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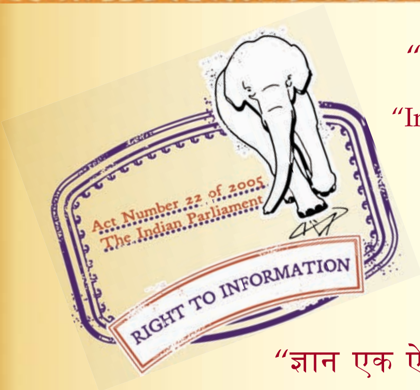
IS 802-1-1 (1995): Code of Practice for Use of Structural Steel In Overhead Transmission Line Towers, Part 1 Materials, Loads and Permissible Stresses, Section 1: Materials and Loads [CED 7: Structural Engineering and structural sections]



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"Knowledge is such a treasure which cannot be stolen"

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भारतीय मानक

शिरोपरि प्रेषण लाईन टावरों में संरचना इस्पात उपयोग की रीति संहिता

भाग 1 सामग्री भार और अनुमत प्रतिबल

अनुभाग 1 सामग्री और भार

(तीसरा पुनरीक्षण)

Indian Standard

USE OF STRUCTURAL STEEL IN OVERHEAD TRANSMISSION LINE TOWERS — CODE OF PRACTICE

PART 1 MATERIALS, LOADS AND PERMISSIBLE STRESSES

Section 1 Materials and Loads

(Third Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

September 1995 **Price Group 8**

FOREWORD

This Indian Standard (Third Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Structural Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

The standards under IS 802 series have been prepared with a view to establish uniform practices for design, fabrication, inspection and testing of overhead transmission line towers. Part 1 of the standard covers requirements in regard to material, loads and permissible stresses apart from other relevant design provisions. Provisions for fabrication, galvanizing, inspection and packing have been covered in Part 2 whereas provisions for testing of these towers have been covered in Part 3.

This standard was first published in 1967 and subsequently revised in 1973 and in 1977. In this revision, the standard has been split in two sections, namely Section 1 Materials and loads, and Section 2 Permissible stresses.

Some of the major modifications made in this Section are as under:

a) Concept of maximum working load multiplied by the factors of safety as per IE Rules has been replaced by the ultimate load concept.

b) For assessing the loads on tower, concept of reliability, security and safety have been introduced on the basis of IEC 826 : 1991 'Technical report on loading and strength of overhead transmission lines'.

c) Basic wind speed based on peak gust velocity, averaged over 3 seconds duration, as per the wind map of India given in IS 875 (Part 3) : 1987 'Code of practice for design loads (other than earthquake) for buildings and structures : Part 3 Wind loads (*second revision*)' has been kept as the basis of calculating reference wind speed. Terrain and topography characteristics of the ground have been taken into consideration in working out the design wind speeds.

d) Wind loads on towers and conductors have been revised. These are based on the modified wind map of the country. Reference wind speed averaged over 10 minutes duration has been used for the determination of wind loads.

e) Provisions for the 'Temperature Effects' have been modified. In order to permit additional current carrying capacity in the conductor the maximum temperature in the ACSR conductor has now been permitted to be 75°C in any part of the country. For aluminium alloy (AAAC) conductor, the corresponding maximum temperature has been permitted to be 85°C.

f) Provisions for anti cascading checks have been included for angle towers.

g) Provisions for multi circuit towers have been included.

h) Consequent to the merger of IS 226 : 1975 'Structural steel (Standard quality)' in IS 2062 : 1992 'Specification for weldable structural steel (*third revision*)' steels conforming to IS 2062 : 1992 and IS 8500 : 1992 'Specification for weldable structural steel (medium and high strength qualities)' have been included.

j) With the publication of IS 12427 : 1988 'Transmission tower bolts' these bolts (property class 5.6) and bolts of property class 8.8 conforming to IS 3757 : 1985 'High strength structural bolts (*second revision*)' have been included in addition to bolts, of property class 4.6 conforming to IS 6639 : 1972 'Hexagon bolts for steel structures'.

As transmission line towers are comparatively light structures and also that the maximum wind pressure is the chief criterion for the design, the Sectional Committee felt that concurrence of earthquake and maximum wind pressure is unlikely to take place. However in earthquake prone areas the design of towers/foundations shall be checked for earthquake forces corresponding to nil wind and minimum temperature in accordance with IS 1893 : 1984 'Criteria for earthquake resistant design of structures (*fourth revision*)'.

(*Continued on third cover*)

Indian Standard

USE OF STRUCTURAL STEEL IN OVERHEAD TRANSMISSION LINE TOWERS — CODE OF PRACTICE

PART 1 MATERIALS, LOADS AND PERMISSIBLE STRESSES

Section 1 Materials and Loads

(Third Revision)

1 SCOPE

1.1 This standard (Part 1/Sec 1) stipulates materials and loads to be adopted in the design of self-supporting steel lattice towers for overhead transmission lines.

1.1.1 Permissible stresses and other design parameters are covered in IS 802 (Part 1/ Sec 2) : 1992 of this standard.

1.1.2 Provisions on fabrication including galvanizing, inspection and packing, etc, and testing of transmission line towers have been covered in IS 802 (Part 2) : 1978 and IS 802 (Part 3) : 1978 respectively.

1.2 This standard does not cover river crossing towers and guyed towers. These will be covered in separate standards.

2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard

3 STATUTORY REQUIREMENTS

3.1 Statutory requirements as laid down in the 'Indian Electricity Rules, 1956' or by any other statutory body applicable to such structures as covered in this standard shall be satisfied.

3.2 Compliance with this standard does not relieve any user from the responsibility of observing local and provincial building byelaws, fire and safety laws and other civil aviation requirements appilicable to such structures.

4 TERMINOLOGY

4.1 Return Period

Return period is the mean interval between recurrences of a climatic event of defined magnitude. The inverse of the return period gives the probability of exceeding the event in one year.

4.2 Reliability

Reliability of a transmission system is the probabilty that the system would perform its function/task under the designed load conditions for a specified period. In simple terms, the reliability may be defined as the probability that a given item will indeed survive a given service environment and loading for a prescribed period of time.

4.3 Security

The ability of a system to be protected from any major collapse such as cascading effect, if a failure is triggered in a given component. Security is a deterministic concept as opposed to reliability which is a probabilistic.

4.4 Safety

The ability of a system not to cause human injuries or loss of life. It relates, in this code, mainly to protection of workers during construction and maintenance operations.

5 MATERIALS

5.1 Structural Steel

The tower members including cross arms shall be of structural steel conforming to any of the grade, as appropriate, of IS 2062 : 1992. Steel conforming to any of the appropriate grade of IS 8500 : 1992 may also be used.

5.1.1 Medium and high strength structural steels with known properties conforming to other national and international standards may also be used subject to the approval of the purchaser.

5.2 Bolts

5.2.1 Bolts for tower connections shall conform to IS 12427 : 1988 or of property class 4.6 conforming to IS 6639 : 1972.

5.2.2 High strength bolts, if used (only with structural steels of IS 8500 : 1992) shall conform to property class 8.8 of IS 3757 : 1985.

5.2.3 Foundation bolts shall conform to IS 5624 : 1970.

5.2.4 Step bolts shall conform to IS 10238 : 1982.

5.3 Nuts

5.3.1 Nuts shall conform to IS 1363 (Part 3) : 1992. The mechanical properties shall conform to property class 4 or 5 as the case may be as specified in IS 1367 (Part 6) : 1980 except that the proof stress for nuts of property class 5 shall be as given in IS 12427 : 1988.

5.3.2 Nuts to be used with high strength bolts shall conform to IS 6623 : 1985.

5.4 Washers

5.4.1 Washers shall conform to IS 2016 : 1967. Heavy washers shall conform to IS 6610 : 1972. Spring washers shall conform to type B of IS 3063 : 1972.

