

SECTION-IVA

TOWER DESIGN

**(Applicable for Transmission Lines
wherein Tower Design is in Contractor's
scope)**

TECHNICAL SPECIFICATIONS

SECTION-IV A

TOWER DESIGN

Revision History

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TECHNICAL SPECIFICATIONS

SECTION-IV A

TOWER DESIGN

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TECHNICAL SPECIFICATIONS

SECTION- IV A

TOWER DESIGN

1.1 Transmission Tower

The general description of towers applicable for the package and technical particulars thereof are indicated in Section-I of this Specification.

1.2 Tower Extensions

1.2.1 The towers shall be designed so as to be suitable for adding - 3.0m/+0m/+3.0m/+6.0m/+9.0m/+12m/+15m/+18m/+25m body truncations/ extensions/leg extensions for maintaining adequate ground clearances without reducing the factor of safety (actual stress / allowable stress) available for the members of tested extensions to the extent possible.

The towers shall be designed so as to be suitable for adding body truncations/ extensions/leg extensions for maintaining adequate ground clearances without reducing the factor of safety (actual stress / allowable stress) available for the members of tested extensions to the extent possible as per the following:

1) -3.0m/+0m/+3.0m/+6.0m/+9.0m for all types of towers as specified in relevant section of technical specification.

2)+12m/+15m/+18m/+25m for all types of towers except tangent tower/tower type A/DA/QA as specified in relevant section of technical specification.

Contractor shall be required to develop Structural drawing, BOM and shop sketches for all the above body extensions and leg extensions and submit the same for approval of Employer, irrespective of the actual requirement at site. However, delay in submission/approval of documents pertaining to extensions which are not required for project execution, shall not be considered for Liquidated damages (LD) calculation. Charges for the same are deemed to be included in the quoted prices.

1.2.2 For Power Line Crossing or any other obstacle, tower types B/DB/QB, C/DC/QC and D/DD/QD can be used with +12m/ +15m/ +18m/ +25m extensions depending upon the merit of the prevailing site condition (as per relevant Clause of Section-III). The maximum reduced spans for A/DA/QA, B/DB/QB, C/DC/QC and D/DD/QD type towers shall be mentioned in the tower spotting data prepared by contractor based on design. However, this shall, in no case be less than 250 meters. Further, if extension above +25m (i.e. +30/+35/+55m) is required for tower type D/DD/QD, and base width at +55m extension level is more than 35m, than a new tower with narrow base (DN/DDN/QDN) shall be designed for the same. The new narrow base tower shall be designed with base width not more than 35m with Reliability level-3 loading, having span and angle of deviation combination as mentioned below. However, for profiling, stringing, design of foundation, wind

pressure/wind load/Tension/etc. shall be corresponding to the reliability level as mentioned in the relevant section of technical specification for which the transmission line is designed. Extension above +25m shall also be equipped with ladder and platform arrangement as mentioned for special river crossing tower at clause 1.3.1 of Section-IVC Technical specification (ladder and platform arrangement sketch enclosed in drawing section of this specification). Power Line crossing shall be done as described in Section-III.

Design details for DN/DDN/QDN tower

Sl No	Type of Tower	Deviation Limit	Typical Use
1	DN/DDN/QDN	30 – 60 deg.	a. Angle tower with tension insulator string.
			b. Also to be used for uplift forces resulting from an uplift span up to 300m under broken wire condition.
			Dead end with 0 deg to 15 deg deviation both on line side and sub-station side (slack span)
		0 deg.	a. Complete Dead end b. For river crossing anchoring with longer wind span

Span details for DN/DDN/QDN tower

Sl. no.	Tower Type	Wind Span (m)	Weight Span			
			Normal Condition		Broken wire condition	
			Maximum (m)	Minimum (m)	Maximum (m)	Minimum (m)
i)	DN/D DN/Q DN	250	1000	600	0	-300

- 1.2.3 For 400kV and above voltage level lines, the B/DB, C/DC, and D/DD towers shall be designed for providing unequal leg extensions from -3.0m/+0m/+3.0m/+6.0m/+9.0m with maximum difference between the shortest and the longest leg of 3m and in specific cases have 6m maximum leg differential. These unequal leg extensions to be provided in the design shall be used during tower spotting/ execution stage to optimize the benching / revetment requirement besides use of suitable chimney extensions. In situations where difference in leg differential does not suit the standard unequal leg extension provisions on the tower mentioned above, suitable chimney extensions can be provided to reduce benching/ revetment requirement.

