F = shear force acting on the girder, in kgf or N; and

S = geometrical moment of area of the section relating to the neutral axis of the girder, the section of which is intended to be jointed with rivets or bolts, in cm^3 or mm^3.

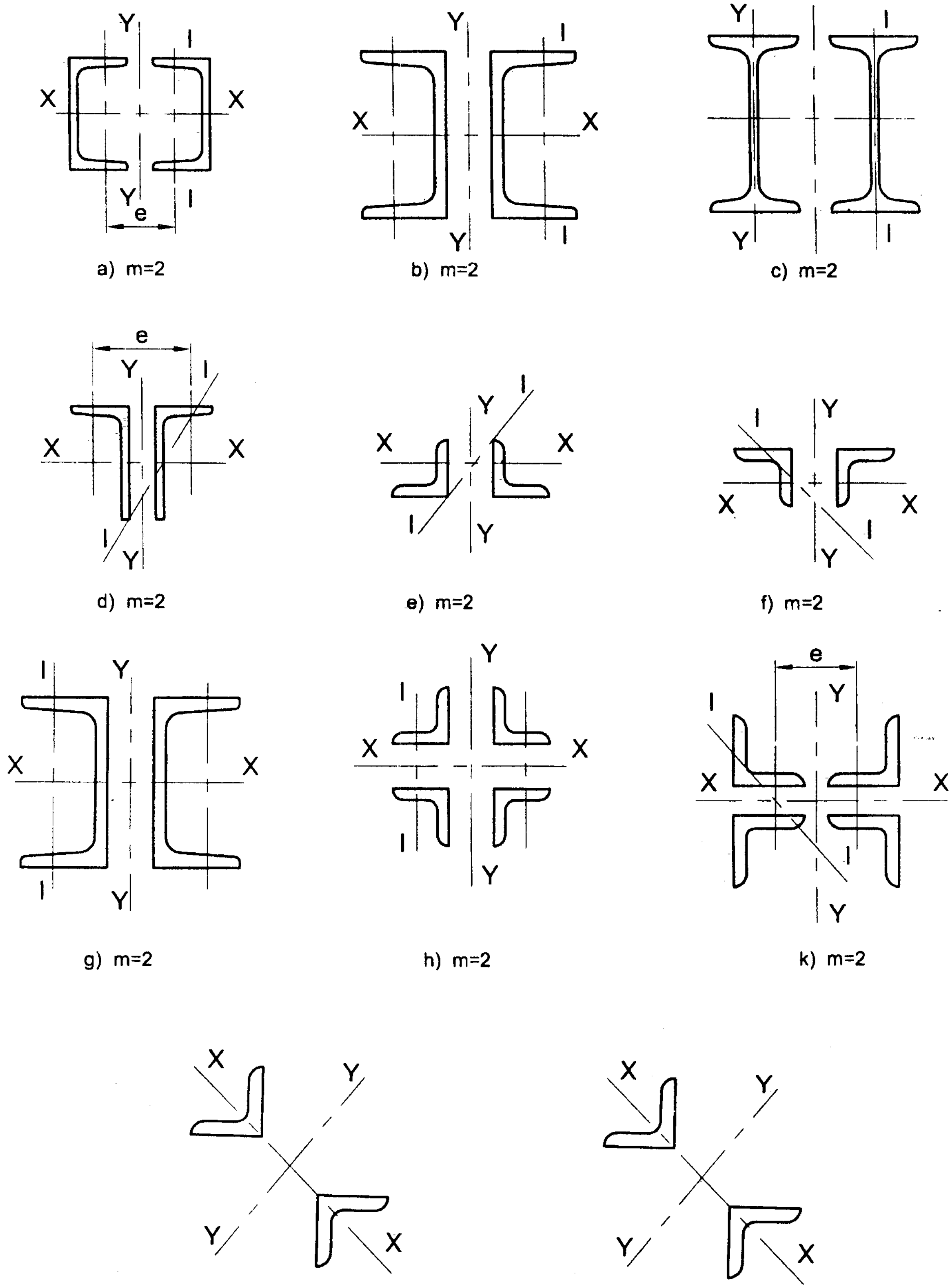


FIG. 21 METHOD OF SLENDERNESS RATIO (*Continued*)

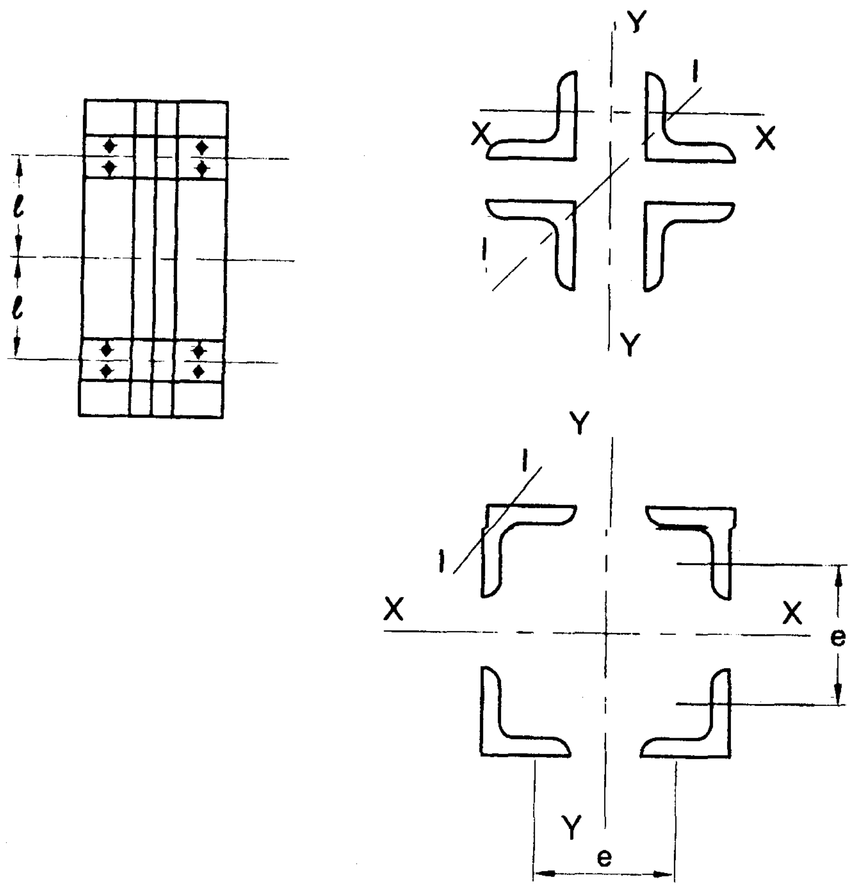


FIG. 21 METHOD OF SLENDERNESS RATIO

18.2 Rivets, Bolts or Welded Directly Subjected to Wheel Load

The rivets, bolts or the welds directly subjected to the wheel load shall be as given in Fig. 22. It shall be assumed that the wheel load is distributed uniformly in the angular direction of 45° from just under 50 mm of the wheel as shown in Fig. 22 where the rail is just on the web and particularly the correct calculation is impossible.

18.3 Web Joint of Plate Girder Receiving Bend

The web joint (*see* Fig. 23) of the plate girder receiving bending moment shall be designed considering both the shear force and the bending moment. Then the maximum resultant force acting on the joining bolts (including rivets) shall be calculated from the following formula. In this case, the allowable strength of bolt shall be reduced according to the ratio of the distance from the flange of plate girder to the neutral axis relative to y_n in the formula:

$$R = \sqrt{\left(\frac{F}{n}\right)^2 + \left(\frac{M_w}{\Sigma y^2} \cdot y_n\right)^2}$$

provided $M_w = M \dfrac{I_w}{I}$

where

- R = resultant force acting on a bolt at y, in kgf or N;
- n = total number of jointing bolts on one side of the joining line;
- F = maximum shear force at the joint, in kgf or N;
- M_w = bending moment on the web, in kgf.cm or N.mm;
- M = bending moment on the welded joint of the girder, in kgf.cm or N.mm;
- I = moment of inertia in cm^4 or mm^4 ;
- I_w = geometric moment of inertia of the web around the neutral axis of the gross section of the girder, in cm^4 or mm^4;
- Σy = total sum of square of distance from joint bolts at one side of the joint line to the neutral axis, in cm^2 or mm^2; and
- y_n = distance from the neutral axis to the furthermost bolt, in cm or mm.

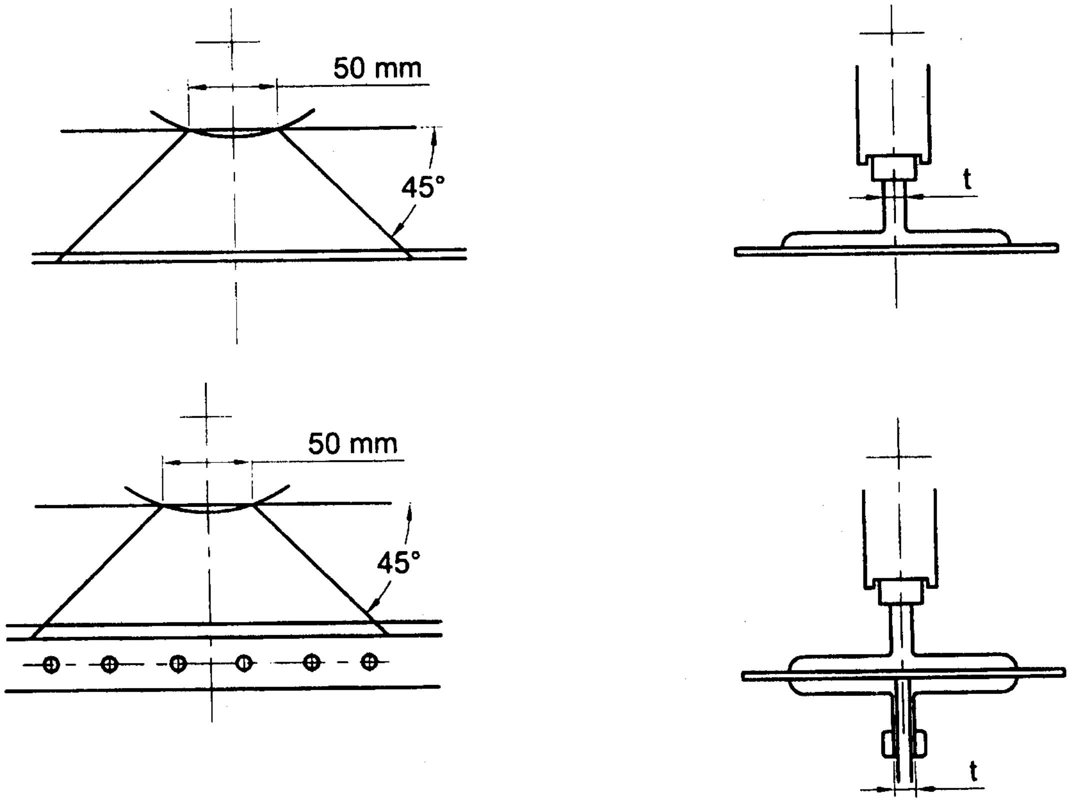
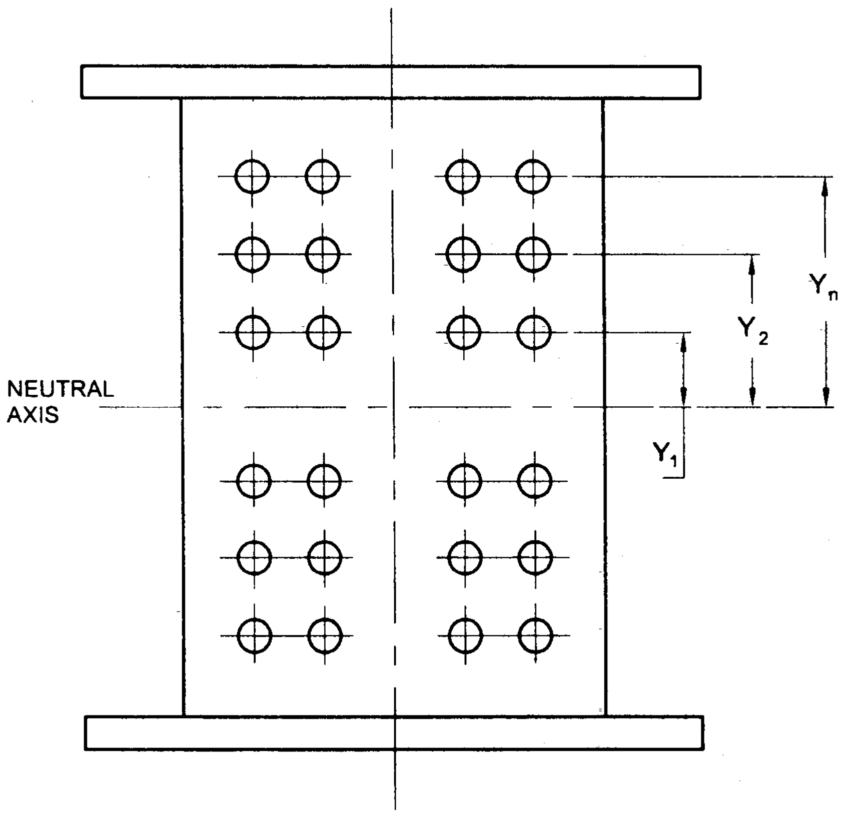