5.4.2 Washers to be used with high strength bolts and nuts shall conform to IS 6649 : 1985.

5.5 Galvanization

5.5.1 Structural members of the towers, plain and heavy washers shall be galvanized in accordance with the provisions of IS 4759 : 1984.

5.5.2 Threaded fasteners shall be galvanized to conform to the requirements of IS 1367 (Part 13) : 1983.

5.5.3 Spring washers shall be hot dip galvanized as per service grade 4 of IS 4759 : 1984 or electro galvanized as per service grade 3 of IS 1573 : 1986 as specified by the purchaser.

5.6 Other Materials

Other materials used in the construction of the tower shall conform to appropriate Indian Standards wherever available.

6 TYPES OF TOWERS

6.1 The selection of the most suitable types of tower for transmission lines depends on the actual terrain through which the line traverses. Experience has, however, shown that any combination of the following types of towers are generally suitable for most of the lines :

i) Suspension towers (with I or V suspension insulator strings)

a) Tangent towers (0°) with suspension string	To be used on straight runs only.
b) Intermediate towers (0° to 2°) with suspension string	To be used on straight runs and upto 2° line deviation.
c) Light angle towers (0° to 5°) with suspension string	To be used on straight runs and upto 5° line deviation.

NOTE — In the selection of suspension tower either (b) above or a combination of (a) and (c) may be followed.

ii) Tension towers

a) Small angle towers (0° to 15°) with tension string	To be used for line deviation from 0° to 15°.
b) Medium angle towers (0° to 30°) with tension string	To be used for line deviation 0° to 30°.
c) Large angle towers (30° to 60°) with tension string	To be used for line deviation from 30° to 60°.
d) Dead-end towers with tension string	To be used as dead-end (terminal) tower or anchor tower.
e) Large angle and dead-end towers with tension string	To be used for line deviation from 30° to 60° or for dead-ends.

NOTE — In the selection of tension towers either (e) above or a combination of (c) and (d) may be followed.

6.2 The angles of line deviation specified in **6.1** are for the design span. The span may, however, be increased upto an optimum limit with reducing angle of line deviation, if adequate ground and phase clearances are available.

7 RELIABILITY CONSIDERATIONS

7.1 Transmission lines shall be designed for the reliability levels given in Table 1. These levels are expressed in terms of return periods in years of climatic (wind) loads. The minimum yearly reliability Ps, corresponding to the return period, T, is expressed as $Ps = \left(1 - \frac{1}{2T}\right)$

Table 1 Reliability Levels of Transmission Lines

(*Clause* 7.1)

Sl No	Description	Reliability Levels		
		1	2	3
	(1)	(2)	(3)	(4)
i)	Return period of design loads, in years, T	50	150	500
ii)	Yearly reliability, P_s	$1-10^{-2}$	$1-10^{-2.5}$	$1-10^{-3}$

7.2 Reliability level 1 shall be adopted for EHV transmission lines upto 400 kV class.

7.3 Reliability level 2 shall be adopted for EHV transmission lines above 400 kV class.

7.4 Triple and quadruple circuit towers upto 400 kV lines shall be designed corresponding to the reliability level 2.

7.5 Reliability level 3 shall be adopted for tall river crossing towers and special towers, although these towers are not covered in this standard.

8 WIND EFFECTS

8.1 Basic Wind Speed, V_b

Figure 1 shows basic wind speed map of India as applicable at 10 m height above mean ground level for the six wind zones of the country. Basic wind speed 'V_b' is based on peak gust velocity averaged over a short time interval of about 3 seconds, corresponds to mean heights above ground level in an open terrain (Category 2) and have been worked out for a 50 years return period [Refer IS 875 (Part 3) : 1987 for further details].

Basic wind speeds for the six wind zones (*see* Fig. 1) are :

Wind Zone	*Basic Wind Speed*, V_b *m/s*
1	33
2	39
3	44
4	47
5	50
6	55

NOTE — In case the line traverses on the border of different wind zones, the higher wind speed may be considered.

8.2 Meteorological Reference Wind Speed, V_R

It is extreme value of wind speed over an averaging period of 10 minutes duration and is to be calculated from basic wind speed 'V_b' by the following relationship :

$$V_R = V_b / K_0$$

where

K_0 is a factor to convert 3 seconds peak gust speed into average speed of wind during 10 minutes period at a level of 10 metres above ground. K_0 may be taken as 1·375.

8.3 Design Wind Speed, V_d

Reference wind speed obtained in **8.2** shall be modified to include the following effects to get the design wind speed:

a) Risk coefficient, K_1; and

b) Terrain roughness coefficient, K_2.

It may be expressed as follows:

$$V_d = V_R \times K_1 \times K_2 .$$

8.3.1 *Risk Coefficient*, K_1

Table 2 gives the values of risk coefficients K_1 for different wind zones for the three reliability levels.

Table 2 Risk Coefficient K_1 for Different Reliability Levels and Wind Zones

(*Clause* 8.3.1)

Reliability Level	Coefficient K_1 for Wind Zones					
	1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	1·00	1·00	1·00	1·00	1·00	1·00
2	1·08	1·10	1·11	1·12	1·13	1·14
3	1·17	1·22	1·25	1·27	1·28	1·30

8.3.2 *Terrain Roughness Coefficient, K_2*

Table 3 gives the values of coefficient K_2 for the three categories of terrain roughness (*see* **8.3.2.1**) corresponding to 10 minutes averaged wind speed.

Table 3 Terrain Roughness Coefficient, K_2

(*Clause* 8.3.2)

Terrain Category	1	2	3
Coefficient, K_2	1·08	1·00	0·85

NOTE — For lines encountering hills/ridges, the value of K_2 for a given terrain shall be changed to next higher value of K_2.

8.3.2.1 *Terrain categories*

a) Category 1 — Exposed open terrain with few or no obstruction and in which the average height of any object surrounding the structure is less than 1·5 m.

NOTE — This category includes open seacoasts, Open stretch of water, deserts and flat treeless plains.

b) Category 2 — Open terrain with well scattered obstructions having height generally between 1·5 m to 10 m.

NOTE — This category includes normal country lines with very few obstacles.

c) Category 3 — Terrain with numerous closely spaced obstructions.

NOTE — This category includes built up areas and forest areas.

8.4 Design Wind Pressure, P_d

The design wind pressure on towers, conductors and insulators shall be obtained by the following relationship :

$$P_d = 0·6\ V_d^2$$

where

P_d = design wind pressure in N/m², and

V_d = design wind speed in m/s.

8.4.1 Design wind pressures P_d for the three reliability levels and pertaining to six wind zones and the three terrain categories have been worked out and given in Table 4.