For 132 kV & 220 kV voltage level lines as well as A/DA/QA type tower of 400 kV & above voltage level lines, the towers shall not be designed for unequal leg extension. However, during execution of the project, suitable chimney extension and/or unequal leg extension shall be used on case-to-case basis considering the actual site condition. The contractor shall submit the proposal for approval of the Employer. For unequal leg extension of these towers, either the same may be considered for use with reduced spans or suitable changes in the design shall be made by the contractor. The design charges for these unequal leg extension towers shall be deemed to be included in the contract price. The charges for the towers shall be paid on pro-rata basis derived from the rates indicated in price schedule of Contract Agreement and final approved weight of the corresponding standard (+ 0m) tower.

- 1.2.4 In situations where difference in leg differential does not suit the standard unequal leg extension provisions on the towers mentioned above, suitable chimney extensions shall be provided to reduce benching/ revetment requirement.
- 1.2.5 The leg extensions, unequal leg extensions, chimney extensions and/ or a combination of these suitable for a tower location shall be selected on the basis of techno-economics evaluation.
- 1.2.6 All above body/ leg extension provisions to towers shall be treated as part of normal tower only.
- 1.2.7 The payment for leg extensions, not specified in BPS, shall be on pro-rata basis derived from the rates indicated in price schedule of Contract Agreement and final approved weight of the corresponding standard (+ 0m) tower. The payment for the new narrow base tower (DN/DDN/QDN) (if not specified in BPS) shall be on the pro-rata basis derived from the rates indicated in price schedule of Contract Agreement and final approved weight of the standard D/DD/QD (+ 0m) tower.
- 1.2.8 During execution, if other types of towers/ structures viz. Gantry, single circuit/ Multi circuit towers in Double circuit line, Double circuit/ Multi-circuit towers in a Single circuit line, Single circuit/ Double circuit towers in a Multi-circuit line, Narrow base towers, Towers of higher extensions (viz. +43m/ +55 m for 765 kV D/C lines wherever applicable), Transposition tower, Towers of different configuration etc. are required, for which design is not in the scope of Contractor, fabrication and installation of these items shall be carried out by the contractor as per Employer supplied design/drawings. If Employer designed towers are not covered in the BPS, payment for these shall be made on the basis of per MT rate(s) derived from the rate(s) contained in the Contract for A+0/DA+0/QA+0 m tower as the case may be.
- 1.2.9 **Gantry structures/ Towers with higher extensions/ Special River Crossing Towers/ Multi Circuit Towers Specified in BPS**

The Bidder shall quote for supply, transportation & installation of towers as well as installation of Stub & Foundations for Gantry structures/ Towers with higher extensions (viz. +43m/ +55 m for 765kV D/C lines wherever applicable)/ Special River Crossing Towers/ Multi Circuit Towers/Transposition tower, based on the Bill of Quantities (BOQ) furnished in the Bid Proposal Sheet (BPS). However, the payment will be made as per actual quantity executed as per Employers' supplied design & drawing and the quoted unit rates.

1.2.10 Towers for Major Crossings

B/DB/QB, C/DC/QC & D/DD/QD towers shall also be used with suitable modifications for very long spans (spans more than that of given in clause 1.3 which cannot be crossed by normal tower with extensions as given in *clause.no.1.2.3* like Major river crossings etc. These Towers shall be developed by strengthening the above B/DB/QB, C/DC/QC and D/DD/QD type towers as per the site requirement. Additional weight of tower due to strengthening shall be paid on pro-rata basis derived from the rates indicated in price schedule of Contract Agreement and final approved weight of the standard (+0m) tower.

1.3 Spans

1.3.1 Design Span or Normal Span

The design Span or normal ruling span of the line of different voltage level is given in Table 1.3.1 below:

Table: 1.3.1: Design Span or Normal Ruling Span

Sl. No.	Voltage Level of Transmission Line	Design Span or Normal Ruling Span
A)	400 kV, 765 kV, ± 500 kV HVDC and ± 800 kV HVDC	400 meters
B)	220 kV	350 meters
C)	132 kV	320 meters

1.3.2 Wind Span

The wind span is the sum of the two half spans adjacent to the tower under consideration. For normal horizontal spans, this equals to normal ruling span.

