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(Incorporating IS : 1911 - 1967)
(Reaffirmed 2008)

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 1 DEAD LOADS — UNIT WEIGHTS OF BUILDING MATERIALS AND STORED MATERIALS

(Second Revision)

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BUREAU OF INDIAN STANDARDS
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AMENDMENT NO. 1 DECEMBER 1997
TO
IS 875 (PART 1) : 1987 CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 1 DEAD LOADS — UNIT WEIGHTS OF BUILDING MATERIALS AND STORED MATERIALS

(Second Revision)

(*Page* 10, *Table* 1, *col* 1, *Item* 39) — Substitute '*Metal sheeting, Protected Galvanized Steel Sheets and Plain*' *for* '*Metal Sheeting, Protected Galvanized Steel Sheets, Plain and Corrugated*'.

(CED 37)

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CONTENTS

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 1 DEAD LOADS — UNIT WEIGHTS OF BUILDING MATERIALS AND STORED MATERIALS

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 1) (Second Revision) was adopted by the Bureau of Indian Standards on 30 October 1987, after the draft finalized by the Structural Safety Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety; and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in this code by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, snow loads and other external loads, the structure would be required to bear. Strict conformity to loading standards recommended in this code, it is hoped, will not only ensure the structural safety of the buildings which are being designed and constructed in the country and thereby reduce the hazards to life and property caused by unsafe structures, but also eliminate the wastage caused by assuming unnecessarily heavy loadings.

0.3 This Indian standard code of practice was first published in 1957 for the guidance of civil engineers, designers and architects associated with planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effect on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs both curved and sloping, were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

0.3.1 With the increased adoption of the code, a number of comments were received on provisions on live load values adopted for different occupancies. Simultaneously, live load surveys have been carried out in America and Canada to arrive at realistic live loads based on actual determination of loading (movable and immovable) in different occupancies. Keeping this in view and other developments in the field of wind engineering, the Sectional Committee responsible for the preparation of the standard has decided to prepare the second revision in the following five parts:

- Part 1 Dead loads
- Part 2 Imposed loads
- Part 3 Wind loads
- Part 4 Snow loads
- Part 5 Special loads and loads combinations

Earthquake load is covered in a separate standard, namely IS : 1893-1984* which should be considered along with the above loads.

0.4 This standard deals with dead loads to be assumed in the design of buildings and same is given in the form of unit weight of materials. The unit weight of other materials that are likely to be stored in a building are also included for the purpose of load calculations due to stored materials.

0.4.1 This standard incorporates IS : 1911† published in 1967. The unit weight of materials incorporated in this standard are based on information available through published Indian standards and various other publications.

0.4.2 The values given in this standard have been rounded off in accordance with IS : 2-1960‡.

*Criteria for earthquake resistant design of structures (*third revision*).

†Schedule of unit weights of building materials (*first revision*).

‡Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This code (Part 1) covers unit weight/mass of materials, and parts or components in a building that apply to the determination of dead loads in the design of buildings.

1.1.1 The unit weight/mass of materials that are likely to be stored in a building are also specified for the purpose of load calculations along with angles of internal friction as appropriate.

NOTE 1 — Table 1 gives the unit weight mass of individual building materials in alphabetical order; Table 2 covers the unit weight mass of parts or components of a building; and Appendix A gives unit weight mass of stored materials.

2. BUILDING MATERIALS

2.1 The unit weight/mass of materials used in building construction are specified in Table 1.

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
1. *Acoustical Material*				
Eelgrass	10	$5{\cdot}70 \times 10^{-3}$ to $7{\cdot}65 \times 10^{-3}$	0·58 to 0·78	m^2
Glass fibre	10	$3{\cdot}80 \times 10^{-3}$	0·39	,,
Hair	10	$19{\cdot}10 \times 10^{-3}$	1·95	,,
Mineral wool	10	$13{\cdot}45 \times 10^{-3}$	1·37	,,
Slag wool	—	2·65	270	m^3
Cork	—	2·35	240	,,
2. *Aggregate, Course*				
Broken stone ballast :				
Dry, well-shaken	—	15·70 to 18·35	1 600 to 1 870	,,
Perfectly wet	—	18·85 to 21·95	1 920 to 2 240	,,
Shingles, 3 to 38 mm	—	14·35	1 460	,,
Broken bricks:				
Fine	—	14·20	1 450	,,
Coarse	—	9·90	1 010	,,
Foam slag (foundry pumice)	—	6·85	700	,,
Cinder*	—	7·85	800	,,
3. *Aggregate, Fine*				
Sand:				
Dry, clean	—	15·10 to 15·70	1 540 to 1 600	,,
River	—	18·05	1 840	,,
Wet	—	17·25 to 19·60	1 760 to 2 000	,,
Brick dust (*SURKHI*)	—	9·90	1 010	,,
4. *Aggregate, Organic*				
Saw dust, loose	—	1·55	160	,,
Peat:				
Dry	—	5·50 to 6·30	560 to 640	,,
Sandy, compact	—	7·85	800	,,
Wet, compact	—	13·35	1 360	,,
5. *Asbestos*				
Felt	10	0·145	15	m^2
Fibres:				
Pressed	—	9·40	960	m^3
Sprayed	10	0·02	2	m^2
Natural	—	29·80	3 040	m^3
Raw	—	5·90 to 8·85	600 to 900	,,
6. *Asbestos Cement Building Pipes* (*see* under 41 'Pipes' in this table)				

*Also used for filling purposes.