9 WIND LOADS

9.1 Wind Load on Tower

In order to determine the wind load on tower, the tower is divided into different panels having a height '*h*'. These panels should normally be taken between the intersections of the legs and bracings. For a lattice tower of square cross-section, the resultant wind load F_{wt} in Newtons, for wind normal to the longitudinal face of tower,

Table 4 Design Wind Pressure P_d, in N/m²

(*Clause* 8.4.1)

Reliability Level	Terrain Category	Design Wind Pressure P_d for Wind Zones					
		1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	1	403	563	717	818	925	1 120
	2	346	483	614	701	793	960
	3	250	349	444	506	573	694
2	1	470	681	883	1 030	1 180	1 460
	2	403	584	757	879	1 010	1 250
	3	291	422	547	635	732	901
3	1	552	838	1 120	1 320	1 520	1 890
	2	473	718	960	1 130	1 300	1 620
	3	342	519	694	817	939	1 170

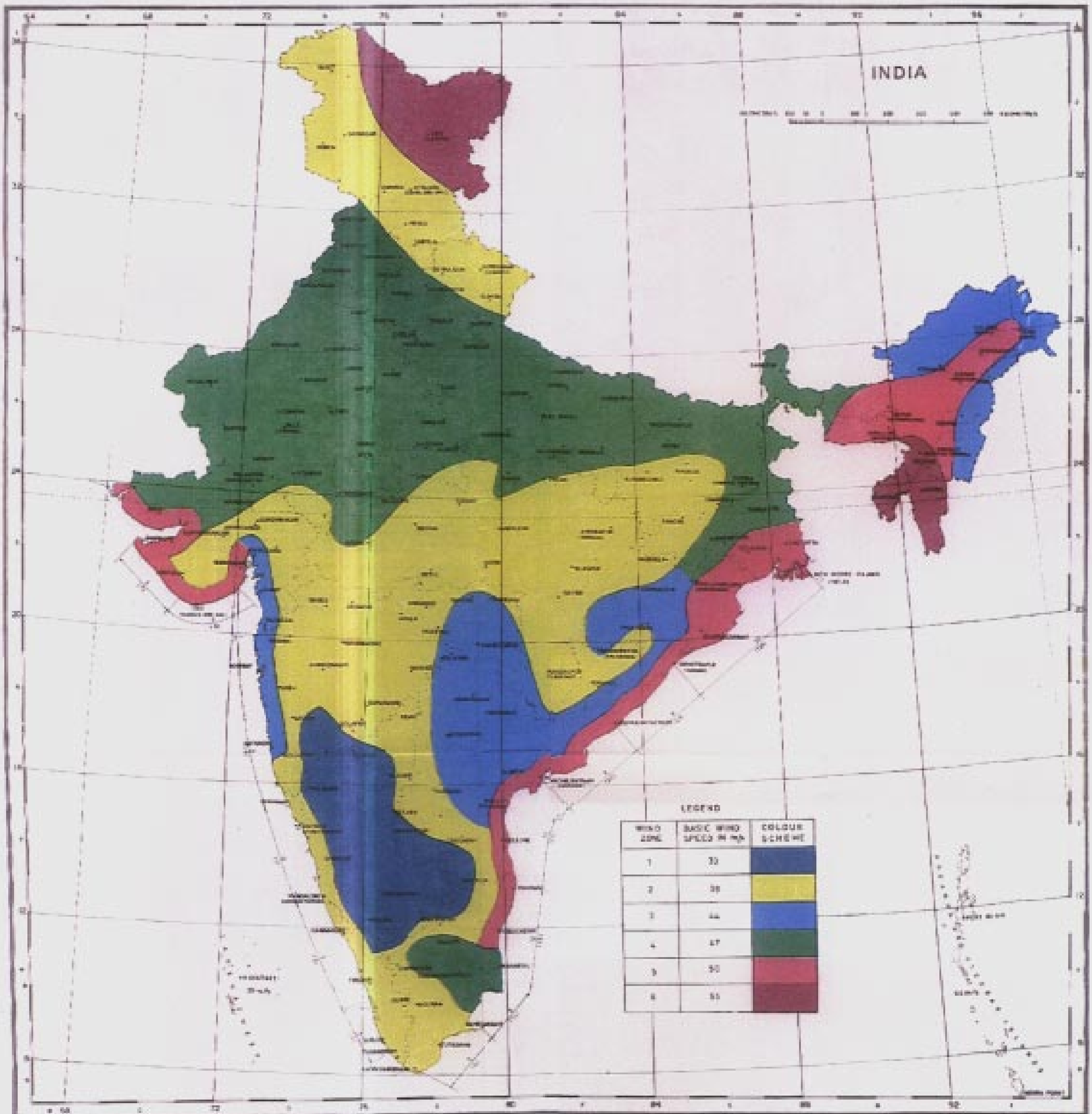


FIG. 1 BASIC WIND SPEED IN m/s (BASED ON 50-YEAR RETURN PERIOD)

As in the Original Standard, this Page is Intentionally Left Blank on a panel height '*h*' applied at the centre of gravity of this panel is:

$$F_{wt} = P_d \times C_{dt} \times A_e \times G_T$$

where

P_d = design wind pressure, in N/m²;

C_{dt} = drag coefficient for panel under consideration against which the wind is blowing. Values of C_{dt} for different solidity ratios are given in Table 5.

Solidity ratio is equal to the effective area (projected area of all the individual elements) of a frame normal to the wind direction divided by the area enclosed by the boundry of the frame normal to the wind direction;

A_e = total net surface area of the legs, bracings, cross arms and secondary members of the panel projected normal to the face in m². (The projections of the bracing elements of the adjacent faces and of the plan-and-hip bracing bars may be neglected while determining the projected surface of a face); and

G_T = gust response factor, peculiar to the ground roughness and depends on the height above ground. Values of G_T for the three terrain categories are given in Table 6.

Table 5 Drag Coefficient, C_{dt} for Tower

(*Clause* 9.1)

Solidity Ratio	Drag Coefficient C_{dt}
(1)	(2)
Up to 0·05	3·6
0·1	3·4
0·2	2.9
0·3	2·5
0·4	2·2
0·5 and above	2·0

NOTES

1 Intermediate values may be linearly interpolated.

2 Drag coefficient takes into account the shielding effect of wind on the leeward face of the tower. However, in case the bracing on the leeward face is not shielded from the windward face, then the projected area of the leeward face of the bracing should also be taken into consideration.

9.1.1 In case of horizontal configuration towers, outer and inner faces countering the wind between the waist and beam level should be considered separately for the purposes of calculating wind load on the tower, as shown in Fig. 2.

Table 6 Gust Response Factor for Towers (G_T) and for Insulators (G_i)

(*Clauses* 9.1 *and* 9.3)

Height Above Ground	Values of G_T and G_i for Trerain Categories		
m	1	2	3
(1)	(2)	(3)	(4)
Up to 10	1·70	1·92	2·55
20	1·85	2·20	2·82
30	1·96	2·30	2·98
40	2·07	2·40	3·12
50	2·13	2·48	3·24
60	2·20	2·55	3·34
70	2·26	2·63	3·46
80	2·31	2·69	3·58

NOTE — Intermediate values may be linearly interpolated.

9.2 Wind Load on Conductor and Groundwire

The load due to wind on each conductor and groundwire, F_{wc} in Newtons applied at supporting point normal to the line shall be determined by the following expression:

$$F_{wc} = P_d \times C_{dc} \times L \times d \times G_c$$

where

P_d = design wind pressure, in N/m²;

C_{dc} = drag coefficient, taken as 1·0 for conductor and 1·2 for groundwire;

L = wind span, being sum of half the span on either side of supporting point, in metres;

d = diameter of cable, in metres; and

G_c = gust response factor, takes into account the turbulance of the wind and the dynamic response of the conductor. Values of G_c are given in Table 7 for the three terrain categories and the average height of the conductor/groundwire above the ground.

NOTE — The average height of conductor/groundwire shall be taken up to clamping point of top conductor/groundwire on tower less two-third the sag at minimum temperature and no wind.

9.2.1 The total effect of wind on bundle conductors shall be taken equal to the sum of the wind load on sub-conductors without accounting for a possible masking effect of one of the subconductors on another.