1.3.3 Weight span

The weight span is the horizontal distance between the lowest point of the conductor on the two spans adjacent to the tower. For spotting of structures, the span limits are given in Table 1.3.2 below:

Table: 1.3.2: Weight Span

Sl. no.	Tower Type	Normal Condition		Broken wire condition	
		Maximum (m)	Minimum (m)	Maximum (m)	Minimum (m)
A)	400 kV, 765 kV, \pm500 kV HVDC and \pm800 kV HVDC line				
i)	A/DA/QA	600	200	360	100
ii)	B/DB/QB, C/DC/QC	600	0	360	-200
iii)	D/DD/QD	600	0	360	-300
iv)	Dead End condition for D/ DD/QD	300	0	60	0
v)	Dead End with Slack Span condition for D/DD/QD	450	0	330	-300
B)	220 kV line				
i)	A/DA/QA	525	200	315	100
ii)	B/DB/QB, C/DC/QC	525	0	315	(-) 200
iii)	D/DD/QD	525	0	315	(-) 300
iv)	Dead End condition for D/ DD/QD	263	0	53	0
v)	Dead End with Slack Span condition for D/DD/QD	413	0	300	(-) 300
C)	132 kV line				
i)	A/DA/QA	480	200	300	100
ii)	B/DB/QB, C/DC/QC	480	0	310	(-) 200
iii)	D/DD/QD	480	0	310	(-) 300
iv)	Dead End condition for D/ DD/QD	240	0	48	0
v)	Dead End with Slack Span condition for D/DD/QD	390	0	270	(-) 300

1.3.4 In case at certain locations where actual spotting spans exceed the design spans and cross-arms & certain members of towers are required to be modified/

reinforced, in that case design, structural & shop drawings for the modified/reinforced towers will be prepared by the Contractor as per the requirement on the basis of approved line diagram without any additional financial implications to the Employer for the design and drawings.

1.4 Electrical Clearances

1.4.1 Ground Clearance

The minimum ground clearance from the bottom conductor at maximum sag conditions i.e. at max. operating temperature and still air shall be as indicated in *Section-IA* of TS.

1.4.2 Live Metal Clearance

The minimum live metal clearance to be provided between the live parts and steel work of superstructure shall be as given in Tables below

For 765kV S/C (Vertical Delta)/ 765kV D/C transmission lines:

Wind pressure Condition	Minimum electrical clearance
A. For "I" Suspension Insulator Strings (for A/DA Tower):	
1. 0° Swing	6100 mm (For D/C) 5600 mm (for S/C)
2. 25° Swing	4400 mm
3. 55° Swing	1300 mm
B. For Jumpers in tension insulator strings (with or without Pilot)	
1. 0° Swing	6100 mm (For D/C) 5600 mm (for S/C)
2. 25° Swing	4400 mm
3. 55° Swing	1300 mm

For 765kV D/C, Pilot insulator strings are to be used for D/DD/QD towers and C/DC/QC towers only. For D/DD/QD towers, maximum two (2) nos. of pilot strings per phase and for C/DC/QC towers, maximum one (1) no. of pilot string per phase shall be permissible.

For 765kV S/C (Vertical Delta), Pilot Insulator Strings (maximum two (2) nos.) are to be used in the top cross-arm for all Vertical Delta tension towers (as per indicative sketch enclosed in the technical specification). Only for D type towers, Pilot insulator strings (maximum two (2) nos.) are also to be used in the bottom cross-arm.

For 765kV S/C (Horizontal Configuration) transmission lines:

Wind pressure Condition	Minimum electrical clearance
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A. For "I" Suspension Insulator Strings (for A type Tower):	
1. 0° Swing	5600 mm
2. 25° Swing	4400 mm
3. 55° Swing	1300 mm
B. For "I" Suspension Insulator Strings (for B type Tower):	
1. 20° Swing	5600 mm
2. 41° Swing	4400 mm
3. 64° Swing	1300 mm
C. For Jumpers in tension insulator strings (with I pilot or without Pilot)- for C type towers	
1. 15° Swing	5600 mm
2. 25° Swing	4400 mm
3. 40° Swing	1300 mm
D. For Jumpers in tension insulator strings (with I pilot or without Pilot)- for D type towers	
1. 20° Swing	5600 mm
2. 30° Swing	4400 mm
3. 40° Swing	1300 mm
E. For V string used in Central phase of Tower type A & B and V-Pilot string used in Central phase of Tower type C & D	
To boom frame	5100 mm
To window frame	5600 mm