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS		
		kN	kg	per
(1)	(2)	(3)	(4)	(5)
7. *Asbestos Cement Gutters* [*see* IS : 1626 (Part 2)-1980*]				
Boundry wall gutters:				
400 × 150 × 250 mm	12·5	0·16	16·0	m
450 × 150 × 300 mm	12·5	0·16	16·0	,,
300 × 150 × 225 mm	12·5	0·13	13·0	,,
275 × 125 × 175 mm	10·0	0·085	8·5	,,
Valley gutters:				
900 × 200 × 225 mm	12·5	0·245	24·8	,,
600 × 150 × 225 mm	12·5	0·160	16·1	,,
450 × 125 × 150 mm	12·5	0·145	14·6	,,
400 × 125 × 250 mm	12·5	0·130	13·2	,,
Half round gutters:				
150 mm	9·5	0·043	4·4	,,
250 mm	9·5	0·079	8·1	,,
300 mm	9·5	0·087	8·9	,,
8. *Asbestos Cement Pressure Pipes*				
(*see* under 41 'Pipes' in this table)				
9. *Asbestos Cement Sheeting* (*see* IS : 459-1970†)				
Corrugated (pitch = 146 mm)	6	0·118 to 0·130	12·0 to 13·3	m²
Semi-corrugated (pitch = 340 mm)	6	0·118 to 0·127	12·0 to 13·0	,,
Plain	5	0·09	9·16	,,
10. *Bitumen*	—	0·102	10·40	m²
11. *Blocks*				
Lime-based solid blocks (*see* IS : 3115-1978‡)	—	8·65 to 12·55	880 to 1 280	,,
Hollow (open and closed cavity concrete blocks) [*see* IS : 2185 (Part 1)-1979§]				
Grade A (load bearing)	—	1·41	144	,,
Grade B (load bearing)	—	1·41 to 0·94	144 to 96	,,
Grade C (non-load bearing)	—	1·41 to 0·94	144 to 96	,,
Solid concrete blocks	—	17·65	1 800	,,
12. *Boards*				
Cork boards:				
Compressed	10	0·04	4	m²
Ordinary	10	0·02	2	,,
Fibre building boards (*see* IS : 1658-1977‖)				
Medium hardboard	6	0·028 to 0·047	2·88 to 4·80	,,
	8	0·038 to 0·063	3·84 to 6·40	,,
	10	0·047 to 0·078	4·80 to 8·00	,,
	12	0·056 to 0·095	5·76 to 9·60	,,

*Specification for asbestos cement building pipes and pipe fittings, gutters and gutter fittings and roofing fittings: Part 2 Gutters and gutter fittings (*first revision*).

†Specification for unreinforced corrugated and semi-corrugated asbestos cement sheets (*second revision*).

‡Specification for lime based block (*first revision*).

§Specification for concrete masonry units: Part 1 Hollow and solid concrete blocks (*second revision*).

‖Specification for fibre hardboards (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Standard hardboard	3	0·024 to 0·035	2·40 to 3·60	m²
	4	0·031 to 0·047	3·20 to 4·80	,,
	5	0·039 to 0·059	4·00 to 6·00	,,
Tempered hardboard	6	0·047 to 0·071	4·80 to 7·20	,,
	9	0·071 to 0·106	7·20 to 10·80	,,
Fire insulation board (*see* IS : 3348-1965*)	9	0·035	3·6	,,
	12	0·047	4·8	,,
Fibre insulation board, ordinary or flame-retardant type, bitumen-bounded fibre insulation board	18	0·071	7·2	,,
	25	0·098	10·0	,,
Gypsum plaster boards (*see* IS : 2095-1982†)	9·5	0·069 to 0·098	7·0 to 10·0	,,
	12·5	0·093 to 0·147	9·5 to 15·0	,,
	15	0·110 to 0·154	11·25 to 15·75	,,
Insulating board (fibre)	12	0·034	3·5	,,
Laminated board (fibre)	6	0·034	3·5	,,
Wood particle boards (*see* IS : 3087-1985‡) Designation:				
FPSI	—	4·90 to 8·85	500 to 900	m³
FPTH	—	4·90 to 8·85	500 to 900	,,
XPSO	—	4·90 to 8·85	500 to 900	,,
XPTU	—	4·90 to 8·85	500 to 900	,,
Wood particle boards for insulation purposes (*see* IS : 3129-1985§)	—	3·90	400	,,
High density wood particle boards (*see* IS : 3478-1966‖)				
Type 1, Grade A	—	0·117	12	m²
Type 1, Grade B	—	0·088	9	,,
Type 2, Grade A	—	0·117	12	,,
Type 2, Grade B	—	0·088	9	,,

NOTE 1 — Density of medium hardboard varies from 350 to 800 kg/m³.

NOTE 2 — Density of normal hardboard varies from 800 to 1 200 kg/m³.

NOTE 3 — Density of tempered hardboard varies according to treatment. The actual value may be had from the manufacturers.

NOTE 4 — All the three types of hardboards are manufactured to width of 1·2 m.

13. *Bricks*				
Common burnt clay bricks (*see* IS : 1077-1987¶)	—	15·70 to 18·85	1 600 to 1 920	m³
Engineering bricks	—	21·20	2 160	,,
Heavy duty bricks (*see* IS : 2180-1985**)	—	24·50	2 500	,,
Pressed bricks	—	17·25 to 18·05	1 760 to 1 840	,,
Refractory bricks	—	17·25 to 19·60	1 760 to 2 000	,,
Sand cement bricks	—	18·05	1 840	,,
Sand lime bricks	—	20·40	2 080	,,
14. *Brick Chips and Broken Bricks* (*see* under 2 'Broken bricks' in this table)				
15. *Brick Dust (SURKHI)*	—	9·90	1 010	,,

*Specification for fibre insulation boards.
†Specification for gypsum plaster boards (*first revision*).
‡Specification for wood particle boards (medium density) for general purposes (*first revision*).
§Specification for low density particle boards (*first revision*).
‖Specification for high density wood particle boards.
¶Specification for common burnt clay building bricks (*fourth revision*).
**Specification for heavy-duty burnt clay building bricks (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

Material	Nominal Size or Thickness mm	Weight/Mass kN	kg	per
(1)	(2)	(3)	(4)	(5)
16. *Cast Iron, Manhole Covers* (*see* IS : 1726*)				
Double triangular (HD)	500	1·16	118	Cover
	560	1·37	140	,,
Circular (HD)	500	1·16	118	,,
	560	1·37	140	,,
Circular (MD)	500	0·57	58	,,
	560	0·63	64	,,
Rectangular (MD)	—	0·78	80	,,
Rectangular (LD) :				
Single seal (Pattern 1)	—	0·23	23	,,
(Pattern 2)	—	0·15	15	,,
Double seal	—	0·28	29	,,
Square (LD) :				
Single seal	455	0·13	13	,,
	610	0·25	26	,,
Double seal	455	0·23	23	,,
	610	0·36	37	,,
17. *Cast Iron, Manhole Frames* (*see* IS : 1726*)				
Double triangular (HD)	500	1·09	111	Frame
	560	1·13	115	,,
Circular (HD)	500	0·83	85	,,
	560	1·06	108	,,
Circular (MD)	500	0·57	58	,,
	560	0·63	64	,,
Rectangular (MD)	—	0·63	64	,,
Rectangular (LD) :				
Single seal (Pattern 1)	—	0·15	15	,,
(Pattern 2)	—	0·10	10	,,
Double seal	—	0·23	23	,,
Square (LD) :				
Single seal	455	0·07	7	,,
	610	0·13	13	,,
Double seal	455	0·15	15	,,
	610	0·18	18	,,
18. *Cast Iron Pipes* (*see* under 41 'Pipes' in this table)				
19. *Cement* (*see* IS : 269-1976†)				
Ordinary and aluminous	—	14·10	1 440	m³
Rapid-hardening	—	12·55	1 280	,,
20. *Cement Concrete, Plain*				
Aerated	—	7·45	760	,,
No-fines, with heavy aggregate	—	15·70 to 18·80	1 600 to 1 920	,,
No-fines, with light aggregate	—	8·65 to 12·55	880 to 1 280	,,
With burnt clay aggregate	—	17·25 to 21·20	1 760 to 2 160	,,
With expanded clay aggregate	—	9·40 to 16·50	960 to 1 680	,,
With clinker aggregate	—	12·55 to 17·25	1 280 to 1 760	,,
With pumice aggregate	—	5·50 to 11·00	560 to 1 120	,,
With sand and gravel or crushed natural stone aggregate	—	22·00 to 23·50	2 240 to 2 400	,,
With saw dust	—	6·30 to 16·50	640 to 1 680	,,
With foamed slag aggregate	—	9·40 to 18·05	960 to 1 840	,,