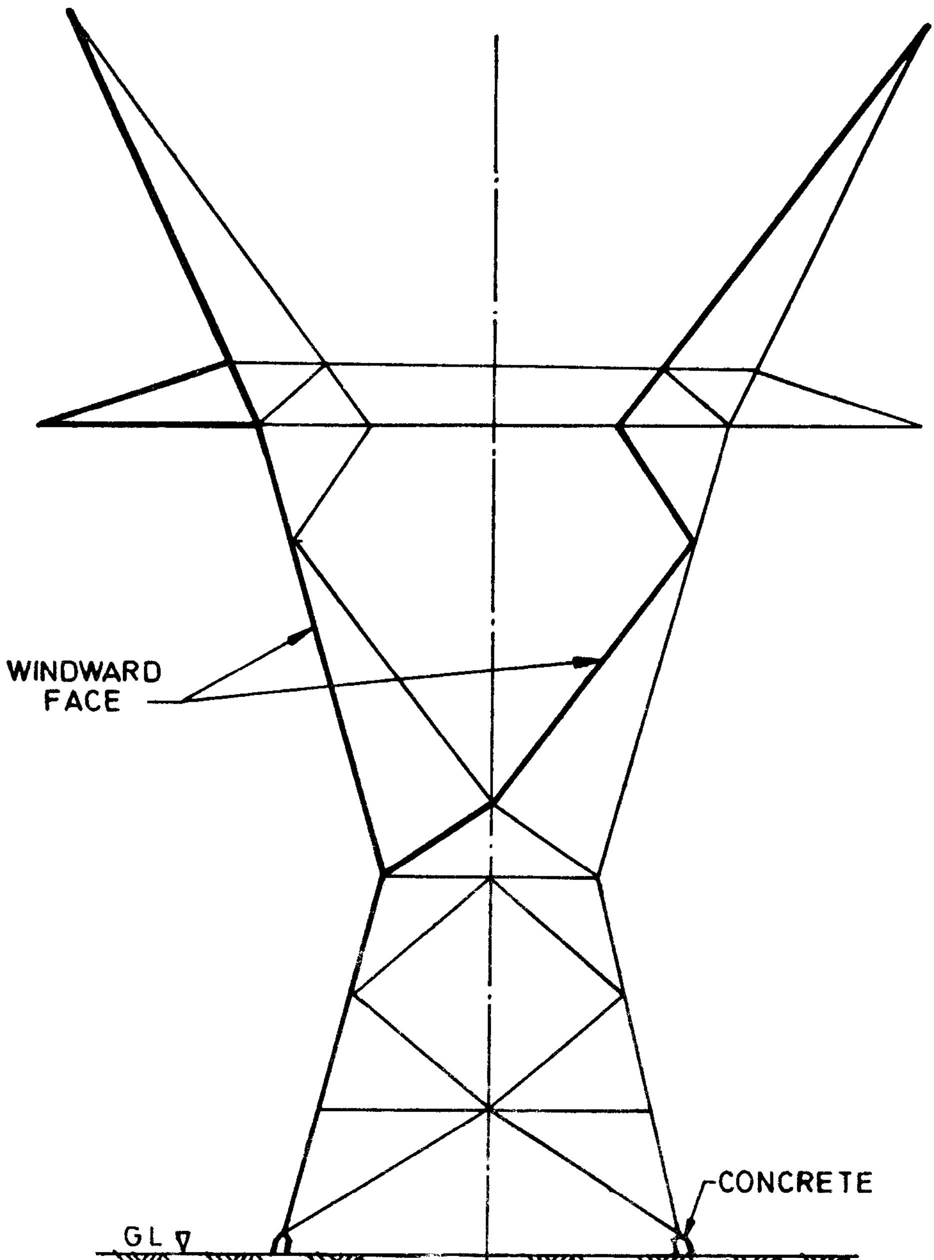


FIG. 2 HORIZONTAL CONFIGURATION TOWER

Table 7 Values of Gust Response Factor G_c for Conductor and Groundwire

(*Clause* 9.2)

Terrain Category		Height Above Ground, m	Values of G_c for Ruling Span of, in m						
			Up to 200	300	400	500	600	700	800 and above
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Up to	10	1·70	1·65	1·60	1·56	1·53	1·50	1·47
		20	1·90	1·87	1·83	1·79	1·75	1·70	1·66
		40	2·10	2·04	2·00	1·95	1·90	1·85	1·80
		60	2·24	2·18	2·12	2·07	2·02	1·96	1·90
		80	2·35	2·25	2·18	2·13	2·10	2·06	2·03
2	Up to	10	1·83	1·78	1·73	1·69	1·65	1.60	1·55
		20	2·12	2·04	1·95	1.88	1·84	1.80	1·80
		40	2·34	2·27	2·20	2·13	2·08	2·05	2·02
		60	2·55	2·46	2·37	2·28	2·23	2·20	2·17
		80	2·69	2·56	2·48	2·41	2·36	2·32	2·28
3	Up to	10	2·05	1·98	1·93	1·88	1·83	1·77	1·73
		20	2·44	2·35	2·25	2·15	2·10	2·06	2·03
		40	2·76	2·67	2·58	2·49	2·42	2·38	2·34
		60	2·97	2·87	2·77	2·67	2·60	2·56	2·52
		80	3·19	3·04	2·93	2·85	2·78	2·73	2·69

NOTE — Intermediate values may be linearly interpolated.

9.3 Wind Load on Insulator Strings

Wind load on insulator strings 'F_{wI}' shall be determined from the attachment point to the centre line of the conductor in case of suspension tower and up to the end of clamp in case of tension tower, in the direction of the wind as follows:

$$F_{wI} = C_{dI} \times P_d \times A_I \times G_I$$

where

C_{dI} = drag coefficient, to be taken as 1.2;

P_d = design wind pressure in N/m²;

A_I = 50 percent of the area of insulator string projected on a plane which is parallel to the longitudinal axis of the string; and

G_I = gust response factor, peculiar to the ground roughness and depends on the height of insulator attachment point above ground. Values of G_I for the three terrain categories are given in Table 6.

9.3.1 In case of multiple strings including V strings, no masking effect shall be considered.

10 TEMPERATURE EFFECTS

10.1 General

The temperature range varies for different localities under different diurnal and seasonal conditions. The absolute maximum and minimum temperature which may be expected in different localities in the country are indicated on the map of India in Fig. 3 and Fig. 4 respectively. The temperature indicated in these maps are the air temperatures in shade. These may be used for assessing the temperature effects.

10.2 Temperature Variations

10.2.1 The absolute maximum temperature may be assumed as the higher adjacent isopleth temperature shown in Fig. 3.

10.2.2 The absolute minimum temperature may be assumed as the lower adjacent isopleth temperature shown in Fig. 4.

10.2.3 The average everyday temperature shall be 32°C anywhere in the country, except in regions experiencing minimum temperature of −5°C or lower (*see* Fig. 4), where everyday temperature may be taken as 15°C or as specified by the power utilities.

10.2.4 The maximum conductor temperature may be obtained after allowing increase in temperature due to radiation and heating effect due to current etc over the absolute maximum temperature given in Fig. 3. The tower may be designed to suit the conductor temperature of 75°C (*Max*) for ACSR and 85°C (*Max*) for aluminium alloy conductor. The maximum temperature of groundwire exposed to sun may be taken as 53°C.

10.3 Sag Tension

Sag tension calculation for conductor and groundwire shall be made in accordance with the relevant provisions of IS 5613 (Part 2/ Sec 1) : 1985 for the following combinations:

a) 100 percent design wind pressure after accounting for drag coefficient and gust response factor at everyday temperature, and

b) 36 percent design wind pressure after accounting for drag coefficient and gust response factor at minimum temperature.

11 LOADS ON TOWER

11.1 Classification of Loads

Transmission lines are subjected to various loads during their lifetime. These loads are classified into three distinct categories, namely,

a) *Climatic loads* — related to the reliability requirements.

b) *Failure containment loads* — related to security requirements.

c) *Construction and maintenance loads* — related to safety requirements.