I Pilot string (maximum one (1) no.) shall be used in outer phases of only Tower type C & D

V Pilot string (maximum one (1) no.) shall be used in central phase of only Tower type C & D

For 400kV transmission lines:

Wind pressure Condition	Minimum electrical clearance
A. For Single Suspension Insulator Strings	
1. 0° Swing	3050 mm
2. 22° Swing	3050 mm
3. 44° Swing	1860 mm
B. For Jumpers in tension insulator strings	
1. 0° Swing	3050 mm
2. 25° Swing	3050 mm
3. 40° Swing	1860 mm
C. For Pilot insulator strings	

1. 0° Swing	3050 mm
2. 15° Swing	3050 mm

The pilot insulator strings are to be used for D/DD /QD towers only. Maximum two (2) nos. of pilot strings/ phase shall be permissible in case of 400kV (Quad) transmission lines and Maximum one (1) nos. of pilot strings/ phase shall be permissible in case of 400kV (Twin) transmission lines

For 220 kV transmission lines:

The minimum live metal clearances for 220 kV D/C transmission lines shall be considered as follows:

- (i) Under stationary conditions
From tower body: 2.13 m
- (ii) Under swing conditions

Wind pressure Condition	Minimum electrical clearance
For "I" Suspension Insulator Strings	
1. 0° Swing	2130 mm
2. 15° Swing	1980 mm
3. 30° Swing	1830 mm
4. 45° Swing	1675 mm
For Jumpers in tension insulator strings	
Without Pilot	
1. Swing angle 0°	2130 mm
2. Swing angle 10°	2130 mm
3. Swing angle 20°	1675 mm
With Pilot	
1. Swing angle 0°	2130 mm
2. Swing angle 10°	2130 mm
3. Swing angle 15°	1980 mm

The pilot insulator strings are to be used for D/DD /QD towers only (maximum one (1) no. per phase).

For 132 kV transmission lines:

The minimum live metal clearances for 132 kV transmission lines shall be considered as follows:

- (i) Under stationary conditions
From tower body: 1530 mm
- (ii) Under swing conditions

Wind pressure Condition	Minimum electrical clearance
For "I" Suspension Insulator Strings	
1. Swing angle (15°)	1530 mm
2. Swing angle (30°)	1370 mm
3. Swing angle (45°)	1220 mm
4. Swing angle (60°)	1070 mm
For Jumpers in tension insulator strings (without Pilot)	
1. Swing angle (0°)	1530 mm
2. Swing angle (10°)	1530 mm
3. Swing angle (20°)	1070 mm
4. Swing angle (30°)	1070 mm

Pilot (s) is not to be considered for Jumper Swing

The bidder is permitted to adopt separate cross arm for D/DD/QD type towers under dead end conditions provided adequate live metal clearance is available with at least 15° angle on both sides i.e. line side and slack span side, and also provided that all the specified conditions of the specification are fulfilled.

For 765kV S/C Vertical Delta Tension Towers, provisions shall be made so that the top cross arm can be attached to either side of the tower body.

- 1.4.3 Bidder shall adopt same cross arm design where jumper is projecting outside of cross-arm for D/DD/QD type tower, used as dead end and angle tower.
- 1.4.4 For computing the live metal clearances, the dimensions of strings shall be taken from the drawings enclosed. The design of the tower shall be such that it should satisfy all the above conditions when clearances are measured from any live point of the strings.
- 1.4.5 Cross arm projections for Dead end towers shall be fixed in such a way that it can accommodate a condition of 15degree deviation of conductors towards tower at

both Left and Right-side cross arms on slack span side and 0-15 degrees deviation on line side.

1.4.6 For Dead End Tower design conditions, following wind span is to be considered:

Wind Span for Dead End

Tower Type	Normal Condition	Broken wire condition
For 765kV & 400kV		
Dead End	200	40
Dead End with Slack Span	300	220
For 220kV		
Dead End	175	35
Dead End with Slack Span	275	195
For 132kV		
Dead End	160	32
Dead End with Slack Span	260	180

1.4.7 **Angle of Shielding**

The angle of shielding is defined as the angle formed by the line joining the centre lines of the earthwire/OPGW and outer power conductor in still air at tower supports, to the vertical line through the centre line of the earthwire. Bidders shall design the tower in such a way that the angle of shielding does not exceed the value given in the table below. The drop of the earthwire clamp equal to 150 mm should be considered while calculating the minimum angle of protection:

Sl. No.	Voltage Level of Transmission Line	Angle of Shielding
A)	765 kV D/C \pm 500 kV HVDC and \pm 800 kV HVDC line	10 ⁰
B)	765 kV S/C and 400 kV line	20 ⁰
C)	220 kV and 132 kV line	30 ⁰

1.4.8 **Mid Span Clearance**

The minimum vertical mid span clearance between the earthwire/OPGW and the nearest power conductor shall not be less than the value given below, which shall mean the vertical clearance between earthwire/OPGW and the nearest conductor under all temperatures and still air condition in the normal ruling span. Further, the tensions of the earthwire/ OPGW and power conductor shall be so co-

ordinated that the sag of earthwire/ OPGW shall be at least 10% less than that of power conductors under all temperature loading conditions.

Sl. No.	Voltage Level of Transmission Line	Mid Span Clearance
A)	± 800 kV HVDC	12000 mm
B)	400 kV, 765 kV and ± 500 kV HVDC	9000 mm
C)	220 kV	8500 mm
D)	132 kV	6100 mm

1.4.9 Tower Loading Conditions:

- I) The design of towers shall be carried out by the Contractor as per IS 802 (Part 1/section-1)2015* except for drag coefficients which shall be as per IS 802 (Part 1/section-1) 1995 and considering Wind Zone as per Section-I of the TS.
- II) Terrain category shall be considered as 2, unless otherwise mentioned in Section-1A.
- III) Reliability level shall be considered as 1 for 132kV, 220kV & 400 kV (twin bundle conductor) and 2 for triple & quadruple circuit towers and towers with more than two sub-conductors per phase upto 400 kV & 765 kV towers.
- IV) Contractor shall offer tower/ foundation design considering the type of conductor, being supplied by them under the package and the conductor, earthwire & OPGW properties as per those mentioned in the respective sections.
- V) Under broken wire condition, tower shall be designed considering transverse load based on maximum angle of deviation and longitudinal load based on minimum angle of deviation mentioned in **Section-I** of Technical specifications.
- VI) To take care of cyclonic wind loading, design of towers in coastal areas (wherever mentioned in BPS), shall be carried out considering design wind speed based on multiplying an additional factor $K_4 = 1.3$ to the reference wind speed. The increased wind pressure so calculated, shall be applied to Tower structure only and normal wind as per IS 802 shall be applied on Conductor/Earthwire/OPGW/Insulator.

Further, the provisions for Narrow front wind loading condition shall remain as per IS 802 and no any additional coastal factor shall be considered.

* Note:

- i) As per Clause 12.1.2.1 b) 2) of IS 802:2015 & AMENDMENT NO. 1 MARCH 2024 , Under security condition for tension and dead end towers, the transverse loads due to line deviation shall be the component of 100 percent mechanical tension of conductor and ground wire/ OPGW corresponding to 75% of design wind pressure at everyday temperature **(unless otherwise mentioned in Section-1A)** or 36% design wind pressure at minimum temperature after accounting for drag coefficient and gust response factor.
- ii) As per Clause 15 of IS 802:2015, for 400kV and higher voltage lines, the final unloaded tension of conductor at everyday temperature shall not exceed 22 percent of the ultimate tensile strength of conductors and 20 percent of the ultimate tensile strength of ground wire/ OPGW irrespective of the design criteria specified for conductor.
- iii) For normal towers, the value of final unloaded tension of conductor at everyday temperature considered for Tower Design under Safety Condition and Anti-cascading condition, shall not be less than 25% of the ultimate tensile strength of conductors for below 400kV voltage level transmission lines and not less than 22% of the ultimate tensile strength of conductors for 400 kV and higher voltage lines.
- iv) At ruling span, the final unloaded tension of conductor at everyday temperature of upper phase shall not be less than that of conductor in lower phase so as to maintain the phase-to-phase spacing.
- v) The main load carrying members shall be designed in such a way that even under the worst combination of unequal /equal leg extensions and loading, utilization of members does not exceed the values indicated in the table below:

Sl. No	Members	Utilizations	
		Compression	Tension
1	Leg / peak	98 %	98 %
2	Bracings (Diagonals/ Horizontals)	95 %	98 %
3	Cross Arm/Boom members i. e. Top/ Bottom member	95%	98%

vi) For clause 5.2.2.3 of IS 802 redundant members shall be checked as follows:

- a) 2.5% of axial load carried by the member (i.e., Legs, Horizontal, bracings, cross arm, etc.) it supports in one plane.