*Specification for cast iron manhole covers and frames.

†Specification for ordinary and low heat Portland cement (*third revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL			NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)			(2)	(3)	(4)	(5)
21. *Cement Concrete, Prestressed* (conforming to IS : 1343-1980*)			—	23·50	2 400	m³
22. *Cement Concrete, Reinforced* With sand and gravel or crushed natural stone aggregate:						
With 1 percent steel			—	22·75 to 24·20	2 310 to 2 470	,,
With 2 percent steel			—	23·25 to 24·80	2 370 to 2 530	,,
With 5 percent steel			—	24·80 to 26·50	2 530 to 2 700	,,
23. *Cement Concrete Pipes* (*see* under 41 'Pipes' in this table)						
24. *Cement Mortar*			—	20·40	2 080	,,
25. *Cement Plaster*			—	20·40	2 080	,,
26. *Cork*			—	2·35	240	,,
27. *Expanded Metal* (conforming to IS : 412-1975†)						
Reference No.	Size of Mesh, Nominal SWM mm	LWM mm				
1	100	250		0·030	3.08	m²
2	100	250		0·024	2·47	,,
3	100	250		0·016	1·60	,,
4	75	200		0·042	4·28	,,
5	75	200		0·032	3·29	,,
6	75	200		0·021	2·14	,,
7	40	115		0·080	8·02	,,
8	40	115		0·060	6·17	,,
9	40	75		0·060	6·17	,,
10	40	75		0·028	2·85	,,
11	40	115		0·039	4·01	,,
12	40	75		0·039	4·01	,,
13	40	115		0·020	2·04	,,
14	40	75		0·020	2·04	,,
15	25	75		0·054	5·53	,,
16	25	75		0·038	3·93	,,
17	25	75		0·028	2·81	,,
18	25	75		0·021	2·19	,,
19	20	60		0·070	7·15	,,
20	20	50		0·070	7·15	,,
21	20	60		0·050	5·09	,,
22	20	50		0·050	5·09	,,
23	20	60		0·036	3·63	,,
24	20	50		0·036	3·63	,,
25	20	60		0·021	2·18	,,
26	20	50		0·021	2·18	,,
27	12·5	50		0·050	5·04	,,
28	12·5	40		0·050	5·04	,,
29	12·5	50		0·040	4·00	,,
30	12·5	50		0·030	3·13	,,
31	12·5	40		0·030	3·13	,,
32	12·5	50		0·025	2·50	,,
33	12·5	40		0·025	2·50	,,
34	10	40		0·050	5·98	,,
35	10	40		0·035	3·59	,,
36	10	40		0·028	2·87	,,

*Code of practice for prestressed concrete (*first revision*).

†Specification for expanded metal steel sheets for general purposes (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm		WEIGHT/MASS kN	kg	per
(1)	(2)		(3)	(4)	(5)
Reference No.	Size of Mesh, Nominal SWM mm	LWM mm			
37	9.5	28·5	0·050	5·19	m²
38	9·5	28·5	0·028	2·81	,,
39	9·5	28·5	0·020	2·09	,,
40	6	25	0·074	7·55	,,
41	6	25	0·048	4·88	,,
42	6	25	0·038	3·90	,,
43	5	20	0·050	5·01	,,
44	3	15	0·041	4·28	,,
28. *Felt, Bituminous for Waterproofing and Damp-proofing* (*see* IS : 1322-1982*)					
Fibre base:					
Type 1 (Underlay)	—		$8{\cdot}34 \times 10^{-3}$	0·85	,,
Type 2 (Self-finished felt):					
Grade 1	—		$21{\cdot}48 \times 10^{-3}$	2·19	,,
Grade 2	—		$30{\cdot}21 \times 10^{-3}$	3·08	,,
Hessian base:					
Type 3 (Self-finished felt):					
Grade 1	—		$21{\cdot}87 \times 10^{-3}$	2·23	,,
Grade 2	—		$35{\cdot}70 \times 10^{-3}$	3·64	,,

NOTE 1 — The weight of untreated based shall be taken as in the dry condition.

NOTE 2 — The weights given above are indicative of the total weight of ingredients used in the manufacture of felt and not of the ingredients determined from a physical analysis of the finished material.

29. *Foam Slag, Foundry Pumice*	—		6·85	700	m³
30. *Glass* (*see* IS : 2835-1977†)					
Sheet	2·0		0·049	5·0	,,
	2·5		0·062	6·3	,,
	3·0		0·074	7·5	,,
	4·0		0·098	10·0	,,
	5·0		0·123	12·5	,,
	5·5		0·134	13·7	,,
	6·5		0·167	17·0	,,
31. *Gutters, Asbestos Cement* (*see* under 7 'Asbestos cement gutter' in this table)					
32. *Gypsum*					
Gypsum mortar	—		11·75	1 200	m³
Gypsum powder	—		13·89 to 17·25	1 410 to 1 760	,,
33. *Iron*					
Pig	—		70·60	7 200	,,
Gray, cast	—		68·95 to 69·90	7 030 to 7 130	,,
White, cast	—		74·30 to 75·70	7 580 to 7 720	,,
Wrought	—		75·50	7 700	,,
34. *Lime*					
Lime concrete with burnt clay aggregate	—		18·80	1 920	,,

*Specification for bitumen felts for waterproofing and damp-proofing (*third revision*).