11.2 Climatic Loads

These are random loads imposed on tower, insulator string, conductor and groundwire due to action of wind on transmission line and do not act continuously. Climatic loads shall be determined under either of the following climatic conditions, whichever is more stringent:

i) 100 percent design wind pressure at everyday temperature, or

ii) 36 percent design wind pressure at minimum temperature.

NOTE — Condition (ii) above is normally not crucial for tangent tower but shall be checked for angle or dead-end towers, particularly for short spans.

11.3 Failure Containment Loads

These loads comprise of:

i) Anti cascading loads, and

ii) Torsional and longitudinal loads.

11.3.1 *Anti Cascading Loads*

Cascade failure may be caused by failure of items such as insulators, hardware, joints, failures of major components such as towers, foundations, conductor due to defective material or workmanship or from climatic overloads or sometimes from casual events such as misdirected aircraft, avalanches, sabotage etc. The security measures adopted for containing cascade failures in the line is to provide angle towers at specific intervals which shall be checked for anti-cascading loads (*see* **14**).

11.3.2 *Torsional and Longitudinal Loads*

These loads are caused by breakage of conductor(s) and/or groundwire. All the towers shall be designed for these loads for the number of conductor (s) and/or groundwire considered broken according to **16**.

11.3.2.1 The mechanical tension of conductor/ groundwire is the tension corresponding to 100 percent design wind pressure at every day temperature or 36 percent design wind pressure at minimum temperature after accounting for drag coefficient and gust response factor.

11.4 Construction and Maintenance Loads

These are loads imposed on towers during construction and maintenance of transmission lines.

12 COMPUTATION OF LOADS

12.1 Transverse Loads

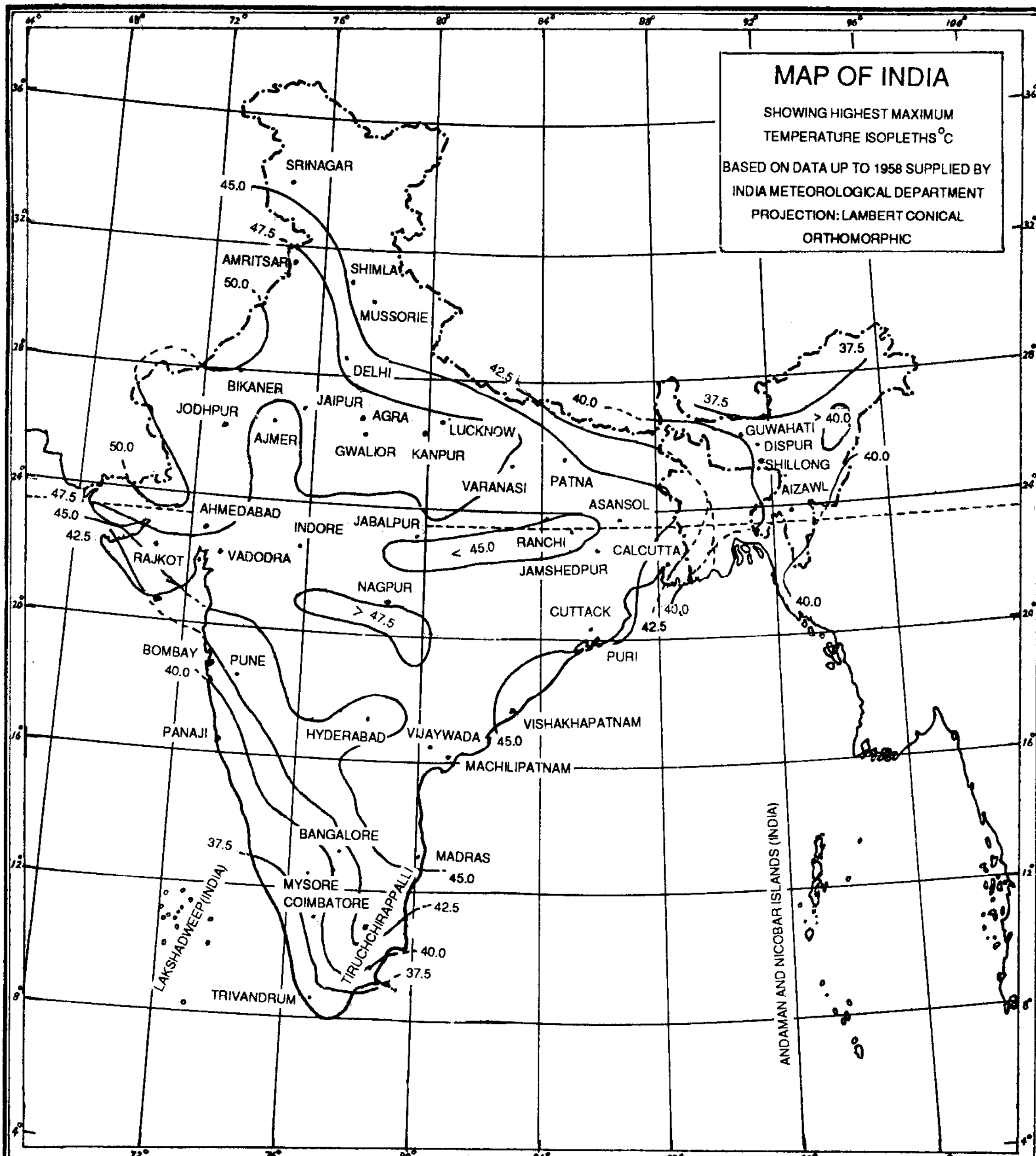
Transverse loads shall be computed for reliability, security and safety requirements.

12.1.1 *Reliability Requirements*

These loads shall be calculated as follows:

i) Wind action on tower structures, conductors, groundwires and insulator strings computed according to **9.1**, **9.2** and **9.3** respectively for both the climatic conditions specified in **11.2**.

ii) Component of mechanical tension F_{wd} of conductor and groundwire due to wind computed as per **11.3.2.1**.