This provision shall be applied for redundant members as per the following:

- l) Redundant members if not modelled in tower design software, shall be designed to withstand percentage of member force it supports in one plane as shown in figure below for example.

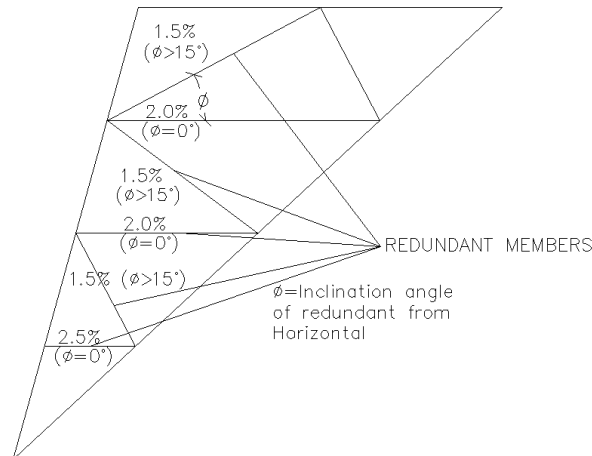


Diagram showing percentage of force to be considered for redundant design

- II) Redundant members modelled in tower design software shall be designed to withstand 2.5% of axial load carried by member it supports in one plane subject to minimum 1.25% of axial load to be carried by redundant members individually.

i. Design Temperatures

The following temperature range for the conductors and ground wires shall be adopted for transmission line design:

- i) Minimum Temperature: Minimum Ambient Temperature as per Section IA
- ii) Every day temperature : 32⁰C
- iii) Max. temperature of
 - a) Conductor (ACSR/ Al59/AAAC) : 85⁰C
 - b) Conductor (HTLS) : Refer TS for HTLS conductor
 - b) Earthwire exposed to sun : 53⁰C

ii. Phase Configuration

For single circuit towers of Horizontal Configuration, three phases shall be in Horizontal formation. For single circuit towers of Vertical Delta configuration, three phases shall be in vertical delta formation (as per the drawing enclosed with Technical Specifications) and for double circuit towers, three phases shall be in vertical formation. The phase to phase spacing for conductors shall be not less than 15000 mm for 765 kV & 8000 mm for 400 kV vertically. For 220kV & 132kV, required vertical phase to phase spacing shall be governed by the tower design as well as minimum live metal clearances under different insulator swing angles.

b. BOLTS, NUTS, JOINTS AND PANEL HEIGHT

- i. The minimum bolt spacing and rolled edge distance and sheared edge distance from the centers of bolt holes to be maintained are given in the Table below:

Diameter of Bolt (mm)	Hole diameter (mm)	Minimum Bolt spacing (mm)	Minimum Rolled distance (mm)	Minimum Sheared Edge distance (mm)
12	13.5	32	16	20
16	17.5	40	20	23
24	25.5	60	33	38

Bolts sizes mentioned above shall only be used. The minimum width of the flanges without bolt holes shall be 30 mm.

- ii. For the purpose of calculating shearing stress and bearing stress for 5.6 grade bolts, clause 5.4 of IS 802 (Part-1/Sec 2):2016 shall be referred. Bearing stress for 6.8 grade bolts shall be considered as 720 MPa.
- iii. The bolt positions in assembled towers shall be as per IS 5613 (Part-II / Section 2): 1976.
- iv. Joints shall be designed so as to avoid eccentricity. The use of gusset plates for jointing tower member shall be avoided as far as possible. However, where connections are such that the elimination of the gusset plates would result in eccentric joints then gussets plates and spacer plates may be used in conformity with modern practices. The thickness of the gusset plate, required to transmit stress, shall not be less than that of the thinnest of connected member but not less than 5 mm in any case.
- v. For butt joints, the cleat area shall not be less than 60% of the area of the smaller section and the total area of plate and cleat shall not be less than 1.2 times the area of the smaller section
- vi. Height of any panel shall not be more than 17 meters.
- vii. For designing of towers, rationalized steel sections conforming to IS 808 or BS EN 10025 shall be used.
- viii. The maximum length of any member shall not be more than 9m.