†Specification for flat transparent sheet glass (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

Material	Nominal Size or Thickness mm	Weight/Mass kN	kg	per
(1)	(2)	(3)	(4)	(5)
Lime mortar	—	15·70 to 18·05	1 600 to 1 840	m^3
Lime plaster	—	17·25	1 760	,,
Lime stone in lumps, uncalcined	—	12·55 to 14·10	1 280 to 1 440	,,
Lime, unslaked, freshly burnt in pieces	—	8·60 to 10·20	880 to 1 040	,,
Lime slaked, fresh	—	5·70 to 6·30	580 to 640	,,
Lime slaked, after 10 days	—	7·85	800	,,
Lime, unslaked (*KANKAR*)	—	11·55	1 180	,,
Lime, slaked (*KANKAR*)	—	10·00	1 020	,,
35. *Linoleum* (*see* IS : 653-1980*)				
Sheets and tiles	4·4	0·056 9	5·8	m^2
	3·2	0·040 2	4·1	,,
	2·0	0·026 5	1·7	,,
	1·6	0·021 5	2·2	,,
36. *Masonry, Brick*				
Common burnt clay bricks	—	18·85	1 920	m^3
Engineering bricks	—	23·55	2 400	,,
Glazed bricks	—	20·40	2 080	,,
Pressed bricks	—	22·00	2 240	,,
37. *Masonry, Stone*				
Cast	—	22·55	2 300	,,
Dry rubble	—	20·40	2 080	,,
Granite ashlar	—	25·90	2 640	,,
Granite rubble	—	23·55	2 400	,,
Lime stone ashlar	—	25·10	2 560	,,
Marble dressed	—	26·50	2 700	,,
Sand stone	—	22·00	2 240	,,
38. *Mastic Asphalt*	10	0·215	22	m^2
39. *Metal Sheeting, Protected Galvanized Steel Sheets, Plain and Corrugated* (*see* IS : 277-1985†)				
Class 1	1·60	0·131	13·31	,,
	1·26	0·104	10·56	,,
	1·00	0·084	8·60	,,
	0·80	0·069	7·03	,,
	0·63	0·056	5·70	,,
Class 2	1·60	0·129	13·16	,,
	1·25	0·102	10·41	,,
	1·00	0·083	8·45	,,
	0·80	0·067	6·88	,,
	0·63	0·054	5·55	,,
Class 3	1·60	0·128	13·01	,,
	1·25	0·101	10·26	,,
	1·00	0·081	8·30	,,
	0·80	0·066	6·73	,,
	0·63	0·053	5·40	,,
Class 4	1·60	0·127	12·94	,,
	1·25	0·100	10·19	,,
	1·00	0·081	8·22	,,
	0·80	0·065	6·66	,,
	0·63	0·052	5·32	,,
40. *Mortar*				
Cement	—	20·40	2 080	m^3
Gypsum	—	11·80	1 200	,,
Lime	—	15·70 to 18·05	1 600 to 1 840	,,

*Specification for linoleum sheets and tiles (*second revision*).
†Specification for galvanized steel sheets (plain and corrugated) (*fourth revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
41. *Pipes*				
Asbestos cement pipes [*see* IS : 1626 (Part) 1-1980*]	50	0·032 to 0·034	3·3 to 3·5	m
	60	0·032 to 0·043	3·3 to 4·4	,,
	80	0·051 to 0·054	5·2 to 5·5	,,
	90	0·052 to 0·060	5·3 to 6·1	,,
	100	0·058 to 0·065	5·9 to 6·6	,,
	125	0·072 to 0·086	7·3 to 8·8	,,
	150	0·086 to 0·108	8·8 to 11·0	,,
Asbestos cement pressure pipes (*see* IS : 1592-1980†)	50	0·056	5·7	,,
	80	0·067	6·8	,,
	100	0·090	9·2	,,
	125	0·139	14·2	,,
	150	0·175	17·8	,,
	200	0·264	26·9	,,
	250	0·380	38·8	,,
	300	0·539	55	,,
Cast iron pipes:				
Rainwater pipes (*see* IS : 1230-1979‡)				
Standard overall length 1·8 m with socket	50	0·073	7·5	pipe
	75	0·108	11·0	,,
	100	0·137	14·0	,,
	125	0·196	20·0	,,
	150	0·255	26·0	,,
Standard overall length 1·5 m with socket	50	0·064	6·5	,,
	75	0·093	9·5	,,
	100	0·123	12·5	,,
	125	0·172	17·5	,,
	150	0·230	23·5	,,
Pressure pipes for water, gas and sewage:				
a) Centrifugally cast (*see* IS : 1536-1976§)				
i) Socket and spigot pipes:				
Barrel:				
Class LA	80	1·144	14·7	m
	100	0·182	18·6	,,
	125	0·237	24·2	,,
	150	0·295	30·1	,,
	200	0·432	44·0	,,
	250	0·582	59·3	,,
	300	0·750	76·5	,,
	350	0·944	96·3	,,
	400	1·146	116·9	,,
	450	1·383	141·0	,,
	500	1·620	165·2	,,
	600	2·156	219·8	,,
	700	2·778	283·2	,,
	750	3·111	317·2	,,
Class A	80	0·157	16·0	,,
	100	0·201	20·5	,,
	125	0·259	26·4	,,
	150	0·326	33·2	,,
	200	0·472	48·1	,,
	250	0·637	65·0	,,
	300	0·824	84·0	,,
	350	1·030	105·0	,,
	400	1·262	128·7	,,
	450	1·530	156·0	,,
	500	1·775	181·0	,,

*Specification for asbestos cement buildings pipes and pipe fittings, gutters and gutter fittings and roofing fittings: Part 1 Pipes and pipe fittings (*first revision*).

†Specification for asbestos cement pressure pipes (*second revision*).

‡Specification for cast iron rainwater pipes and fittings (*second revision*).

§Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

Material	Nominal Size or Thickness mm	Weight/Mass kN	kg	per
(1)	(2)	(3)	(4)	(5)
Class A	600	2·367	241·4	m
	700	3·056	311·6	,,
	750	3·422	348·9	,,
Class B	80	0·172	17·3	,,
	100	0·216	22·0	,,
	125	0·281	28·7	,,
	150	0·352	35·9	,,
	200	0·511	52·1	,,
	250	0·692	70·6	,,
	300	0·896	91·4	,,
	350	1·122	114·5	,,
	400	1·368	139·5	,,
	450	1·657	169·0	,,
	500	1·929	196·7	,,
	600	2·578	262·9	,,
	700	3·317	338·2	,,
	750	3·733	380·6	,,
Sockets for Class LA, Class A and Class B barrels	80	0·054	5·5	Socket
	100	0·069	7·1	,,
	125	0·090	9·2	,,
	150	0·113	11·5	,,
	200	0·165	16·8	,,
	250	0·225	22·9	,,
	300	0·292	29·8	,,
	350	0·368	37·5	,,
	400	0·454	46·3	,,
	450	0·549	56·0	,,
	500	0·647	66·0	,,
	600	0·876	89·3	,,
	700	1·145	116·8	,,
	750	1·292	131·7	,,
ii) Flanged pipe with screwed flanges:				
Barrel:				
Class A	80 to 300	Same as for centrifugally cast socket and spigot pipes, Class A		
Class B	80 to 300	Same as for centrifugally cast socket and spigot pipes, Class B		
Flanges for Class A and Class B barrels	80	0·042	4·3	Flange
	100	0·049	5·0	,,
	125	0·065	6·6	,,
	150	0·080	8·2	,,
	200	0·112	11·4	,,
	250	0·144	14·7	,,
	300	0·182	18·6	,,
b) Vertically cast socket and spigot pipes (*see* IS : 1537-1976*)				
Barrel:				
Class A	80 to 750	Same as for centrifugally cast socket and spigot pipes, Class A		
	800	3·82	389	m
	900	4·65	474	,,
	1 000	5·59	570	,,
	1 100	6·59	672	,,
	1 200	7·67	783	,,
	1 500	11·98	1 222	,,
Class B	80 to 750	Same as for centrifugally cast socket and spigot pipes, Class B		
	800	4·15	423	m
	900	5·07	516	,,
	1 000	6·07	619	,,
	1 100	7·23	739	,,
	1 200	8·35	851	,,
	1 500	13·07	1 333	,,

*Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

Material	Nominal Size or Thickness mm	Weight/Mass kN	kg	per
(1)	(2)	(3)	(4)	(5)
	80 to 750	Same as for centrifugally cast socket and spigot pipes, Class A and Class B		
Socket for Class A and Class B barrels	800	1·45	147	Socket
	900	1·79	182	,,
	1 000	2·18	222	,,
	1 100	2·60	265	,,
	1 200	3·07	313	,,
	1 500	4·91	501	,,
c) Sand cast (flanged pipes):				
Barrel:				
Class A	80 to 750	Same as for centrifugally cast socket and spigot pipes, Class A		
	800 to 1 500	Same as for vertically cast socket and spigot pipes, Class A		
Class B	80 to 750	Same as for centrifugally cast socket and spigot pipes, Class B		
	800 to 1 500	Same as for vertically cast socket and spigot pipes, Class B		
Flanges for Class A and Class B Barrels	80	0·036	3·7	Flange
	100	0·041	4·2	,,
	125	0·052	5·3	,,
	150	0·066	6·7	,,
	200	0·091	9·3	,,
	250	0·117	12·0	,,
	300	0·145	14·8	,,
	350	0·186	19·4	,,
	400	0·229	23·4	,,
	450	0·250	26·5	,,
	500	0·315	32·1	,,
	600	0·431	44·0	,,
	700	0·587	59·9	,,
	750	0·685	69·8	,,
	800	0·792	80·8	,,
	900	0·928	94·6	,,
	1 000	1·18	120·0	,,
	1 100	1·38	139·0	,,
	1 200	1·70	173·0	,,
	1 500	2·71	276·2	,,
Concrete pipes (*see* IS : 458-1971*)				
Class NP1 (unreinforced non-pressure pipes)	80	0·19	19	m
	100	0·22	22	,,
	150	0·30	31	,,
	250	0·40	41	,,
	300	0·69	70	,,
	350	0·84	86	,,
	400	0·95	97	,,
	450	1·17	119	,,
Class NP2 (reinforced concrete, light duty, non-pressure pipes)	80	0·196	20	,,
	100	0·235	24	,,
	150	0·324	33	,,
	250	0·510	52	,,
	300	0·736	75	,,
	350	0·902	92	,,
	400	1·02	104	,,
	450	1·26	128	,,
	500	1·38	141	,,
	600	1·89	193	,,
	700	2·19	223	,,
	800	2·81	287	,,
	900	3·51	358	,,

*Specification for concrete pipes (with and without reinforcement) (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Class NP2 (reinforced concrete, light duty, non-pressure pipes)	1 000	4·30	438	m
	1 100	5·15	525	,,
	1 200	6·09	620	,,
	1 400	8·18	834	,,
	1 600	9·93	1 013	,,
	1 800	12·58	1 283	,,
Class NP3 (reinforced concrete, heavy duty, non-pressure pipes)	350	2·35	240	,,
	400	2·63	269	,,
	450	2·91	297	,,
	500	3·19	325	,,
	600	4·02	410	,,
	700	4·61	470	,,
	800	5 92	604	,,
	900	7·39	754	,,
	1 000	8·13	829	,,
	1 100	10·34	1 054	,,
	1 200	11·18	1 140	,,
Class P1 (reinforced concrete pressure pipes safe for 20 MPa pressure tests)	80	0·196	20	,,
	100	0·235	24	,,
	150	0·324	33	,,
	250	0·510	52	,,
	300	0·736	75	,,
	350	0·902	92	,,
	400	1·02	104	,,
	450	1·26	128	,,
	500	1·38	141	,,
	600	1·89	193	,,
	700	2·19	223	,,
	800	2·81	287	,,
	900	3·51	358	,,
	1 000	4·30	437	,,
	1 100	5·15	525	,,
	1 200	6·09	620	,,
Class P2 (reinforced concrete pressure pipes safe for 40 MPa pressure tests)	80	0·196	20	,,
	100	0·235	24	,,
	150	0·324	33	,,
	250	0·608	63	,,
	300	1·01	103	,,
	350	1·31	134	,,
	400	1·67	170	,,
	450	1·84	188	,,
	500	1·56	261	,,
	600	3·20	326	,,
Class P3 (reinforced concrete pressure pipes safe for 60 MPa pressure tests)	80	0·196	20	,,
	100	0·235	24	,,
	150	0·324	33	,,
	250	0·736	75	,,
	300	1·15	117	,,
	350	1·65	168	,,
	400	2·04	204	,,
Lead pipes [*see* IS : 404 (Part 1)-1977*] (service and distribution pipes to be laid underground) :				
For working pressure 40 MPa	10	0·018	1·87	,,
	15	0·031	3·13	,,
	20	0·042	4·24	,,
	25	0·060	6·11	,,
	32	0·074	7·50	,,
	40	0·091	9·28	,,
	50	0·142	14 45	,,