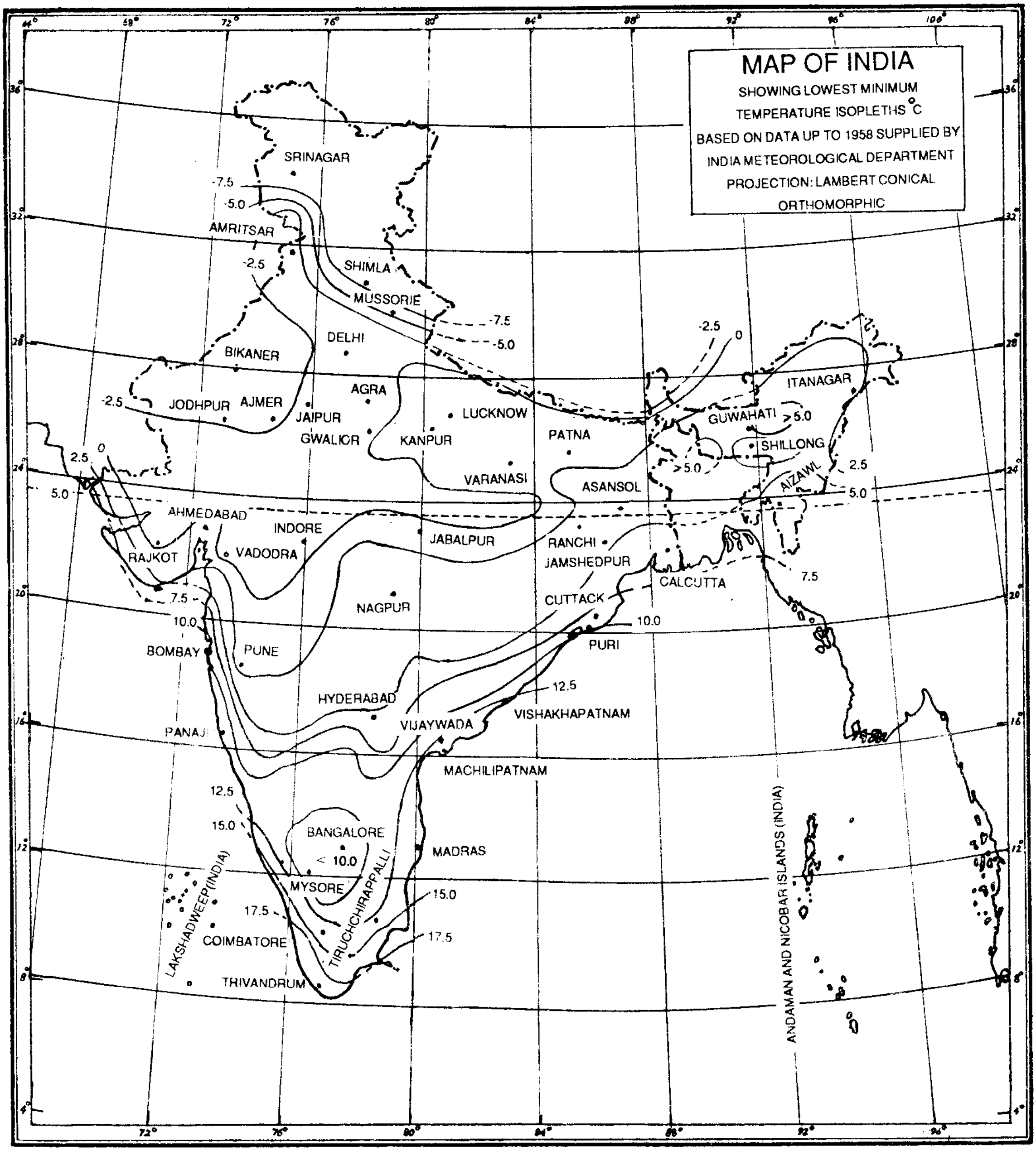


Based upon Survey of India Outline map printed in 1987.

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

Responsibility for the correctness of internal details shown on the map rests with the publisher.

FIG. 3 CHART SHOWING HIGHEST MAXIMUM TEMPERATURE ISOPLETHS



Based upon Survey of India Outline map printed in 1987.

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

Responsibility for the correctness of internal details shown on the map rests with the publisher.

FIG. 4 CHART SHOWING LOWEST MINIMUM TEMPERATURE ISOPLETHS

Thus, total transverse load = (i) + (ii)
$= F_{wt} + F_{wc} + F_{wl} + F_{wd}$

where

'F_{wc}', 'F_{wl}' and 'F_{wd}' are to be applied on all conductors/groundwire points and 'F_{wt}' to be applied on tower at groundwire peak and cross arm levels and at any one convenient level between bottom cross arm and ground level for normal tower. In case of tower with extensions, one more application level shall be taken at top end of extension.

12.1.2 *Security Requirements*

These loads shall be taken as under:

i) *Suspension towers*

a) Transverse loads due to wind action on tower structures, conductors, groundwires and insulators shall be taken as nil.

b) Transverse loads due to line deviation shall be based on component of mechanical tension of conductors and groundwires corresponding to everyday temperature and nil wind condition. For broken wire spans the component shall be corresponding to 50 percent mechanical tension of conductor and 100 percent mechanical tension of groundwire at everyday temperature and nil wind.

ii) *Tension and dead end towers*

a) Transverse loads due to wind action on tower structure, conductors, groundwires and insulators shall be computed as per **12.1.1** (i). 60 percent wind span shall be considered for broken wire condition and 100 percent wind span for intact span condition.

b) Transverse loads due to line deviation shall be the component of 100 percent mechanical tension of conductor and groundwire as defined in **11.3.2.1**.

12.1.3 *Safety Requirements*

Transverse loads on account of wind on tower structures, conductors, groundwires, and insulators shall be taken as nil for normal and brokenwire conditions. Transverse loads due to mechanical tension of conditions and groundwire at everyday temperature and nil wind condition on account of line deviation shall be taken for both normal and broken wire conditions.

12.2 Vertical Loads

Vertical loads shall be computed for reliability, security and safety requirements.

12.2.1 *Reliability Requirements*

These loads comprise of:

i) Loads due to weight of conductors/groundwire based on design weight span, weight of insulator strings and accessories, and

ii) Self weight of tower structure up to point/level under consideration.

The effective weight of the conductor/groundwire should be corresponding to the weight span on the tower. The weight span is the horizontal distance between the lowest points of the conductor/groundwire on the two spans adjacent to the tower under consideration. The lowest point is defined as the point at which the tangent to the sag curve or to the sag curve produced, is horizontal.

12.2.2 *Security Requirements*

These shall be taken as:

i) Same as in **12.2.1** (i) except for broken wire condition where the load due to weight of conductor/groundwire shall be considered as 60 percent of weight span, and

ii) Same as in **12.2.1** (ii).

12.2.3 *Safety Requirements*

These loads comprise of:

i) Loads as computed in **12.2.2**,

ii) Load of 1 500 N considered acting at each cross arm, as a provision of weight of lineman with tools,

iii) Load of 3 500 N considered acting at the tip of cross arms up to 220 kV and 5 000 N for 400 kV and higher voltage for design of cross arms, and

iv) Following erection loads at lifting points, for 400 kV and higher voltage, assumed as acting at locations specified below:

Tension Tower with	*Vertical Load*, N	*Distance, from the Tip of Cross Arm*, mm
Twin bundle conductor	10 000	600
Multi bundle conductor	20 000	1 000

All bracing and redundant members of the towers which are horizontal or inclined up to 15° from horizontal shall be designed to with stand an ultimate vertical loads of 1 500 N considered acting at centre independent of all other loads.

12.3 Longitudinal Loads

Longitudinal loads shall be computed for reliability, security and safety requirements.

12.3.1 *Reliability Requirements*

These loads shall be taken as under:

i) Longitudinal load for dead-end towers to be considered corresponding to mechanical tension of conductors and groundwire as defined in **11.3.2.1**.

ii) Longitudinal loads which might be caused on tension towers by adjacent spans of unequal lengths can be neglected in most cases, as the strength of the supports for longitudinal loads is checked for security requirements and for construction and maintenance requirements.

iii) No longitudinal load for suspension and tension towers.

12.3.2 *Security Requirements*

These loads shall be taken as under:

i) For suspension towers, the longitudinal load corresponding to 50 percent of the mechanical tension of conductor and 100 percent of mechanical tension of groundwire shall be considered under every day temperature and no wind pressure.

ii) Horizontal loads in longitudinal direction due to mechanical tension of conductors and groundwire shall be taken as specified in **11.3.2.1** for broken wires and nil for intact wires for design of tension towers.

iii) For dead end towers, horizontal loads in longitudinal directon due to mechanical tension of conductor and groundwire shall be taken as specified in **11.3.2** for intact wires. However for broken wires, these shall be taken as nil.

12.3.3 *Safety Requirements*

These loads shall be taken as under:

i) *For normal conditions* — These loads for dead end towers shall be considered as corresponding to mechanical tension of conductor/groundwire at every day temperature and no wind. Longitudinal loads due to unequal spans may be neglected.

ii) *For brokenwire conditions*

a) *Suspension towers* — Longitudinal load per sub-conductor and groundwire shall be considered as 10 000 N and 5 000 N respectively.

b) *Tension towers* — Longitudinal load equal to twice the sagging tension (sagging tension shall be taken as 50 percent of tension at everyday temperature and no wind) for wires under stringing and 1·5 times the sagging tension for all intact wires (stringing completed).