FIG. 22 DISTRIBUTION OF WHEEL LOAD



Y_1 Y_2 ---------- Y_n — DISTANCES FROM NEUTRAL AXIS (cm or mm)

FIG. 23 WEB JOINT

19 WELDING OF INDUSTRIAL AND MILL CRANES

19.1 The following points shall be taken into consideration:

a) Weldability classification of qualified steel;
b) Allowable stress in welds;
c) Fatigue stress in welds; and
d) Classification of welded joints
   1) Weld joint design.
   2) Weld joint category.

19.2 Weld joint design, welding procedure and inspection of welds given in Annex B.

20 LIMITING DEFLECTION

The deflection of members or the structure as a whole (without taking into consideration the impact factor) should not be such as would impair the strength or efficiency of the structure or lead to damage to finishing.

The maximum vertical deflection of the girder produced by the dead load, the weight of the trolley and the rated load shall not exceed 1/750 of the span of the crane (if the span of the cranes is more than 12 m), and 1/600 of the span (if the span of the crane is less than 12 m).

21 CAMBERS

Girders shall be cambered to an amount approximately equal to the dead load deflection plus one-half the live load deflection.

22 DIAPHRAGMS AND VERTICAL STIFFNESS

The spacing of vertical web stiffness shall not exceed

$$\frac{800\,t}{\sqrt{v}}$$

where

t = thickness of one web plate, in mm; and

v = shear stress in web plate, in kg/cm^2.

If the spacing exceeds 1.75 m or depth of the web (h), whichever is greater, web plate shall be reinforced with full depth diaphragms at major load points.

22.1 Diaphragms

The distance between the adjacent diaphragm (longer/short) shall not exceed

$$\frac{7\,600\,S}{W}$$

where

S = section modules of rail, in mm^3; and

W = maximum trolley wheel load, in kg (without impact).

Short diaphragm shall be placed between the full depth diaphragm to support the bridge rail. All diaphragms shall bear against the top cover plate and shall be welded to the web plates.

23 GIRDER END CONNECTION

A substantial end tie must be provided to give horizontal fixed end for rigidity to girder. The girders with the truck shall be provided by the large gusset plate welded to the bottom of the truck and attached to girders with bolts in reamed holes.

24 BRIDGE TRUCKS

The cranes having bogie trucks, the wheel base is measured from centre line to centre line of the two wheels which are far apart on the runways.

Cranes with fixed bogie trucks require a flexible end connection to obtain the equalizing effect. Cranes with equalizing bogie trucks require a rigid end connection.

24.1 Ratio of Crane Span to End Carriage Wheel Base

Following condition to be considered:

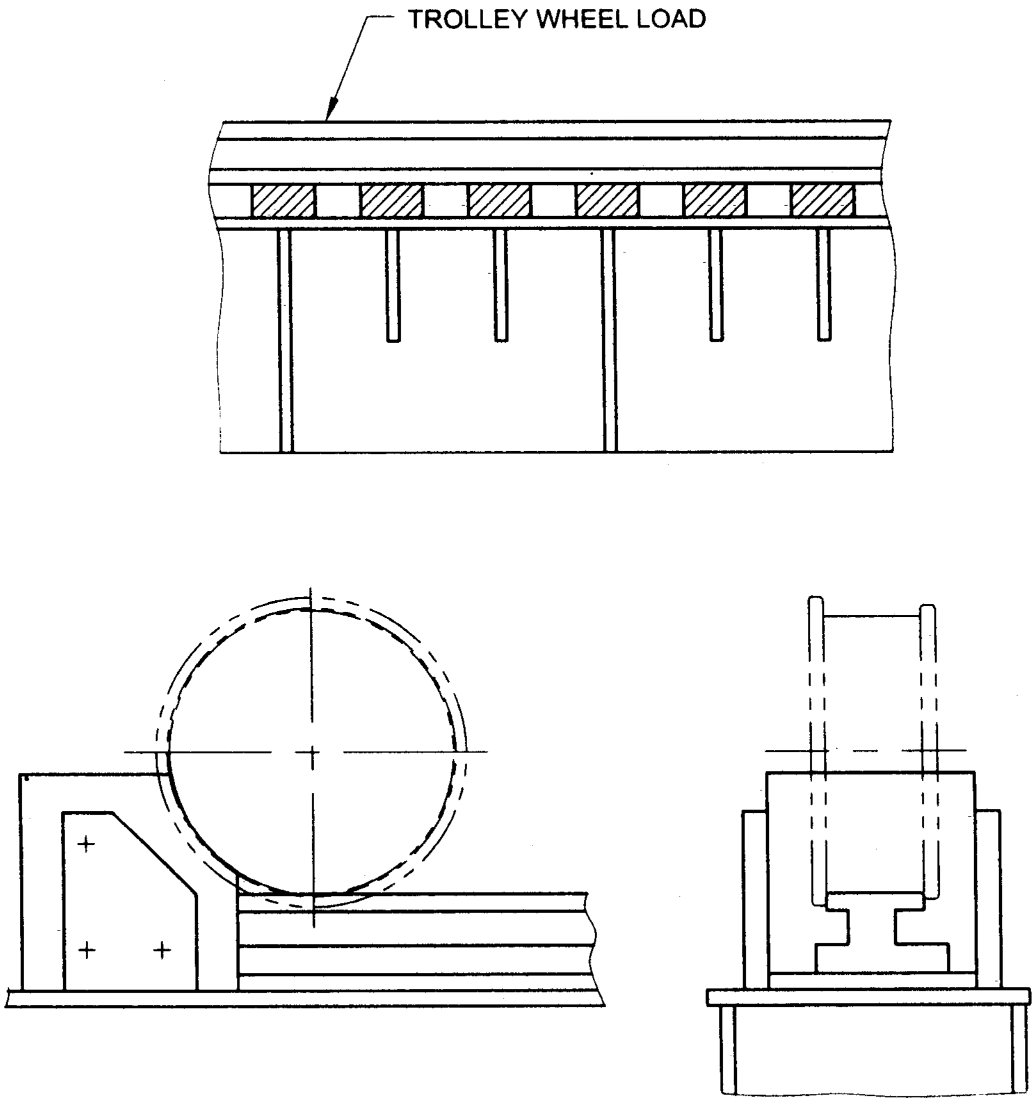
a) For cranes up to and including 20 m span not less than one-sixth of the span;
b) For cranes over 21 m span and up to 24.5 m, not less than 3.5 m of the span; and
c) For cranes over 24.5 m span not less than one-seventh of the span.

24.2 Bridge and Gantry Rails

The selection of bridge rails as well as gantry rails depends upon the wheel load (maximum) and wheel diameter. The rails shall be selected based on the IRS (Indian Rail Steel), CR (Crane Rail) or equivalent rails for both for bridge rails as well as gantry rails. The bridge rail shall be attached to the bridge girders by means of alternately spaced rail clips that are welded to the girder or attached with welded studs. The welding of clips are preferred. It is recommended that the bridge rails shall be supported on wear plate welded on top of the top cover plate and positioned above each girder diaphragm, so that the bending stress produced in the rail by trolley wheel load is not transmitted into the top cover plate.

25 WELDED BOX GIRDERS

Welded box girders (Fig. 24) shall be fabricated of structural steel with continuous (full penetration butt and fillet welds) longitudinal welds running the full length of the girders. All welds shall be designed for maximum shear and bending.



TROLLEY STOPS :- A SOLID STOP SHALL BE WELDED TO GIRDERS AS SHOWN IN THE FIGURE

FIG. 24 GIRDER ARRANGEMENT

25.1 Girder Proportion

The box girder shall be designed for suitable size taking into account of the following proportions:

a) l/h shall not exceed 25,

b) l/b shall not exceed 60, and

c) b/c shall not exceed 60.

where

l = span of the crane, in mm;

h = depth of the girder, in mm;

b = width of the girder, in mm; and

c = thickness of the top cover plates, in mm.

25.2 Height — Thickness (*h/t*) Ratio of Web Plate

$$c\,(k+1)\sqrt{\frac{1\,235}{f_c}} \text{ shall not exceed } M$$

where

c = thickness of top cover plates, in mm;

f_c = maximum compressive stress, in kgf or mm²;

k = f_t/f_c; and

t = thickness of web, in mm.