*Specification for lead pipes: Part 1 For other than chemical purposes (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
For working pressure 70 MPa	10	0·022	2·26	m
	15	0·038	3·83	,,
	20	0.050	5·11	,,
	25	0·069	7·03	,,
	32	0·126	12·80	,,
	40	0·175	17·82	,,
For working pressure 100 MPa	10	0·029	2·96	,,
	15	0·048	4·88	,,
	20 (*see* Note below)	0·067	6·86	,,
	25 (*see* Note below)	0·105	10·75	,,
Service pipes to be fixed or laid above ground:				
For working pressure 40 MPa	10	0·014	1·45	,,
	15	0·021	2·15	,,
	20	0·027	2·74	,,
	25	0·036	3·67	,,
	32	0·059	6·00	,,
	40	0·091	9·28	,,
	50	0·142	14·45	,,
For working pressure 70 MPa	10	0·018	1·81	,,
	15	0·024	2·47	,,
	20	0·030	3·11	,,
	25	0·069	7·03	,,
	32	0·126	12·80	,,
	40	0·175	17·82	,,
For working pressure 100 MPa	10	0·029	2·96	,,
	15	0·048	4·88	,,
	20 (*see* Note below)	0·067	6·86	,,
	25 (*see* Note below)	0·105	10·75	,,
Cold water distribution pipes to be fixed or laid above ground:				
For working pressure 25 MPa	10	0·014	1·45	,,
	15	0·021	2·15	,,
	20	0·027	2·74	,,
	25	0·036	3·67	,,
	32	0·048	4·85	,,
	40	0·067	6·79	,,
	50	0·084	8·53	,,
For working pressure 40 MPa	10	0·014	1·45	,,
	15	0·021	2·15	,,
	20	0·027	2·74	,,
	25	0·036	3·67	,,
	32	0·059	6·00	,,
	40	0·091	9·29	,,
	50	0·142	14·45	,,
Hot water distribution pipes to be fixed or laid above ground:				
For working pressure 20 MPa	10	0·015	1·50	,,
	15	0·023	2·34	,,
	20	0·031	3·13	,,
	25	0·041	4·13	,,
	32	0·062	6·30	,,
	40	0·082	8·38	,,
	50	0·142	14·45	,,

NOTE — The maximum working pressure for these sizes is 90 MPa.

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS – *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
For working pressure 35 MPa	10	0·015	1.50	m
	15	0·027	2·34	,,
	20	0·045	4·56	,,
	25	0·085	8·69	,,
	32	0·132	13·51	,,
Soil, waste, and soil and waste ventilation pipes	50	0·050	5·07	,,
	75	0·073	7·48	,,
	100	0·097	9·88	,,
	150	0·160	16·36	,,
Flushing and warning pipes	20	0·020	2·09	,,
	25	0·025	2·56	,,
	32	0·032	3·28	,,
	40	0·039	3·95	,,
	50	0·049	5·07	,,
Gas pipes:				
Heavy weight gas pipes	10	0·008	0·81	,,
	15	0·017	1·70	,,
	20	0·025	2·60	,,
	25	0·034	3·44	,,
	32	0·045	4·57	,,
	40	0·061	6·27	,,
	50	0·071	7·20	,,
Light weight gas pipes	10	0·008	0·81	,,
	15	0·012	1·21	,,
	20	0·020	2·09	,,
	25	0·029	2·99	,,
	32	0·037	3·74	,,
	40	0·047	4·76	,,
	50	0·058	5·87	,,
Stoneware, salt-glazed pipes (*see* IS : 651-1980*)	100	0·137	14	,,
	150	0·216	22	,,
	200	0·324	33	,,
	230 (*see* Note below)	0·412	42	,,
	250	0·510	52	,,
	300	0·775	79	,,
	350	0·980	100	,,
	400	1·26	128	,,
	450	1·44	147	,,
	500	1·77	180	,,
	600	2·35	240	,,
42. *Plaster* (*see also* 6 'Finishing' in Table 2)				
Cement	—	20·40	2 080	m^3
Lime	—	17·25	1 760	,,
Acoustic	10	0·078	8	m^2
Anhydrite	10	0·206	21	,,
Barium sulphate	10	0·284	29	,,
Fibrous	10	0·088	9	,,
Gypsum	10	0·186	19	,,
43. *Sheeting*				
Asbestos (*see* under 9 'Asbestos cement sheeting' in this table)				
Galvanized iron (*see* under 39 'Metal sheeting, protected' in this table)				
Glass (*see* under 30 'Glass' in this table)				
Plywood	1	0·007	0·7	,,

NOTE — This is non-preferred size and its manufacture is permitted for a limited period.

*Specification for salt-glazed stoneware pipes and fittings (*fourth revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
44. *Slagwool*	—	2·65	270	m³
45. *Soils and Gravels*				
Aluvial ground, undisturbed	—	15·69	1 600	,,
Broken stone ballast:				
Dry, well-shaken	—	15·70 to 18·35	1 600 to 1 870	,,
Perfectly wet	—	18·85 to 21·95	1 920 to 2 240	,,
Chalk	—	15·70 to 18·85	1 600 to 1 920	,,
Clay:				
China, compact	—	21·95	2 240	,,
Clay fills:				
Dry, lumps	—	10·20	1 040	,,
Dry, compact	—	14·10	1 440	,,
Damp, compact	—	17·25	1 760	,,
Wet, compact	—	20·40	2 080	,,
Undisturbed	—	18·85	1 920	,,
Undisturbed, gravelly	—	20·40	2 080	,,
Earth:				
Dry	—	13·85 to 18·05	1 410 to 1 840	,,
Moist	—	15·70 to 19·60	1 600 to 2 000	,,
Gravel:				
Loose	—	15·70	1 600	,,
Rammed	—	18·85 to 21·20	1 920 to 2 160	,,
Kaolin, compact	—	25·50	2 600	,,
Loam:				
Dry, loose	—	11·75	1 200	,,
Dry, compact	—	15·70	1 600	,,
Wet, compact	—	18·85	1 920	,,
Loess, dry	—	14·10	1 440	,,
Marl, compact	—	17·25 to 18·85	1 760 to 1 920	,,
Mud, river, wet	—	17·25 to 18·85	1 760 to 1 920	,,
Peat:				
Dry	—	5·50 to 6·30	560 to 640	,,
Sandy, compact	—	7·85	800	,,
Wet, compact	—	13·35	1 360	,,
Rip-rap	—	12·55 to 14·10	1 280 to 1 440	,,
Sand:				
Dry, clean	—	15·10 to 15·70	1 540 to 1 600	,,
River	—	18·05	1 840	,,
Wet	—	17·25 to 19·60	1 760 to 2 000	,,
Shingles:				
Aggregate 3 to 38 mm	—	13·75	1 400	,,
Fine sand:				
Dry	—	15·70	1 600	,,
Saturated	—	20·40	2 080	,,
Silt, wet	—	17·25 to 18·85	1 760 to 1 920	,,
46. *Steel Sections*				
Hot rolled [*see* IS : 808 (Part 1)-1978*]				
Beams — Designation				
MB 100	—	0·113	11·5	m
MB 125	—	0·131	13·4	,,
MB 150	—	0·147	15·0	,,
MB 175	—	0·191	19·5	,,
MB 200	—	0·249	25·4	,,
MB 225	—	0·306	31·2	,,