13 LOADING COMBINATIONS

13.1 Reliability Conditions

i) *Transverse loads* — as per **12.1.1**.

ii) *Vertical loads* — as per **12.2.1**.

iii) *Longitudinal loads* — as per **12.3.1**.

13.2 Security Conditions

i) *Transverse loads* — as per **12.1.2**.

ii) *Vertical loads* -- as per **12.2.2**.

iii) *Longitudinal loads* — as per **12.3.2**.

13.3 Safety Conditions

i) *Transverse loads* — as per **12.1.3**.

ii) *Vertical loads* — shall be the sum of:

a) Vertical loads as per **12.2.2** (i) multiplied by the overload factor of 2.

b) Vertical loads calculated as per **12.2.2** (ii), **12.2.3** (ii), **12.2.3** (iii) and **12.2.3** (iv).

iii) *Longitudinal loads* — as per **12.3.3**.

14 ANTI CASCADING CHECKS

All angle towers shall be checked for the following anti-cascading conditions with all conductors and groundwire intact only on one side of the tower

a) *Transverse loads* — These loads shall be taken under no wind condition.

b) *Vertical loads* — These loads shall be the sum of weight of conductor/groundwire as per weight span of intact conductor/ground wire, weight of insulator strings and accessories.

c) *Longitudinal loads* — These loads shall be the pull of conductor/groundwire at everyday temperature and no wind applied simultaneously at all points on one side with zero degree line deviation.

15 TENSION LIMITS

Conductor/groundwire tension at everyday temperature and without external load, should not exceed the following percentage of the ultimate tensile strength of the conductor:

Initial unloaded tension	35 percent
Final unloaded tension	25 percent

provided that the ultimate tension under everyday temperature and 100 percent design wind pressure, or minimum temperature and 36 percent design wind pressure does not exceed 70 percent of the ultimate tensile strength of the conductor/ground wire.

NOTE — For 400 kV and 800 kV lines, the final unloaded tension of conductors at everyday temperature shall not exceed 22 perrent of the ultimate tensile strength of conductors and 20 percent of the ultimate tensile strength of groundwire

16 BROKEN WIRE CONDITION

The following broken wire conditions shall be assumed in the design of towers:

a) Single circuit towers	Any one phase or groundwire broken; whichever is more stringent for a particular member.
b) Double, triple circuit and quadruple circuit towers:	
i) Suspension towers	Any one phase or groundwire broken; whichever is more stringent for a particular member.
ii) Small and medium angle towers	Any two phases broken on the same side and same span or any one phase and one groundwire broken on the same side and same span whichever combination is more stringent for a particular member.
iii) Large angle tension towers/ dead end towers	Any three phases broken on the same side and same span or any two of the phases and one groundwire broken on the same side and same span; whichever combination constitutes the most stringent condition for a particular member.

NOTE — Phase shall mean all the sub-conductors in the case of bundle conductors.

17 STRENGTH FACTORS RELATED TO QUALITY

The design of tower shall be carried out in accordance with the provisions covered in IS 802 (Part 1/Sec 2) : 1992. However, to account for the reduction in strength due to dimensional tolerance of the structural sections and yield strength of steel used, the following strength factors shall be considered:

i) If steel with minimum guaranteed yield strength is used for fabrication of tower, the estimated loads shall be increased by a factor of 1.02.

ii) If steel of minimum guaranteed yield strength is not used for fabrication of tower, the estimated loads shall be increased by a factor of 1·05, in addition to the provision (i) above.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
802 (Part 1/ Sec 2) : 1992	Code of practice for use of structural steel in overhead transmission line towers: Part 1 Material, loads and permissible stress, Section 2 Permissible stresses (*third revision*)
875 (Part 3) : 1987	Code of practice for design loads (other than earthquake) for buildings and structures: Part 3 Wind loads (*second revision*)
1363 (Part 3) : 1992	Hexagon head bolts, screws and nuts of product Grade C : Part 3 Hexagon nuts (size range M 5 to M 64) (*third revision*)
1367	Technical supply conditions for threaded steel fasteners:
(Part 6) : 1980	Part 6 Mechanical properties and test methods for nuts with specified proof loads (*second revision*)
(Part 13) : 1985	Part 13 Hot-dip galvanized coatings on threaded fasteners (*second revision*)
1573 : 1986	Electroplated coatings of zinc on iron and steel (*second revision*)
2016 : 1967	Plain washers (*first revision*)
2062 : 1992	Steel for general structural purposes (*fourth revision*)

IS No.	*Title*
3063 : 1972	Single coil rectangular section spring washers for bolts, nuts and screws (*first revision*)
3757 : 1985	High strength structural bolts (*second revision*)
4759 : 1984	Hot-dip zinc coatings on structural steel and other allied products (*third revision*)
5613 (Part 2/ Sec 1) : 1985	Code of practice for design, installation and maintenance of overhead lines: Part 2 Lines above 11 kV and up to and including 220 kV, Section 1 Design (*first revision*)
5624 : 1970	Foundation bolts
6610 : 1972	Heavy washers for steel structures
6623 : 1985	High strength structural nuts (*first revision*)
6639 : 1972	Hexagon bolts for steel structures
6649 : 1985	Hardened and tempered washers for high strength structural bolts and nuts (*first revision*)
8500 : 1992	Structural steel—Microalloyed (medium and high strength qualities) (*first revision*)
10238 : 1982	Step bolts for steel structures
12427 : 1988	Transmission tower bolts

ANNEX B

(*Foreword*)

Composition of Structural Engineering Sectional Committee, CED 7

Chairman	*Representing*
SHRI M. L. MEHTA	Metallurgical and Engineering Consultant (India) Ltd, Ranchi
Members	
SHRI S. K. DATTA (*Alternate* to Shri M. L. Mehta)	
SHRI R. N. BISWAS	Indian Oil Corporation, New Delhi
SHRI YOGENDRA SINGH (*Alternate*)	
SHRI RAMESH CHAKRABORTY	Joint Plant Committee, Calcutta
SHRI S. K. SUMAN (*Alternate*)	
CHIEF MANAGER (ENGINEERING)	RITES, New Delhi
GENERAL MANAGER (STRUCTURAL) (*Alternate*)	
DR P. DAYARATNAM	IIT, Kanpur
DIRECTOR (TRANSMISSION)	Central Electricity Authority, New Delhi
DEPUTY DIRECTOR (TRANSMISSION) (*Alternate*)	
SHRI S. C. DUGGAL	Richardson & Cruddas (1972) Ltd, Bombay
SHRI V. G. MANGRULKAR (*Alternate*)	
SHRI D. K. DATTA	Jessop & Co Limited, Calcutta
SHRI A. K. SEN (*Alternate*)	
SHRI S. K. GANGOPPADHYAY	Braithwaite & Co Ltd, Calcutta
SHRI P. BIMAL (*Alternate*)	
SHRI S. GANGULI	Projects & Development India Ltd, Dhanbad
SHRI S. P. GARARI (*Alternate*)	
DR JANARDAN JHA	Institution of Engineers (India), Calcutta
SHRI S. P. JAMDAR	Road & Building Department, Gandhinagar
SHRI S. S. RATHORE (*Alternate*)	
JOINT DIRECTOR STANDARDS (B & S)-SB-I	Ministry of Railways, Lucknow
DEPUTY DIRECTOR STANDARDS (B & S)-SB (*Alternate*)	
DR V. KALYANARAMAN	IIT, Madras
DR J. N. KAR	Bengal Engineering College, Civil Engineering Department. Government of West Bengal, Calcutta
PROF SAIBAL GHOSH (*Alternate*)	
SHRI N. K. MAJUMDAR	Hindustan Steel Works Construction Ltd, Calcutta
SHRI D. M. SRIVASTAVA (*Alternate*)	
SHRI S. M. MUNJAL	DGS & D, Inspection Wing, New Delhi
SHRI A. K. VERMA (*Alternate*)	
SHRI M. K. MUKHERJEE	Indian Roads Congress, New Delhi
SHRI S. K. SINHA (*Alternate*)	
SHRI B. B. NAG	Engineers India Limited, New Delhi
SHRI G. P. LAHIRI (*Alternate*)	
SHRI V. NARAYANAN	Central Water Commission, New Delhi
SHRI A. K. BAJAJ (*Alternate*)	
SHRI P. N. NARKHADE	Bombay Port Trust, Bombay
SHRI M. V. BEDEKAR (*Alternate*)	
DR S. M. PATEL	Birla Vishvakarma Mahavidyala, Vallabh Vidyasagar, Gujarat
SHRI D. P. PAL	M. N. Dastur & Co Pvt Ltd, Calcutta
SHRI B. P. DE (*Alternate*)	
SHRI D. PAUL	Industrial Fasteners Association of India, Calcutta
SHRI N. RADHAKRISHNAN	Binny Ltd, Madras
SHRI P. APPA RAO (*Alternate*)	
SHRI M. B. RANGARAO	Tata Consulting Engineers, Bombay
SHRI M. S. C. NAYAR (*Alternate*)	
SHRI C. S. S. RAO	Engineer-in-Chief's Branch, Ministry of Defence, New Delhi
SHRI P. S. RAY (*Alternate*)	
DR T. V. S. R. APPA RAO	Structural Engineering Research, Madras
SHRI P. R. NATARAJAN (*Alternate*)	