The coefficients C and M

For Longitudinal Stiffness	C	M
None	81	188
One	162	376
Two	243	564

At reduced stress level, the maximum value 'M' for h/t may be as follows:

a) Maximum h/t for 1 145 kg/cm² compression stress = 188

b) Maximum h/t for 845 kg/cm² compression stress = 220

c) Maximum h/t for 700 kg/cm² compression stress = 240

25.3 Compression Stress

a) Compression stress is less than 1 235 kg/cm² when the ratio of b/c (*see* Table 30), is equal to or less than 38.

b) When the ratio of b/c exceeds 38 (*see* Table 30), the allowable compression stress shall be computed from the following formula:

$$f_c = 1\,235\sqrt{\left(\frac{38}{b/c}\right)^3}$$

Table 30 Values of Compression Shear Stress

Sl No.	b/c	f_c (kgf/cm²)
i)	40	1 145
ii)	44	990
iii)	48	870
iv)	52	770
v)	56	690
vi)	60	625

ANNEX A

(*Clauses* 9.4.2 *and* 9.4.6)

CLASSIFICATION OF JOINTS

A-1 DESIGN OF BOLTED JOINTS

A-1.1 Coefficient of Friction (μ)

The coefficient of friction used for calculation of the force transmitted by friction depends upon the joined material and upon the preparation of the surfaces.

A minimum preparation before joining shall consist of removing every trace of dust, rust, oil and paint by energetic brushing with a clean metallic brush. Oil stains must be removed by flame cleaning or by the application of suitable chemical products (carbon tetrachloride for instance).

A more careful preparation may increase the coefficient of friction. This could be sand blasting, shot blasting or oxy-acetylene flame cleaning done not more than five hours before tightening, brushing must be done just prior to jointing.

The coefficient of friction are given in Table 31.

Table 31 Values of Coefficient of Friction (μ)

Sl No.	Joined Material	Normally Prepared Surfaces (Degreased and Brushing)	Special Prepared Surfaces (Flame Cleaned Shot or Sand Blasted)
(1)	(2)	(3)	(4)
i)	St 37	0.30	0.50
ii)	St 42	0.30	0.50
iii)	St 52	0.30	0.55

It is necessary to insert two washers, one under the bolt head, and the other above the nut. These washers shall have a 45° bevel, at least on the internal rim and turned towards the bolt head or the nut. They shall be heat treated so that their hardness shall be at least equal to that of metal constituting the bolt.

A.1.2 Bolts Tightening

Value of the tension induced in the bolt shall be pre-determined by calculation. The tension, resulting from tightening, can be measured by calculation of the torque to be applied to the bolt and given by the formula:

$$\mu_a = 1.10\, c.d.F$$

where

- μ_a = torque to be applied, in m-kg;
- d = nominal diameter of the bolt, in mm;
- F = nominal tension to be induced in the bolt, in tonnes; and
- c = coefficient depending on the thread form, the friction coefficient on the threads and between the nut and the washer, c = 0.18 (metric bolts).

A-1.3 Value of the Tensile Stress Area of the Bolts

When determining the stress in the bolt, the tensile area shall be calculated by taking the arithmetic mean of the core (minor) diameter and the effective thread diameter. These values are given in Table 32.

A-1.4 Quality of the Bolts

Bolts used for this type of joint have a high elastic limit.

The ultimate tensile strength σ_R must be greater than the values given in Table 33.

where

σ_E = elastic limit.

The diameter of holes shall not exceed by more than 2 mm of bolt diameter.

Effective friction surface shall be considered as:

a) m = 1,

b) m = 2, and

c) m = 3

where m is the friction surface.

Property values of bolts are given in Table 34. Schematic diagram is shown in Fig. 25.

Table 32 Values of Tensile Stress

(*Clause* A-1.3)

Nominal Diameter, in mm	8	10	12	14	16	18	20	22	24	27	30
Tensile Stress Area, in mm^2	36.6	58	84.3	115	157	192	245	303	353	459	561

Table 33 Tensile Strength of Bolts

(*Clause* A-1.4)

Sl No.	σ_E (0.2%), kg/mm^2	σ_R, kgf/mm^2
(1)	(2)	(3)
i)	< 70	> 1.15σ_E
ii)	70 to 85	> 1.12σ_E
iii)	> 85	> 1.10σ_E

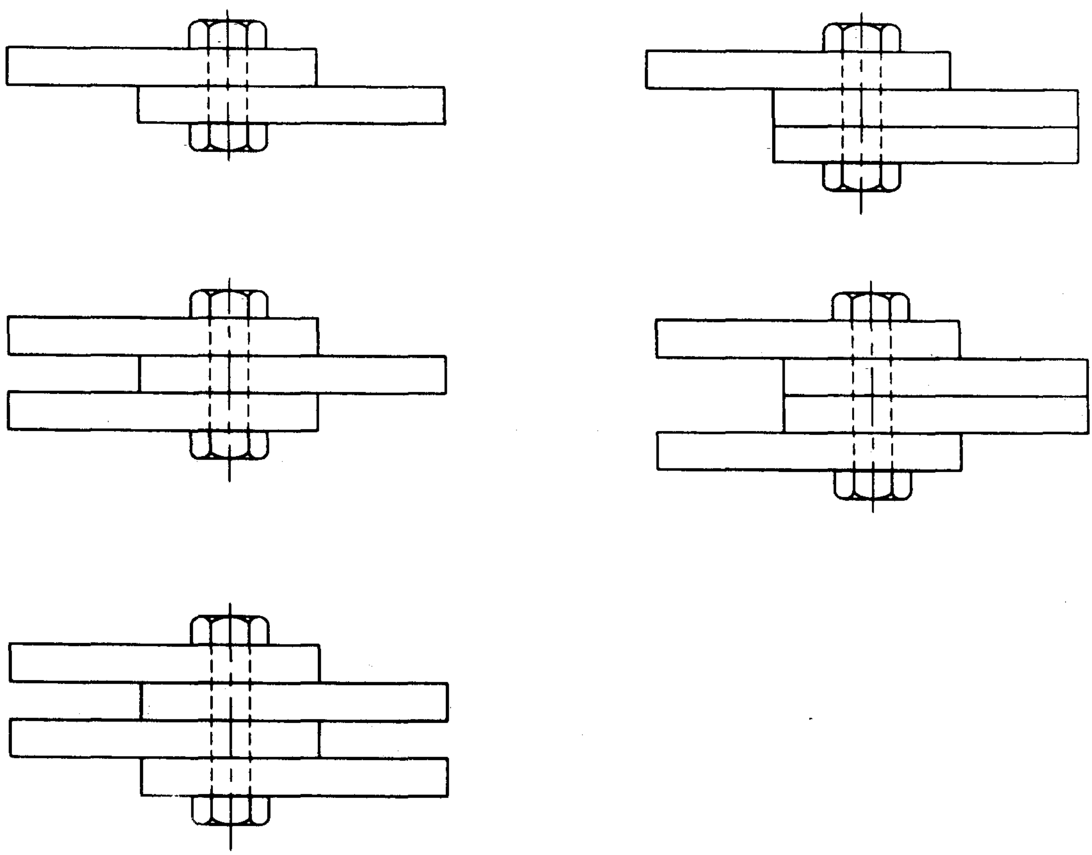


FIG. 25 EFFECTIVE FRICTION SURFACE

Table 34 Property Values of Bolts

(*Clause* A-1.4)

Sl No.	Bolt Dia mm	Tensile Stress Area mm²	Clamping Force t	Applied Torque kg.m	Normally Prepared Surfaces Steels A-37, A-42, A-52			Specially Prepared Surfaces					
					$\mu = 0.3$			Steels A-37, A-42 $\mu = 0.50$			Steels A-52 $\mu = 0.55$		
					Case I t	Case II t	Case III t	Case I t	Case II t	Case III t	Case I t	Case II t	Case III t
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	10	58	4.17	8.27	0.83	0.94	1.14	1.39	1.57	1.89	1.52	1.72	2.08
ii)	12	84.3	6.06	14.4	1.21	1.36	1.55	2.02	2.28	2.75	2.22	2.50	3.03
iii)	14	115	8.27	22.9	1.55	1.86	2.25	2.75	3.10	3.76	3.02	3.42	4.14
iv)	16	157	11.30	35.8	2.26	2.55	3.08	3.79	4.25	5.14	4.15	4.68	5.65
v)	18	192	13.80	49.2	2.76	3.10	3.76	4.60	5.18	6.27	5.06	5.70	6.90
vi)	20	245	17.60	69.7	3.52	3.97	4.80	5.85	6.61	8.00	6.45	7.27	8.80
vii)	22	303	21.80	95.0	4.36	4.93	5.97	7.25	8.20	9.90	8.00	9.02	10.90
viii)	24	353	25.40	120	5.08	5.71	6.94	8.45	9.55	11.55	9.31	10.50	12.70
ix)	27	459	33.00	176	6.60	7.42	9.00	11.00	12.40	15.00	12.10	13.60	16.50

NOTE — For bolt with elastic limit of σ_E, the values of the forces and of the torque indicated in this table are to be multiplied by the ratio $\sigma_E/90$. Where no special measures are taken to avoid stripping of the threads ($\sigma_a = 0.7\ \sigma_E$) these values are to be divided by 1.14.

ANNEX B

(*Clause* 19.2)

WELD JOINT DESIGN, WELDING PROCEDURES AND INSPECTION OF WELDING FOR INDUSTRIAL AND MILL CRANES

B-1 ALLOWABLE STRESSES

a) Base metal, and
b) Weld metal.

B-2 BASE METAL

The allowable tensile or compressive stress in the base metal shall be 50 percent of the yield strength and the allowable shear stress in the base metal shall be 40 percent of the yield strength for members not controlled by buckling.

B-3 WELD METAL

Allowable stresses in the weld metal shall conform to Table 35.

B-4 FATIGUE

The maximum stress in welded joints to repeated stress fluctuation or reversals shall not exceed

a) the basic allowable stress, or
b) the allowable fatigue stress and the stress range does not exceed the value given in Table 36, Table 37 and Fig. 26 to 28.

B-5 WELD JOINT DESIGN

Following points to be considered:

a) General requirements,
b) Groove welds,
c) Intermittent groove weld,
d) Fillet welds,
e) Intermittent fillet welds,
f) Staggered intermittent fillet welds, and
g) Plug and slot welds.

B-5.1 General Requirements

Complete information regarding location type, size and extent of all welds and welded joints shall be shown on the drawing.

B-5.2 Groove Welds

a) The effective area of a full penetration weld shall be the effective weld length multiplied by the effective throat. The dimensions for different metal thickness are given in Table 37.
b) A complete joint penetration groove weld is one that has been welded from both sides or from one side, in which the weld metal completely fill the groove and is fused to the base metal throughout its total thickness.

B-5.3 Intermittent Groove Welds

Intermittent groove welds are prohibited, except in secondary members.

B-5.4 Fillet Welds

Types of fillet weld shown in Fig. 29.

a) The minimum fillet weld size shall be as given in Table 38 except where fillet weld size as shown in Fig. 29 and where fillet welds are used to reinforce groove welds.
b) The maximum fillet weld size permitted along the edges of members should be:
   1) Thickness of the base metal when the metal is less than 6 mm thick.
   2) Thickness of the base metal 1.6 mm when the metal is more than 6 mm thick.
c) The effective weld area shall be the effective weld length multiplied by the effective throat. The shear stress in a fillet weld shall be considered as applied to this effective area regardless of the direction of applied load.
d) Fillet welds shall not be used in skewed T-joints that have an included angle of less than 60°.
e) The edges of the abutting member shall be beveled when necessary, to limit the root opening to 3 mm maximum.