*Dimensions for hot-rolled steel sections: Part 1 MB series (beams) (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Beams — Designation				
MB 250	—	0·365	37·3	m
MB 300	—	0·452	46·1	,,
MB 350	—	0·514	52·4	,,
MB 400	—	0·604	61·6	,,
MB 450	—	0·710	72·4	,,
MB 500	—	0·852	86·9	,,
MB 550	—	1·00	104	,,
MB 600	—	1·21	123	,,
Columns — Designation [*see* IS : 808 (Part 2)-1978*]				
SC 100	—	0·196	20·0	,,
SC 120	—	0·257	26·2	,,
SC 140	—	0·327	33·3	,,
SC 160	—	0·411	41·9	,,
SC 180	—	0·495	50·5	,,
SC 200	—	0·591	60·3	,,
SC 220	—	0·690	70·4	,,
SC 250	—	0·839	85·6	,,
Channels — Designation [*see* IS : 808 (Part 3)-1979†]				
Medium weight channel sections with sloping flanges				
MC 75	—	0·070	7·14	,,
MC 100	—	0·098	10·0	,,
MC 125	—	0·165	16·8	,,
MC 150	—	0·192	19·6	,,
MC 175	—	0·219	22·3	,,
MC 200	—	0·256	26·1	,,
MC 225	—	0·300	30·6	,,
MC 250	—	0·356	36·3	,,
MC 300	—	0·419	42·7	,,
MC 350	—	0·491	50·1	,,
MC 400	—			
Medium weight channel sections with parallel flanges (*see* Note below)				
MCP 75	—	0·070	7·14	,,
MCP 100	—	0·094	9·56	,,
MCP 125	—	0·128	13·1	,,
MCP 150	—	0·165	16·8	,,
MCP 175	—	0·192	19·6	,,
MCP 200	—	0·219	22·3	,,
MCP 225	—	0·256	26·1	,,
MCP 250	—	0·300	30·6	,,
MCP 300	—	0·356	36·3	,,
MCP 350	—	0·419	42·7	,,
MCP 400	—	0·491	50·1	,,
Equal leg angles — Size [*see* IS : 800 (Part 5)-1976‡]				
ISA 2020	3·0	0·009	0·9	m
	4·0	0·011	1·1	,,
ISA 2525	3·0	0·011	1·1	,,
	4·0	0·014	1·4	,,
	5·0	0·018	1·8	,,
ISA 3030	3·0	0·014	1·4	,,
	4·0	0·018	1·8	,,
	5·0	0·022	2·2	,,

NOTE — These sections are steel in the developmental stage and may be available subject to agreement with the manufacturer.

*Dimensions for hot-rolled steel sections: Part 2 Columns — SC series (*second revision*).
†Dimensions for hot-rolled steel sections: Part 3 Channels, MC and MPC series (*second revision*).
‡Dimensions of hot-rolled steel sections: Part 5 Equal leg angles (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
ISA 3535	3·0	0·016	1·6	m
	4·0	0·021	2·1	,,
	5·0	0·026	2·6	,,
	6·0	0·029	3·0	,,
ISA 4050	3·0	0·018	1·8	,,
	4·0	0·024	2·4	,,
	5·0	0·029	3·0	,,
	6·0	0·034	3·5	,,
ISA 4545	3·0	0·021	2·1	,,
	4·0	0·027	2·7	,,
	5·0	0·033	3·4	,,
	6·0	0·039	4·0	,,
ISA 5050	3·0	0·023	2·3	,,
	4·0	0·029	3·0	,,
	5·0	0·037	3·8	,,
	6·0	0·044	4·5	,,
ISA 5555	5·0	0·040	4·1	,,
	6·0	0·048	4·9	,,
	8·0	0·063	6·4	,,
	10·0	0·077	7·9	,,
ISA 6060	5·0	0·044	4·5	,,
	6·0	0·053	5·4	,,
	8·0	0·069	7·0	,,
	10·0	0·084	8·6	,,
ISA 6565	5·0	0·048	4·9	,,
	6·0	0·057	5·8	,,
	8·0	0·076	7·7	,,
	10·0	0·092	9·4	,,
ISA 7070	5·0	0·052	5·3	,,
	6·0	0·062	6·3	,,
	8·0	0·081	8·3	,,
	10·0	0·100	10·2	,,
ISA 7575	5·0	0·056	5·7	,,
	6·0	0·067	6·8	,,
	8·0	0·087	8·9	,,
	10·0	0·108	11·0	,,
ISA 8080	6·0	0·072	7·3	,,
	8·0	0·094	9·6	,,
	10·0	0·116	11·8	,,
	12·0	0·137	14·0	,,
ISA 9050	6·0	0·080	8·2	,,
	8·0	0·106	10·8	,,
	10·0	0·131	13·4	,,
	12·0	0·155	15·8	,,
ISA 100100	6·0	0·090	9·2	,,
	8·0	0·119	12·1	,,
	10·0	0·146	14·9	,,
	12·0	0·174	17·7	,,
ISA 110110	8·0	0·131	13·4	,,
	10·0	0·163	16·6	,,
	12·0	0·193	19·7	,,
	16·0	0·252	25·7	,,
ISA 130130	8·0	0·156	15·9	,,
	10·0	0·193	19·7	,,
	12·0	0·230	23·5	,,
	16·0	0·301	30·7	,,
ISA 150150	10·0	0·225	22·9	,,
	12·0	0·268	27·3	,,
	16·0	0·351	35·8	,,
	20·0	0·432	44·1	,,
ISA 200200	12·0	0·362	36·9	,,
	16·0	0·476	48·5	,,
	20·0	0·588	60·0	,,
	25·0	0·725	73·9	,,