(*Continued on page* 18)

(*Continued from page* 17)

Members	*Representing*
SHRI A. G. ROY	Bridge & Roof Co (India) Ltd, Howrah
SHRI K. B. CHAKRABORTY (*Alternate*)	
SENIOR SHIPPING ENGINEER	Indian Register of Shipping, Bombay
ASSISTANT NAVAL ARCHITECT (*Alternate*)	
SHRI A. K. SEN	Jessop & Co Limited, Calcutta
SHRI G. SREENIVASAN	Bharat Heavy Electricals Ltd, Hyderabad
SHRI P. SURYA (*Alternate*)	
DR C. N. SRINIVASAN	C. R. Narayana Rao, Madras
SHRI C. R. ARVIND (*Alternate*)	
DR D. N. TRIKHA	University of Roorkee, Roorkee
DR P. N. GODBELE (*Alternate*)	
SHRI U. H. VARYANI	Kothari Associates Private Ltd, New Delhi
SHRI J. R. MEHTA Director (Civ Engg)	Director General, BIS (*Ex-officio Member*)

Member Secretary

SHRI S. S. SETHI

Director (Civ Engg, BIS)

Subcommittee for Use of Steel in Over-Head Line Towers and Switchyard Structures, CED 7 : 1

Convener	
SHRI M. L. SACHDEVA	Central Electricity Authority, New Delhi
Members	
SHRI RAIS-UDDIN (*Alternate* to Shri M. L. Sachdeva)	
ADVISOR (POWER)	Central Board of Irrigation and Power, New Delhi
SHRI D. K. NARSIMHAN (*Alternate*)	
SHRI MUSTAG AHMED	Karnataka Electricity Board, Bangalore
SHRI Y. R. NAGARAJA (*Alternate*)	
SHRI D. K. BHATTACHARJEE	Damodar Valley Corporation, Calcutta
SHRI S. K. SINHA (*Alternate*)	
DR P. BOSE	Electrical Manufacturing Ltd (Projects Construction Division), Calcutta
SHRI L. N. BANERJEE (*Alternate*)	
SHRI UMESH CHANDRA	Power Grid Corporation of India Ltd, New Delhi
SHRI D. CHOWDHURY (*Alternate I*)	
SHRI E. V. RAO (*Alternate II*)	
CHIEF ADMINISTRATOR-CUM-ENGINEER-IN-CHIEF	Bihar State Electricity Board, Patna
CHIEF ENGINEER	Andhra Pradesh Electricity Board, Hyderabad
SUPERINTENDING ENGINEER (TRANSMISSION) (*Alternate*)	
SHRI S. DATTA GUPTA	Larsen and Toubro Ltd, Madras
SHRI S. Z. HUSSAIN	Madhya Pradesh Electricity Board, Jabalpur
SHRI ASHOK BAJPAI (*Alternate*)	
JOINT DIRECTOR (BRIDGE AND STRUCTURE)	Ministry of Railways, New Delhi
ASSISTANT DIRECTOR (TI) (*Alternate*)	
SHRI H. C. KAUSHIK	Haryana Electricity Board, Hissar
SHRI LAL KHUBCHANDANI	KEC International Ltd, Bombay
SHRI B. N. PAI (*Alternate*)	
SHRI D. L. KOTHARI	Bhakara Beas Management Board, Patiala
SHRI P. S. TULSI (*Alternate*)	
DR D. M. LAKHAPATI	SAE (India) Ltd, Calcutta
SHRI P. BHATTACHARYA (*Alternate*)	

(*Continued on page* 19)

(*Continued from page* 18)

Members	*Representing*
DR S. N. MANDAL SHRI K. MOHANDAS (*Alternate*)	National Thermal Power Corporation Ltd, New Delhi
SHRI P. R. NATARAJAN SHRI K. MURALIDHARAN (*Alternate*)	Structural Engineering Research Centre, Madras
SHRI R. V. NEDKARNI SHRI K. N. AWATE (*Alternate*)	Maharashtra State Electricity Board, Bombay
SHRI G. D. RATHOD SHRI A. D. TRIVEDI (*Alternate*)	Transpower Engineering Ltd, Bombay
SHRI V. B. SINGH SHRI SURENDRA NARAIN (*Alternate*)	UP State Electricity Board, Lucknow
SHRI B. SRINIVASAN SHRI M. A. MAJEETH (*Alternate*)	Tamil Nadu Electricity Board, Madras
SUPERINTENDING ENGINEER	Punjab State Elecirjcity Board, Patiala
SHRI R. SUSENDRAN SHRI N. V. RAMESH (*Alternate*)	Central Power Research Institute, Bangalore
SHRI S. M. TAKALKAR SHRI D. C. MEHTA (*Alternate*)	Gujarat Electricity Board, Baroda

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Ice loadings on towers and conductors/ground wires for lines located in the mountaineous regions of the country subjected to snow fall, may be taken into account on the basis of available meteorological data both for ice with wind and without wind. A separate Indian Standard on ice loadings to be considered in the design of transmission line towers has been proposed to be brought out.

Formulae and the values have been given in SI Units only.

While formulating the provisions of this code it has been assumed that structural connections are through bolts only.

While preparing this code, practices prevailing in the country in this field have been kept in view. Assistance has been derived from the following publications:

i) IEC 826 : 1991 'Technical report on loading and strength of overhead transmission lines', issued by the International Electrotechnical Commission.

ii) Project report No. EL-643 'Longitudinal unbalanced loads on transmission line structures' issued by the Electric Power Research Institute USA.

iii) CIGRE Report No. 22-13 of 1978 'Failure containment of overhead lines design' by H. B. White.

iv) Loading and strength of transmission line system, Part 1 to Part 6 issued by 'IEEE Transmission and Distribution Committee Sub-Group on Line loading and strength of transmission line structures', IEEE, PES, Summer 1977 Conference Papers.

v) 'Guide for design of steel transmission line towers' issued by American Society of Civil Engineers, New York, 1988.

vi) 'Guide for new code for design of transmission line towers in India; Publication No. 239, issued by the Central Board of Irrigation and Power, New Delhi.

The composition of the technical committee responsible for the formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standara.