B-5.5 Intermittent Fillet Welds

a) Length of any segment of intermittent fillet weld shall not be less than 4 times the weld size, with a minimum of 51 mm; at least 25 percent of the joint shall be welded. Maximum spacing permitted between welds shall be 300 mm.
b) Intermittent fillet welds may be used to carry calculated loads.
c) Intermittent fillet welds shall not be less than 51 mm in length at each end of the joint.

Table 35 Allowable Stresses in Weld
(*Clause* B-3)

<table>
<tr><th>Sl No.
(1)</th><th>Type of Weld
(2)</th><th colspan="2">Stress Weld
(3)</th><th>Allowable Stress
(4)</th><th>Required Weld Strength Level
(5)</th></tr>
<tr><td rowspan="4">i)</td><td rowspan="4">Complete Joint Penetration</td><td colspan="2">Tension normal to the effective area</td><td>Same as base metal</td><td>Matching weld metal shall be used</td></tr>
<tr><td colspan="2">Compression normal to the effective area</td><td>Same as base metal</td><td>Weld metal with a strength level equal to or one classification less than matching weld metal may be used</td></tr>
<tr><td colspan="2">Tension or compression parallel to the axis of the weld</td><td>Same as base metal</td><td>Weld metal with a strength level equal to or less than matching weld metal may be used</td></tr>
<tr><td colspan="2">Shear on the effective area</td><td>0.27 nominal tensile strength of weld metal, except shear stress on base metal shall not exceed 0.36 yield strength of base metal</td><td></td></tr>
<tr><td rowspan="4">ii)</td><td rowspan="4">Partial Joint</td><td>Compression normal to effective area</td><td>Joint not designed to bear</td><td>0.45 nominal tensile strength of weld metal, except stress on base metal shall not exceed 0.55 percent of base metal</td><td>Weld metal with a strength level equal to or less than matching weld metal may be used</td></tr>
<tr><td colspan="2">Joint designed to bear</td><td>Same as base metal</td><td rowspan="3"></td></tr>
<tr><td colspan="2">Tensile or compression parallel to the axis of the weld</td><td>Same as base metal</td></tr>
<tr><td colspan="2">Shear parallel to axis of weld</td><td>0.27 nominal tensile strength of weld metal, except shear stress on base metal shall not exceed 0.36 yield strength of base metal</td></tr>
<tr><td>iii)</td><td>Partial Joint</td><td colspan="2">Tension nominal to effective area</td><td>0.27 nominal tensile strength of weld metal, except tensile strength on base metal shall not exceed 0.55 yield strength of base metal</td><td></td></tr>
<tr><td rowspan="2">iv)</td><td rowspan="2">Fillet Welds</td><td colspan="2">Shear on effective area</td><td>0.27 nominal tensile strength of weld metal, except shear stress on base metal shall not exceed 0.36 yield strength of base metal</td><td rowspan="2"></td></tr>
<tr><td colspan="2">Tension compression parallel to the axis of weld</td><td>Same as base metal</td></tr>
<tr><td>v)</td><td>Plug and Slot Welds</td><td colspan="2">Shear parallel to effective area</td><td>0.27 nominal tensile strength of weld metal, shear stress on metal shall not exceed 0.36 yield strength of base metal</td><td>Weld metal with a strength level equal to or less than matching weld metal may be used</td></tr>
</table>

Table 36 Fatigue Stress Provisions — Tension or Reversal Stresses

(*Clause* B-4)

Sl No. (1)	General Condition (2)	Situation (3)	Stress Category (4)
i)	Plain Material	Base metal with rolled or cleaned surfaces. Oxygen cut edges with fine smoothness	A
ii)	Built-up Members	Base metal and weld metal in members without attachment, built-up plates or shapes connected by continuous complete or partial joint penetration groove welds or by continuous fillet welds parallel to the direction of applied stress	B
		Calculated flexural stress at toe of transverse stiffener welds on girder web or flanges	C
		Base metal at end or partial length welded cover mates having square or tapered ends with or without welds across the ends	E
iii)	Groove Welds	Base metal and weld metal at complete joint penetration groove welded splices of rolled and welded sections having similar profiles when welds are ground and weld soundness established by non destructive testing	B
		Base metal and weld metal in or adjacent to complete joint penetration groove welded splices at transitions in width or thickness with welds ground to provide slopes no steeper than 1 to 2 ½ and weld soundness established by non-destructive testing	B
iv)	Groove Welded	Base metal at details of any length attached by groove welds subjected to transverse or longitudinal loading or both when weld soundness is transverse to the direction of stress is established by non-destructive testing and the detail embodies a transition radius, *R* with weld termination ground when	Longitudinal loading materials having equal or unequal thickness sloped welds ground web connection
		a) $R > 610$ mm b) 610 mm $> R >$ 152 mm c) 152 mm $> R >$ 51 mm d) 51 mm $> R > 0$	B B C C D D E E
v)	Groove Welds	Base metal and weld metal in or adjacent complete joint penetration groove welded splices either not requiring transition or when metal required with transition having slope not greater than 1 to 2 ½ and when in either case, reinforcement is not removed and weld soundness is established by non-destructive testing	C
vi)	Groove or Fillet Welded Connection	Base metal at details attached by groove or fillet welds subject to longitudinal loading where the details embodied a transition radius *R*, less than 51 mm and when the detail length *L*, parallel to the line of stress is a) < 51 mm b) 51 mm $< L <$ 102 mm c) $L >$ 102 mm	 C D E
vii)	Fillet Welded Connections	Base metal at details attached by fillet welds parallel to the direction of stress regardless of length when the details embodies at transition radius *R*, 51 mm or greater and with weld termination ground a) when $R >$ 610 mm b) when 610 mm $> R >$ 152 mm c) when 152 mm $> R >$ 51 mm	 B C D
viii)	Fillet Welds	Shear stress on throat of fillet welds	F
		Base metal at intermittent welds attaching transverse stiffeners and stud type shear connectors	C
		Base metal at intermittent fillet welds attaching longitudinal stiffeners	E
ix)	Stud Welds	Shear stress on nominal shear area of stud type shear connectors	F
x)	Plug and Slot Welds	Base metal adjacent to or connected by plug or slot welds	E

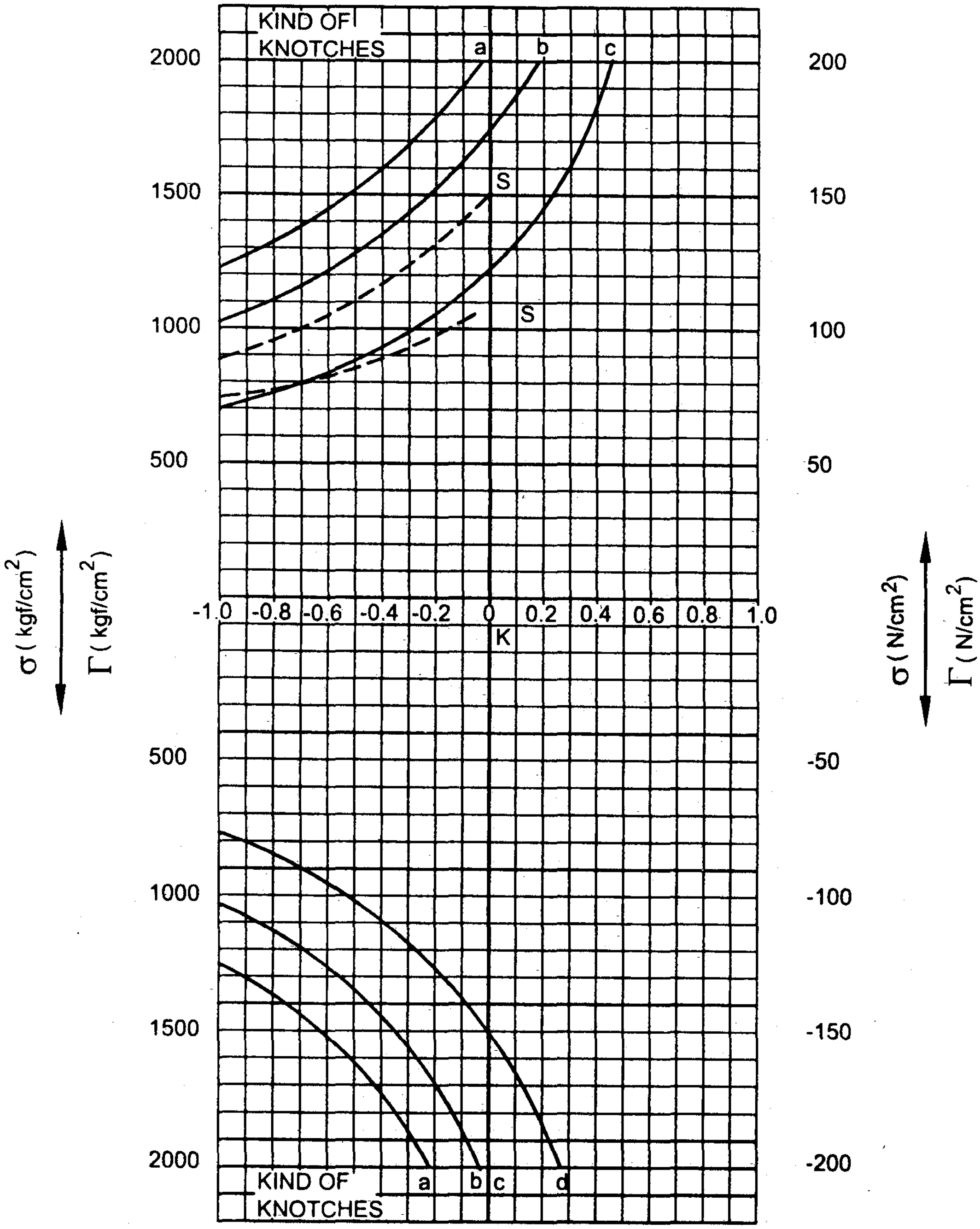


FIG. 26 ALLOWABLE FATIGUE STRESS FOR CRANES (M1 *and* M2)

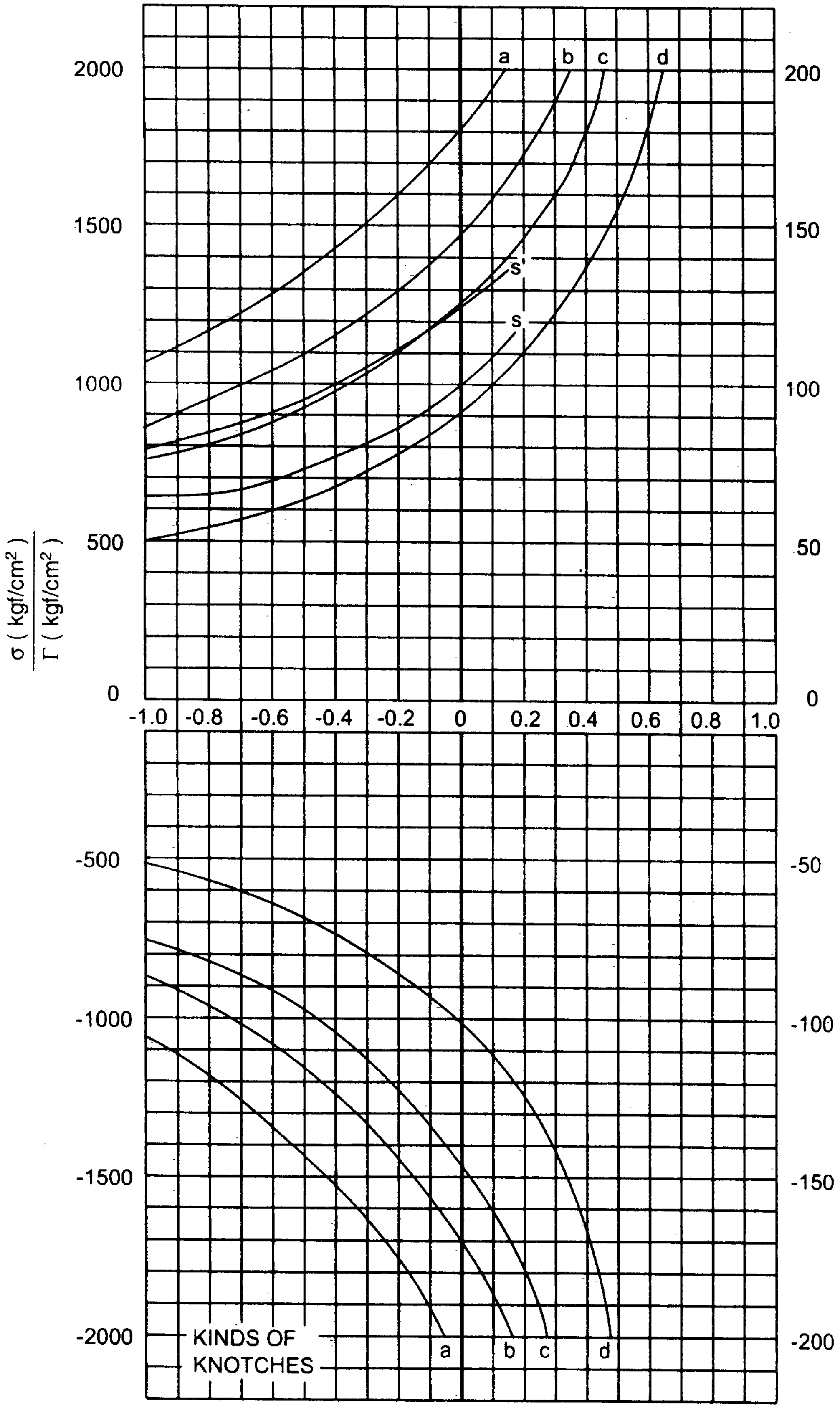


FIG. 27 ALLOWABLE FATIGUE STRESS FOR CRANES (M3, M4 *and* M5)

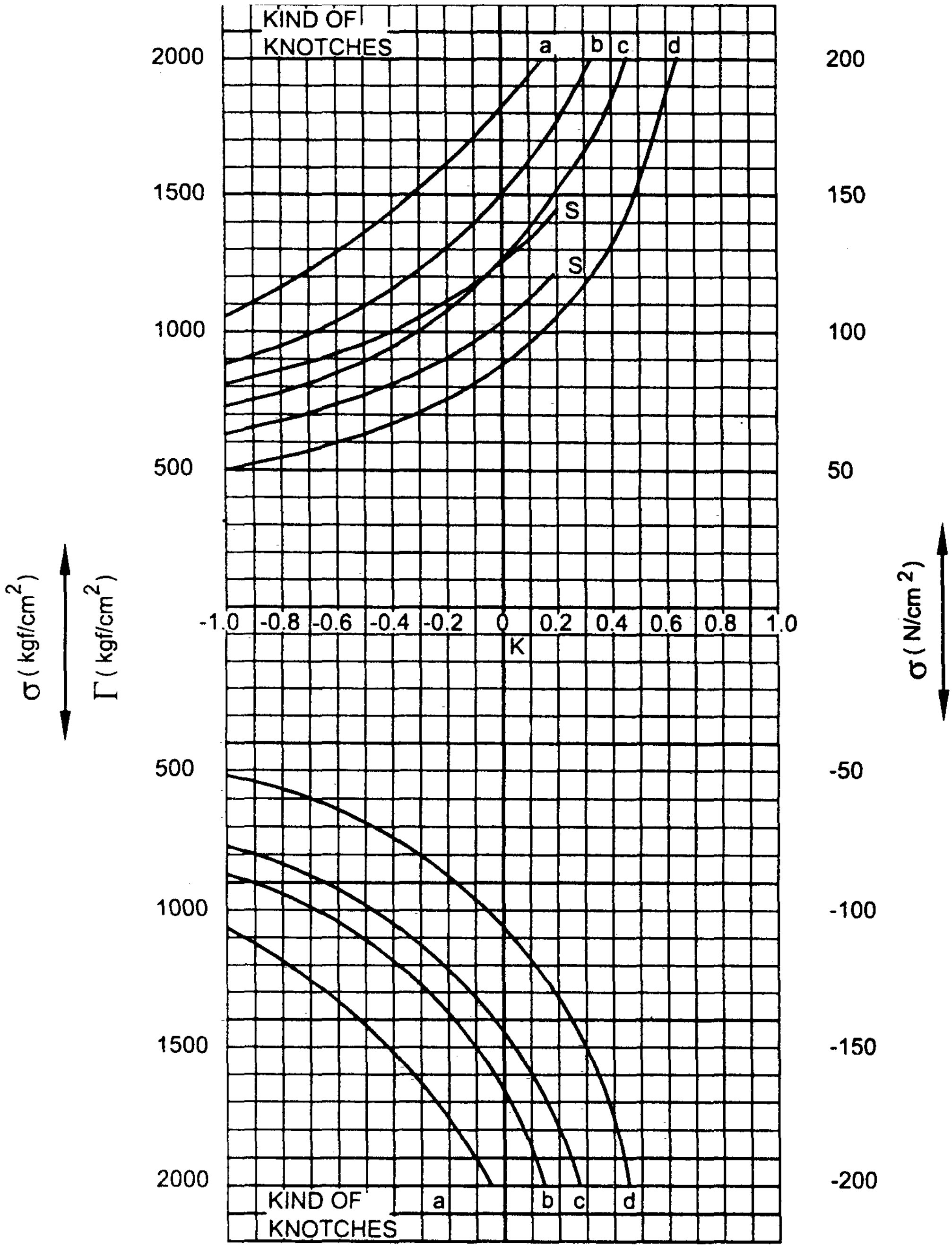
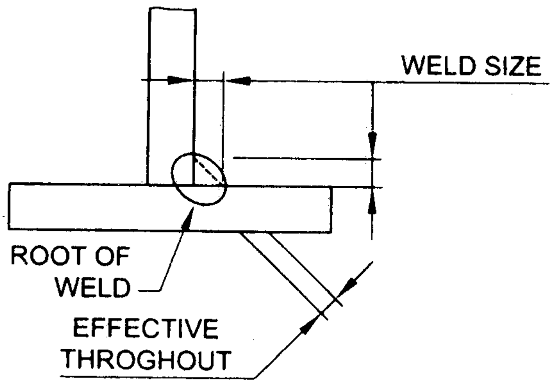
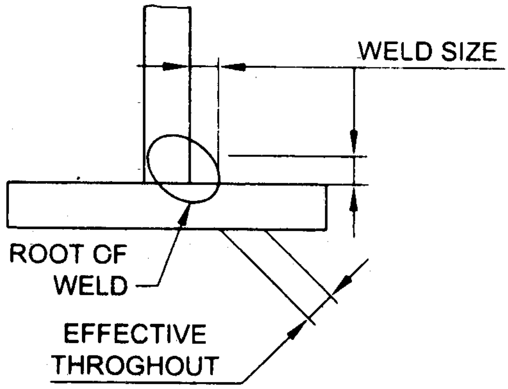


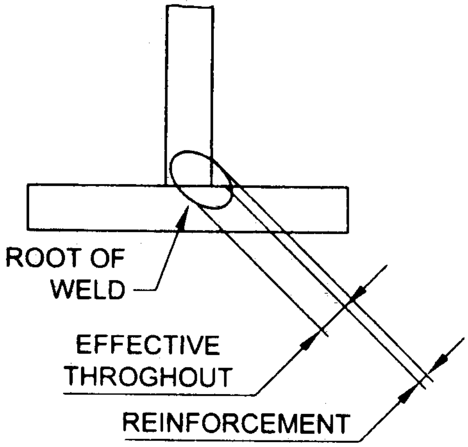
FIG. 28 ALLOWABLE FATIGUE STRESS FOR CRANES (M6, M7 *and* M8)



29A Weld deposit



29B Weld deposit by a deep penetrating process



29C Actual throat of a bevel group weld reinforcernent with a fillet weld

FIG. 29 FILLET WELD

Table 37 Minimum Effective Throat for Partial Joint Penetration Groove Welds

(*Clauses* B-4 *and* B-5.2)

Sl No.	Metal Thickness of Thicker Part Joint mm	Minimum Effective Throat mm
(1)	(2)	(3)
i)	6	3
ii)	6 to 13	5
iii)	13 to 19	6
iv)	19 to 38	8
v)	38.1 to 57.1	10
vi)	57.1 to 152	13
vii)	152	16

Table 38 Minimum Fillet Weld Size

(*Clause* B-5.4)

Sl No.	Weld Size		
	Metal Thickness of Thicker Joints in mm	Shielded Metal Arc Welding in mm	Deep Penetration Process for Single Pass Welds for Horizontal Position in mm
(1)	(2)	(3)	(4)
i)	6	3	3
ii)	6 to 13	5	3
iii)	13 to 19	6	5
iv)	19	8	6

B-5.6 Staggered Intermittent Fillet Welds

a) When staggered intermittent fillet welds are used, the clean spacing shall be considered the distance between two consecutive welds even though they are on opposite sides of the plate.

b) When the total aggregate length of the staggered intermittent fillet weld is 90 percent or more of the joint length, any odd number of weld segments may be used, provided:

1) Welds are placed at each end of the joint on one side, and

2) Clear spacing does not exceed 152 mm.

B-5.7 Plug and Slot Welds

a) Plug or slot welds may be used to transmit shear loading in a lap joint to prevent buckling or separation of lapped parts, or to join component parts of built up members except with quenched and tempered steel.

b) The effective area shall be the nominal area of the hole or slot in the plane of the faying surface.

c) The minimum diameter of the hole for a plug weld shall not be less than the thickness of the part containing it, plus 8 mm. The maximum diameter of the hole shall not be greater than 2 ¼ times the thickness of the weld.

B-6 WELD JOINT CATEGORIES

Different types of weld joint categories are given in Table 39.

B-6.1 Category I

Welded butt joints with complete joint penetration. The root of the first weld is chipped, gouged or ground to sound metal before making the second weld and the weld faces are ground or machined flush with the direction of metal removal parallel to the principal stress. Finished joints shall be non-destructively tested.

B-6.2 Category II

Welded butt or T-joints with complete joint penetration. The root of the first weld is chipped, gouged or ground to sound metal before making the second weld. Finished joints shall be non-destructively tested.

B-6.3 Category III

Complete joint penetration butt, T-joints and corner joint welded from both sides or from one side using a backing strip that is not removed after welding.

B-6.4 Category IV

Complete penetration butt, T-joints and corner joints, partial penetration butt, T-joints and corner joint welded on both sides, fillet welded lap, T-joints and corner joints welded on both sides.

B-6.5 Category V

Partial joint penetration butt, T-joints and corner joints and fillet, plug or slot welded up, T-joints and corner joints welded on one side only.

B-6.6 Category VI

Joints with no special welded groove preparation such as butt, T-joints corner, lap or edge joints, plug welds in joints, welds of secondary importance in strength and structural welded joints of secondary importance.

B-7 WELDING PROCESS

a) Square-groove weld butt joint (*B*), corner joint (*C*);

b) Square - groove weld T-joint (*T*), corner joint (*C*);

c) Single V-groove weld butt joint (*B*), corner joint (*C*);

d) Double V-groove weld butt joint (*B*);

Table 39 Classification of Welded Joints

(*Clause* B-6)

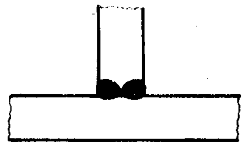
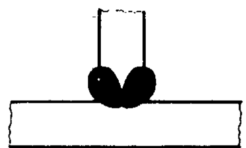
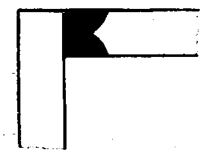
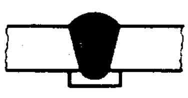
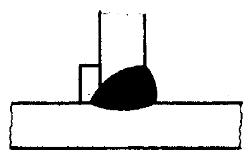
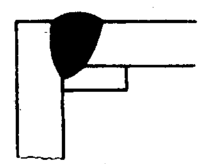
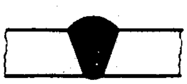
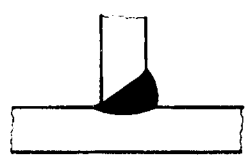
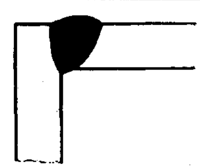
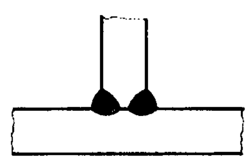
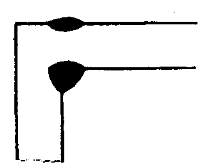
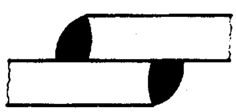
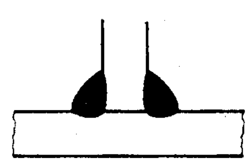
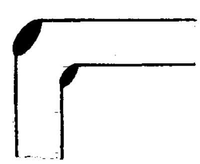
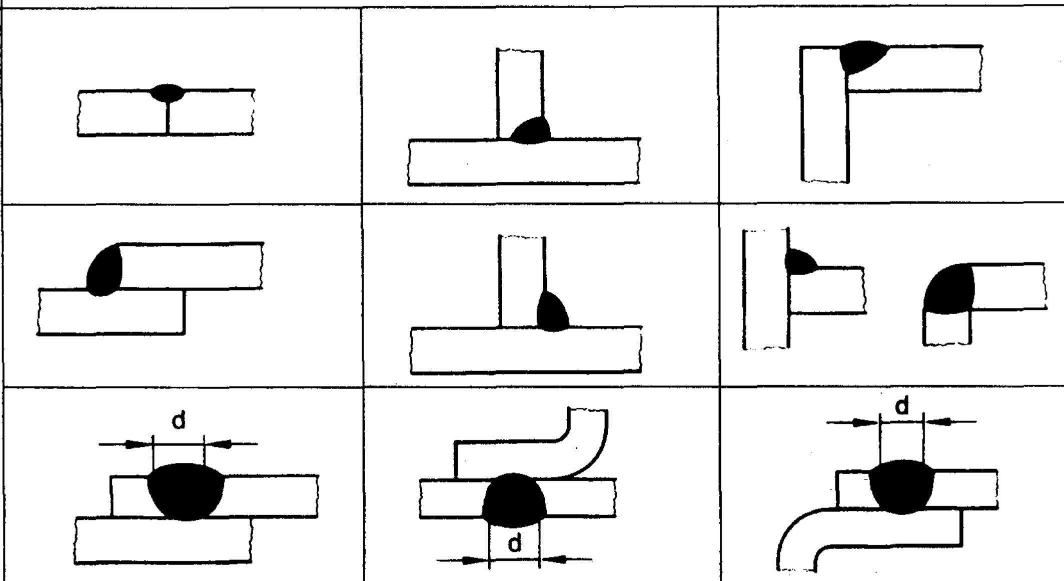
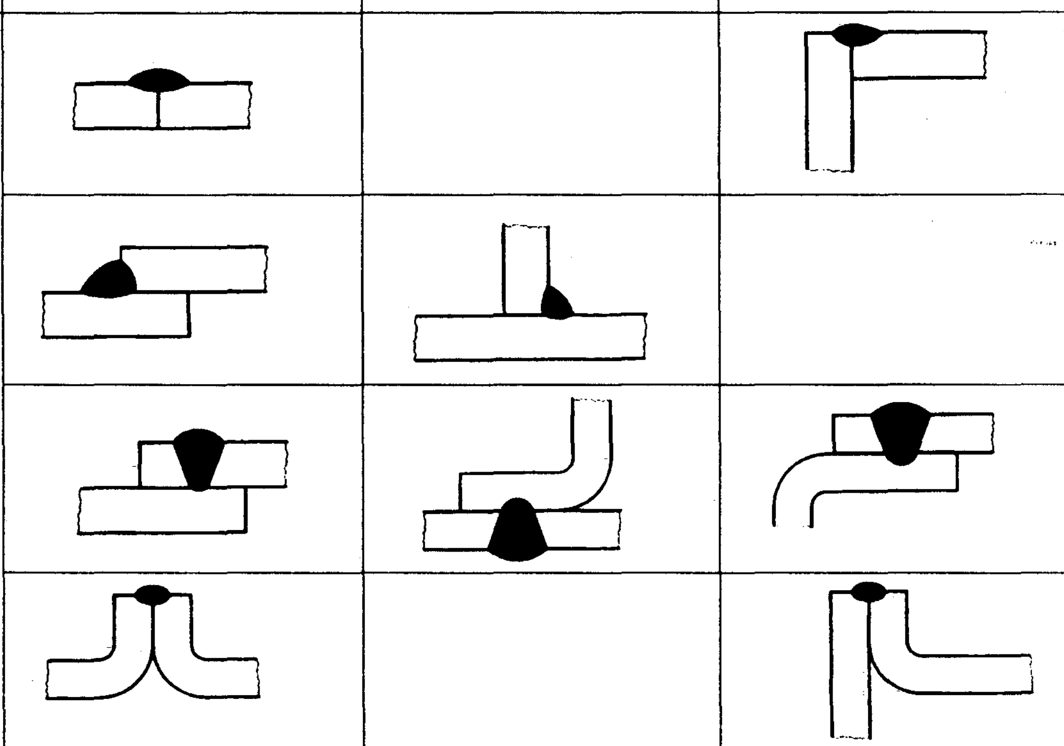
Category	Configuration of Welded Joints		
I			
II			
III			
			
IV			
			
			

Table 39 — *Continued*

Category	Configuration of Welded Joints
V	
VI	

NOTES

1 Details of weld joint (groove design, root opening, etc) are those required for the welding process to be used.

2 The diameters of plug welds or the width of slot welds is indicated by dimension '*d*'.

e) Single-bevel groove weld butt joint (*B*);

f) Single-bevel groove weld T-joint (*T*), corner joint (*C*);

g) Double -bevel groove weld butt joint T-joint, corner joint (*C*);

h) Single U-groove welds butt joint (*B*), corner joint (*C*);

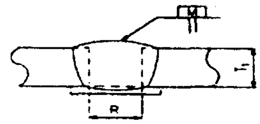
j) Single J-groove weld butt joint (*B*), T-joint (*T*), corner joint (*C*); and

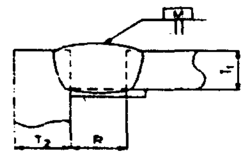
k) Double J-groove weld T-joint (*T*), corner joint (*C*), butt joint (*B*).

Some of various joints are given in Table 40.

Table 40 Square — Grooved Butt Joints (*B*)

(*Clause* B-7)





MILD STEEL

Square-groove weld Butt joint (*B*)

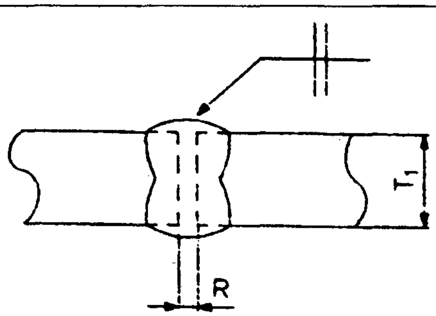
Corner joint (*C*)

Welding Process	Base Metal Thickness (U = Unlimited)		Groove Preparation			Permitted Welding Positions	Gas Shielding for FCAW
				Tolerances in mm			
	T_1 mm	T_2 mm	Root opening	As detailed	As fit up		
Sub-merged Metal Arc Welding (SMAW)	6, *Max*	—	$R = T_1$	+2, –0	+6, –2	All	—
Gas Metal Arc Welding (GMAW)	6, *Max*	U	$R = T_1$	+2, –0	+6, –2	All	—
Flux Cored Arc Welding (FCAW)	10, *Max*	—	$R = T_1$	+2, –0	+6, –2	All	Not required

Square — Groove Butt Joint

Square-groove weld

Butt joint (*B*)

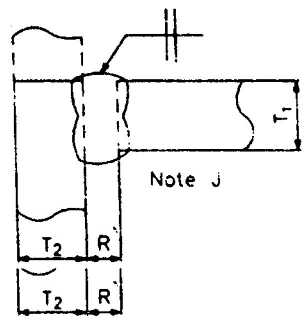


MILD STEEL

Welding Process	Base Metal Thickness (U = Unlimited)		Groove Preparation			Permitted Welding Positions	Gas Shielding for FCAW
				Tolerances in mm			
	T_1 mm	T_2 mm	Root opening	As detailed	As fit up		
Sub-merged Metal Arc Welding	6, *Max*	—	$R = T_1/2$	+2,0	+2, -3,5	All	—
Gas Metal Arc Welding Flux Cored Arc Welding	10, *Max*	—	R = 0-3.5	+2-0	+2, -3,5	All	Not required
Sub-merged Arc Welding (SAW)	12.5, *Max*	—	$R = 0$	±0	+2, -3,5	Flat	—

Square-Groove T-Joint (*T*) Corner Joint (*C*)

Square-groove weld
T- joint (*T*)
Corner joint (*C*)

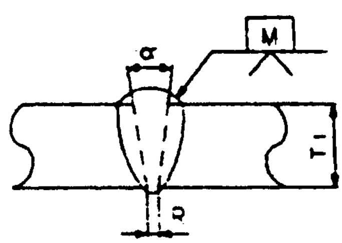


MILD STEEL

Welding Process	Base Metal Thickness (*U* = Unlimited)		Groove Preparation			Permitted Welding Positions	Gas Shielding for FCAW
			Tolerances in mm				
	T_1 mm	T_2 mm	Root opening	As detailed	As fit up		
Sub-merged Metal Arc Welding	6, *Max*	*U*	$R = T_1/2$	+2,0	+2, -3,5	All	—
Gas Metal Arc Welding Flux Cored Arc Welding	10, *Max*	*U*	R = 0 to 3.5	+2,0	+2, -3,5	All	Not required
Sub-merged Arc Welding	10, *Max*	*U*	$R = 0$	±0	+2, 0	Flat	—

Single V-Groove Butt Joint (*B*)

Single V-groove weld
Butt joint (*B*)
MILD STEEL

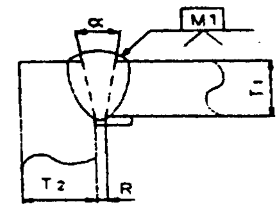


Tolerances	
As detailed	As fit up
R = +2 –0	+6 –2
α = +1 0°, –0°	+10°, –5°

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation		Permitted Welding Positions	Gas Shielding for FCAW
	T_1, mm	T_2, mm	Root Opening	Groove Angle		
Sub-merged Metal Arc Welding	*U*	—	$R = 6$	α = 45°	All	—
			$R = 10$	α = 30°	F,OH	—
			$R = 12.5$	α = 20°	F,OH	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U*	—	$R = 5$	α = 30°	F,V,OH	Required
			$R = 5$	α = 30°	F	Not required
			$R = 6$	α = 30°	V, OH	Not required
Sub-merged Arc Welding	2, *Max*	—	$R = 6$	α = 30°	F	—
Sub-merged Arc Welding	*U*	—	$R = 8$	α = 20°	F	—

Single V-Groove Corner Joint (*B*)

Single V-groove weld
Corner joint (*C*)
MILD STEEL

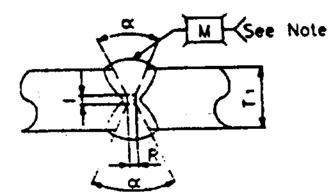


Tolerances	
As detailed	As fit up
R = +2 –0	+6 –2
α = +1 0°, –0°	+10°. –5°

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation		Permitted Welding Positions	Gas Shielding for FCAW
	T_1, mm	T_2, mm	Root Opening	Groove Angle		
Sub-merged Metal Arc Welding	*U*	*U*	*R* = 6	α = 45°	All	—
			R = 10	α = 30°	F, OH	—
			R = 12.5	α = 20°	F, OH	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U*	*U*	*R* = 5	α = 30°	F, V, OH	Required
			R = 10	α = 30°	F	Not required
			R = 6	α = 30°	V, OH	Not required
Sub-merged Arc Welding	12.5, *Max*	*U*	*R* = 6	α = 30°	F	—
Sub-merged Arc Welding	*U*	*U*	*R* = 16	α = 20°	F	—

Double V-Groove Butt Joint (*B*)

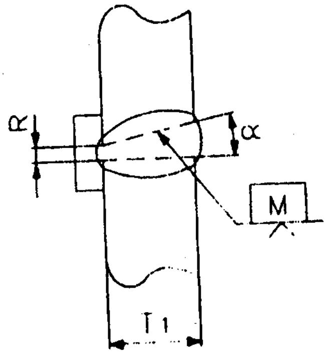
Double V-groove weld
Butt joint (*B*)
MILD STEEL



Tolerances	
As detailed	As fit up
R = 0	= 6. –0
f = ±0	1.5. –0
α = +10°, –0°	+10°. –5°
= ±0	+1.5. –0

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation			Permitted Welding Positions	Gas Shielding for FCAW
	T_1, mm	T_2, mm	Root Opening	Root Face	Groove Angle		
Sub-merged Metal Arc Welding	*U* preferably 16 or thicker spacer = 3 × *R*	—	*R* = 6	*f* = 0 to 3	α = 45°	All	—
			R = 10	*f* = 0 to 3	α = 30°	F, OH	—
			R = 12.5	*f* = 0 to 3	α = 20°	F, OH	—
Sub-merged Arc Welding	*U* spacer = 6 × *R*	—	*R* = 16	*f* = 0 to 6	α = 20°	F	—

Single-Bevel Groove Butt Joint (*B*)

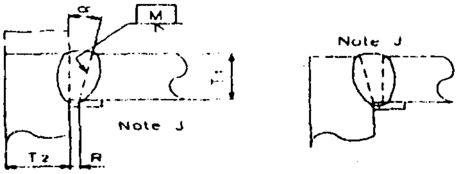
Single-bevel groove weld Butt joint (*B*) MILD STEEL	Tolerances	
	R = +1.5, 0 α = +10°, −0°	+6, −1.5 +10°, −5°

Welding Process	Base Metal Thickness		Groove Preparation		Permitted Welding Positions	Gas Shielding for FCAW
	T_1, mm	T_2, mm	Root Opening	Groove Angle		
Sub-merged Metal Arc Welding	U	—	$R = 6$	$\alpha = 45°$	All	—
			$R = 10$	$\alpha = 30°$	F,OH	—
Gas Metal Arc Welding Flux Cored Arc Welding	U	—	$R = 5$	$\alpha = 30°$	All	Required
			$R = 6$	$\alpha = 45°$	All	Required
			$R = 10$	$\alpha = 30°$	Flat	Not required

Single-Bevel Groove T-Joint (*T*) and Corner Joint (*C*)

(*Clause* B-7)

Single-bevel groove weld
T-joint (*T*)
Corner Joint (*C*)



MILD STEEL

Tolerances	
As detailed	As fit up
R = +1.5, 0	+6, −1.5
α = +10°, −0°	+10°, −5°

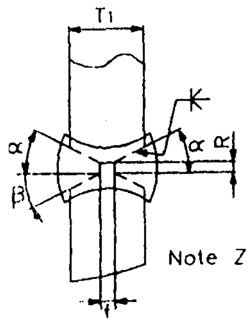
Welding Process	Base Metal Thickness		Groove Preparation		Permitted Welding Positions	Gas Shielding for FCAW
	T_1	T_2	Root Opening mm	Groove Angle		
Sub-merged Metal Arc Welding	*U*	*U*	$R = 6$	$\alpha = 45°$	All	
			$R = 10$	$\alpha = 10°$	* F, OH	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U*	*U*	$R = 5$	$\alpha = 30°$	All	Required
			$R = 10$	$\alpha = 30°$	Flat	Not required
			$R = 6$	$\alpha = 45°$	All	Not required
Sub-merged Arc Welding	*U*	*U*	$R = 10$	$\alpha = 30°$	Flat	—
			$R = 6$	$\alpha = 45°$		

* *F* = Flat, *OH* = Overhead

Double-Bevel Groove Butt Joint (*B*)

(*Clause* B-7)

Double-bevel groove weld
Butt joint (*B*)

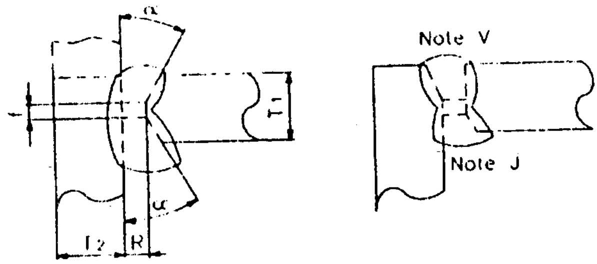


Welding Process	Base Metal Thickness		Groove Preparation			Permitted Welding Positions	Gas Shielding for FCAW
			Root Opening Root Face Groove Angle	Tolerances			
	T_1	T_2		As detailed	As fit up		
Sub-merged Metal Arc Welding	*U* Preferably 16 or thicker	—	R = 0 to 3	1.5, −0	1.5,-3	All	—
			f = 0 to 3	1.5, −0	not limited		
			$\alpha = 45°$				
			β = 0° to 15°	$\alpha + \beta$, + 10°, −0°	$\alpha + \beta$, +10°, −0°		
Gas Metal Arc Welding Flux Cored Arc Welding	*U* Preferably 16 or thicker	—	R = 0 to 3	1.5, −0	1.5, −0	All	Not required
			f = 0 to 3	1.5, −0	Not limited		
			$\alpha = 45°$	+10°, −5°	+10°, −5°		
			$\beta = 0°$	±0°	—		

Double-Bevel Groove T-Joint (*T*) and Corner Joint (*C*)

(*Clause* B-7)

Double-bevel groove weld
T-joint (*T*)
Corner joint (*C*)

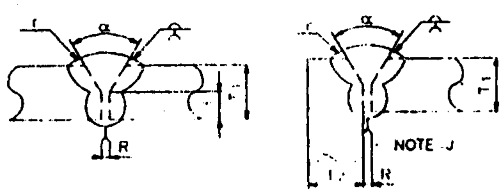


Welding Process	Base Metal Thickness		Groove Preparation			Permitted Welding Positions	Gas Shielding for FCAW
	T_1	T_2	Root Opening Root Face Groove Angle	Tolerances: As detailed	Tolerances: As fit up		
Sub-merged Metal Arc Welding	*U* Preferably 16 or thicker	—	*R* = 0 to 3 *f* = 0 to 3 α = 45°	1.5, –0 1.5, –0 +10°, -0°	1.5, –3 not limited +10°, –5°	All	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U* Preferably 16 or thicker	—				All	Not required
Sub-merged Arc Welding	*U*	*U*	*R* = 0 to 3 *f* = 5, Max α = 60°	±0 +0, –5 +10°, –0°	+6, –0 ±1.5 +10°, –5°	All	Not required

Single U-Groove Butt Joint (*B*) and Corner Joint (*C*)

(*Clause* B-7)

Single U-groove weld
Butt joint (*B*)
Corner joint (*C*)



Tolerances: As detailed	Tolerances: As fit up
R = +1.5, 0	+6, –1.5
α = +10°, –0°	+10°, –5°
f = ±1.5	Not limited
R = +6, –0	+1.5

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation				Permitted Welding Positions	Gas Shielding for FCAW
	T_1	T_2	Root Opening	Root Face	Groove Angle	Groove Radius		
Sub-merged Metal Arc Welding	*U*		*R* = 0 to 3	*f* = 3	α = 45°	*r* = 6	All	—
			R = 0 to 3	*f* = 3	α = 20°	*r* = 6	* F, OH	—
	U		*R* = 0 to 3	*f* = 3	α = 45°	*r* = 6	All	—
			R = 0 to 3	*f* = 3	α = 20°	*r* = 6	F,OH	—
Gas Metal Arc Welding	*U*	*U*	*R* = 0 to 3	*f* = 3	α = 20°	*r* = 6	All	Not required
Flux Cored Arc Welding	*U*	*U*	*R* = 0 to 3	*f* = 3	α = 20°	*r* = 6	All	Not required

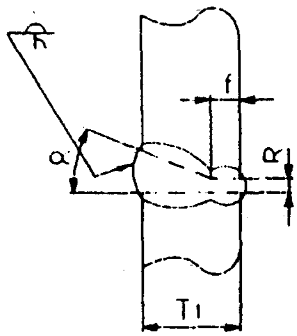
* *F* = Flat, *OH* = Overhead

Single J-Groove Butt Joint (*B*)

(*Clause* B-7)

Single J-groove weld

Butt joint (*B*)



Tolerances	
As detailed	As fit up
R = +1.5, –0	+1.5, –3
α = +10°, –0°	+10°, –5°
f = 1.5, –0	Not limited
r = +6, –0	±1.5

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation				Permitted Welding Positions	Gas Shielding for FCAW
	T_1	T_2	Root Opening	Root Face	Groove Angle	Groove Radius		
Sub-merged Metal Arc Welding	*U*	—	*R* = 0 to 3	*f* = 3	α = 45°	*r* = 10	All	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U*	—	*R* = 0 to 3	*f* = 3	α = 30°	*r* = 10	All	Not required

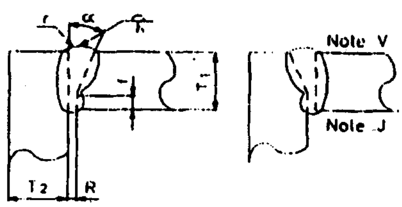
Single J-Groove T-joint (*T*) and Corner Joint (*C*)

(*Clause* B-7)

Single J-groove weld

T-joint (*T*)

Corner joint (*C*)



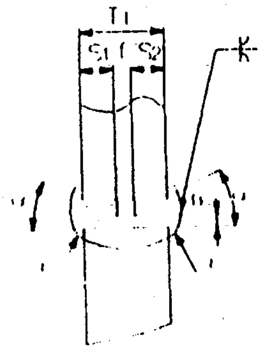
Tolerances	
As detailed	As fit up
R = +1.5, –0	+1.5, –3
α = +10°, –0°	+10°, –5°
f = 1.5, –0	Not limited
r = +6, –0	±1.5

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation				Permitted Welding Positions	Gas Shielding for FCAW
	T_1	T_2	Root Opening	Root Face	Groove Angle	Groove Radius		
Sub-merged Metal Arc Welding	*U*	*U*	*R* = 0 to 3 *R* = 0 to 3	*f* = 3 *f* = 3	α = 45° α = 30°	*r* = 10 *r* = 10	All * F, OH	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U*	*U*	*R* = 0 to 3	*f* = 3	α = 30°	*r* = 10	All	Not required

* *F* = Flat, *OH* = Overhead

Double J-Groove Butt Joint (*B*)

(*Clause* B-7)

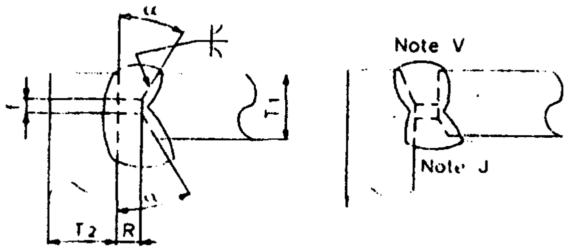
Double J-groove weld Butt joint (*B*)	Tolerances	
	As detailed	As fit up
	R = +1.5, –0	+1.5, –3
	α = +10°, –0°	+10°, –5°
	f = 1.5, –0	Not limited
	r = +6, –0	±1.5

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation				Permitted Welding Positions	Gas Shielding for FCAW
	T_1	T_2	Root Opening	Root Face	Groove Angle	Groove Radius		
Sub-merged Metal Arc Welding	*U* Preferably 16 or thicker	*U*	*R* = 0 to 3	*f* = 3	α = 45°	*r* = 10	All	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U* Preferably 16 or thicker	—	*R* = 0 to 3	*f* = 3	α = 30°	*r* = 10	All	Not required

Double J-Groove T-Joint (*T*) and Corner Joint (*C*)

(*Clause* B-7)

Double J-groove weld
T-joint (*T*)
Corner joint (*C*)



Tolerances	
As detailed	As fit up
R = +1.5, –0	+1.5, –3
α = +10°, –0°	+10°, –5°
f = 1.5, –0	Not limited
r = +6, –0	±1.5

Welding Process	Base Metal Thickness (*U*=Unlimited)		Groove Preparation				Permitted Welding Positions	Gas Shielding for FCAW
	T_1	T_2	Root Opening	Root Face	Groove Angle	Groove Radius		
Sub-merged Metal Arc Welding	*U* Preferably 16 or thicker	—	R = 0 to 3	f = 3	α = 45°	r = 10	All	—
			R = 0 to 3	f = 3	α = 30°	r = 10	*F, OH	—
Gas Metal Arc Welding Flux Cored Arc Welding	*U* Preferably 16 or thicker	—	R = 0 to 3	f = 3	α = 30°	r = 10	All	Not required

* *F* = Flat, *OH* = overhead.

B-7.1 Tolerances for Groove Weld Joint Preparations for Arc Welding

Some joint preparations are shown in Fig. 30 and tolerances given in Table 41.

B-8 CONTROL OF DISTORTION AND SHRINKAGE STRESSES

a) Procedure and welding sequence for assembling and joining parts of a structure or of built-up members or for welding reinforced parts to members shall be designed to minimize distortion and shrinkage.

b) All welds, in so far as practicable, shall be deposited in a sequence that will balance the applied heat while welding progresses.

c) A programme for welding sequence and distortion control shall be provided where shrinkage stresses or distortions are likely to affect the adequacy of the structure.

d) Joints that are expected to produce large shrinkage should usually be welded with as little restraint as possible before other joints that are expected to cause less shrinkage are welded.

B-9 NOMINAL NUMBER OF LOADING CYCLES

For different type of stress category, the loading cycles are given in Table 42.

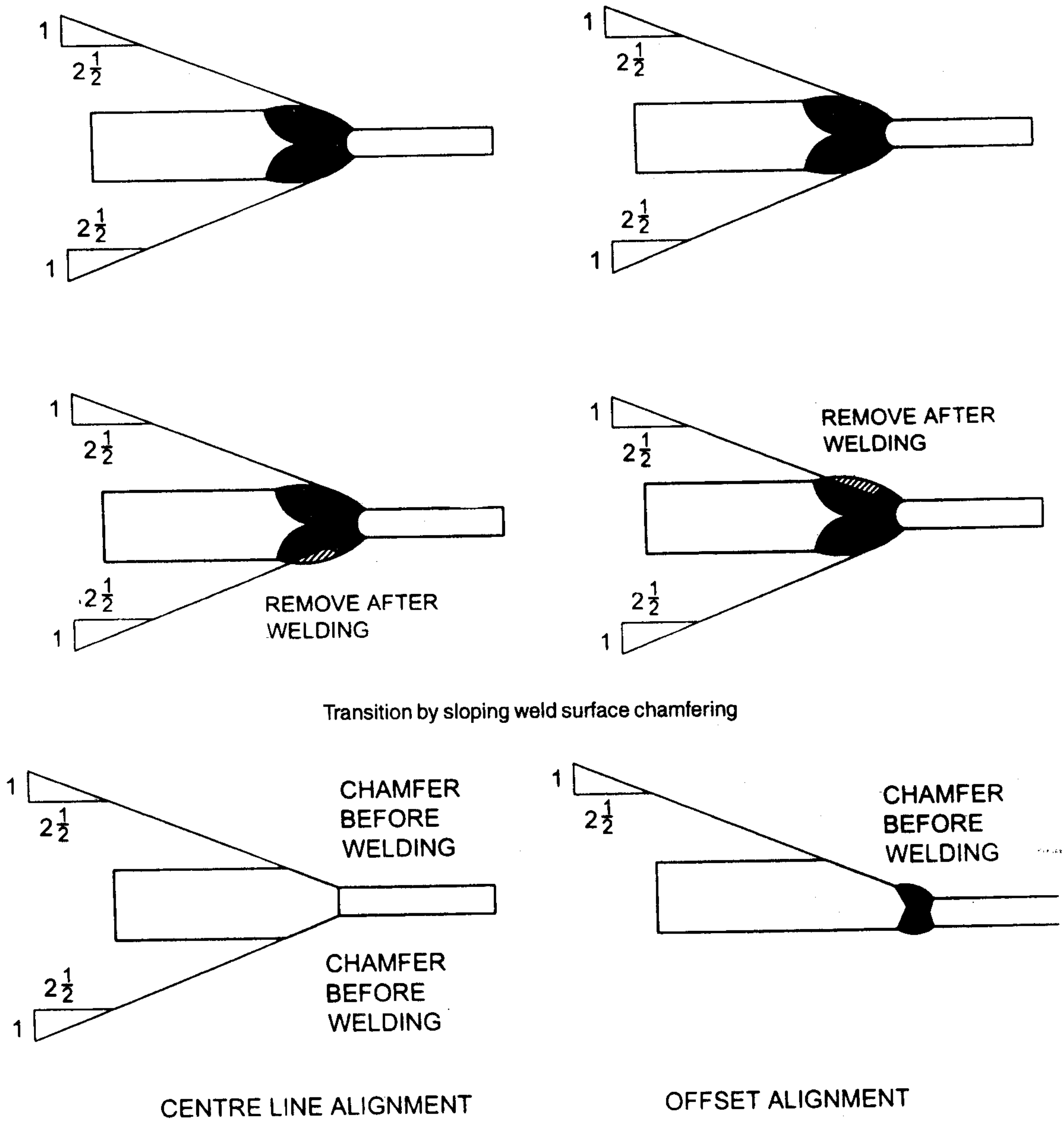


FIG. 30 TRANSITION BY CHAMFERING THICKNESS PART

Table 41 Tolerances for Groove Weld Joint Preparation for Arc Welding

(*Clause* B-7.1)

Sl No.	Weld Preparations	Root not Gouged mm	Root Gouged mm
(1)	(2)	(3)	(4)
i)	Root face	± 1.5	Not limited
ii)	Root opening with other than steel backing	± 1.5	+ 1.5
iii)	Root opening with steel backing	+ 6	Not applicable
iv)	Groove angle	+ 5°	+ 10° – 5°

Table 42 Allowable Range of Stress (MPa)

(*Clause* B-9)

Sl No.	Stress Category	10 000 to 20 000	100 000 to 500 000	500 000 to 2 000 000	Over 2 000 000
(1)	(2)	(3)	(4)	(5)	(6)
i)	A	276	221	166	166
ii)	B	228	172	117	103
iii)	C	193	145	96	83
iv)	D	166	117	69	62
v)	E	117	83	48	41
vi)	F	117	96	76	62

ANNEX C

(*Foreword*)

COMMITTEE COMPOSITION

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This Indian Standard has been developed from Doc : No. ME 14 (0422).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at New India Printing Press, Khurja, India