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Unequal leg angles — Size [*see* IS : 808 (Part 6)-1976*]				
ISA 3020	3·0	0·011	1·1	m
	4·0	0·014	1·4	,,
	5·0	0·018	1·8	,,
ISA 4025	3·0	0·015	1·5	,,
	4·0	0·019	1·9	,,
	5·0	0·024	2·4	,,
	6·0	0·027	2·8	,,
ISA 4530	3·0	0·017	1·7	,,
	4·0	0·022	2·2	,,
	5·0	0·027	2·8	,,
	6·0	0·032	3·3	,,
ISA 5030	3·0	0·018	1·8	,,
	4·0	0·024	1·8	,,
	5·0	0·029	3·0	,,
	6·0	0·034	3·5	,,
ISA 6040	5·0	0·036	3·7	,,
	6·0	0·043	4·4	,,
	8·0	0·057	5·8	,,
ISA 6545	5·0	0·040	4·1	,,
	6·0	0·048	4·9	,,
	8·0	0·063	6·4	,,
ISA 7045	5·0	0·042	4·3	,,
	6·0	0·051	5·2	,,
	8·0	0·066	6·7	,,
	10·0	0·081	8·3	,,
ISA 7550	5·0	0·046	4·7	,,
	6·0	0·055	5·6	,,
	8·0	0·073	7·4	,,
	10·0	0·088	9·0	,,
ISA 8050	5·0	0·048	4·9	,,
	6·0	0·058	5·9	,,
	8·0	0·076	7·7	,,
	10·0	0·092	9·4	,,
ISA 9060	6·0	0·067	6·8	,,
	8·0	0·087	8·9	,,
	10·0	0·108	11·0	,,
	12·0	0·128	13·0	,,
ISA 10065	6·0	0·074	7·5	,,
	8·0	0·087	9·9	,,
	10·0	0·120	12·2	,,
ISA 10075	6·0	0·078	8·0	,,
	8·0	0·103	10·5	,,
	10·0	0·127	13·0	,,
	12·0	0·151	15·4	,,
ISA 12571	6.0	0·090	9·2	,,
	8·0	0·119	12·1	,,
	10·0	0·146	14·9	,,
ISA 12595	6·0	0·099	10·1	,,
	8·0	0·131	13·4	,,
	10·0	0·162	16·5	,,
	12·0	0·193	19·7	,,
ISA 15075	8·0	0·134	13·7	,,
	10·0	0·167	17·2	,,
	12·0	0·198	20·2	,,
ISA 150115	8·0	0·160	16·3	,,
	10·0	0·197	20·1	,,
	12·0	0·235	24·0	,,
	16·0	0·308	31·4	,,
ISA 200100	10·0	0·225	22·9	,,
	12·0	0·268	27·3	,,
	16·0	0·351	35·8	,,

*Dimensions of hot-rolled steel sections: Part 6 Unequal leg angles (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

Material	Nominal Size or Thickness mm	Weight/Mass kN	kg	per
(1)	(2)	(3)	(4)	(5)
ISA 200150	10·0	0·264	26·9	m
	12·0	0·315	32·1	,,
	16·0	0·414	42·2	,,
	20·0	0·510	52·0	,,
Cold formed light gauge structural steel sections (*see* IS : 811-1965*) :				
Light gauge sections — angles				
Size:				
100 × 100	3·15	0·047	4·81	,,
	4·0	0·060	6·07	,,
80 × 80	2·5	0·030	3·05	,,
	3·15	0·037	3·82	,,
	4·0	0·047	4·82	,,
60 × 60	2·0	0·018	1·82	,,
	2·5	0·022	2·26	,,
	3·15	0·028	2·83	,,
	4·0	0·035	3·56	,,
50 × 50	1·6	0·012	1·21	,,
	2·0	0·015	1·51	,,
	2·5	0·018	1·87	,,
	3·15	0·023	2·34	,,
	4·0	0·029	2·93	,,
40 × 40	1·2	0·007	0·75	,,
	1·6	0·009	0·96	,,
	2·0	0·012	1·19	,,
	2·5	0·014	1·48	,,
	3·15	0·018	1·84	,,
30 × 30	1·2	0·005	0·56	,,
	1·6	0·007	0·71	,,
	2·0	0·009	0·88	,,
	2·5	0·010	1·08	,,
20 × 20	1·2	0·004	0·36	,,
	1·6	0·005	0·46	,,
	2·0	0·006	0·56	,,
Channels without lips				
Size:				
100 × 100	3·15	0·070	7·15	,,
	4·0	0·088	9·01	,,
80 × 80	2·5	0·044	4·52	,,
	3·15	0·056	5·66	,,
	4·0	0·070	7·12	,,
60 × 60	2·0	0·026	2·69	,,
	2·5	0·033	3·35	,,
	3·15	0·041	4·18	,,
	4·0	0·051	5·24	,,
50 × 50	1·6	0·018	1·79	,,
	2·0	0·022	2·23	,,
	2·5	0·027	2·76	,,
	3·15	0·034	3·44	,,
	4·0	0·042	4·30	,,
40 × 40	1·25	0·011	1·12	,,
	1·6	0·014	1·42	,,
	2·0	0·017	1·75	,,
	2·5	0·021	2·17	,,
	3·15	0·026	2·70	,,
30 × 30	1·21	0·008	0·82	,,
	1·6	0·010	1·04	,,
	2·0	0·013	1·28	,,
	2·5	0·015	1·58	,,

*Specification for cold formed light gauge structural steel sections (*revised*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Channels without lips				
Size:				
20 × 20	1·25	0·005	0·53	m
	1·6	0·007	0·66	,,
	2·0	0·008	0·81	,,
200 × 50	2·00	0·045	4·58	,,
	2·50	0·056	5·70	,,
	3·15	0·070	7·14	,,
	4·00	0·088	9·01	,,
180 × 50	2·00	0·042	4·27	,,
	2·50	0·052	5·31	,,
	3·15	0·065	6·65	,,
	4·00	0·082	8·38	,,
160 × 50	2·00	0·039	3·95	,,
	2·50	0·048	4·92	,,
	3·15	0·060	6·16	,,
140 × 40	1·60	0·026	2·67	,,
	2·00	0·033	3·33	,,
	2·50	0·041	4·13	,,
	3·15	0·051	5·17	,,
120 × 40	1·60	0·024	2·42	,,
	2·00	0·030	3·01	,,
	2·50	0·037	3·74	,,
100 × 40	1·25	0·017	1·70	,,
	1·60	0·021	2·17	,,
	2·00	0·026	2·70	,,
	2·50	0·033	3·35	,,
80 × 30	1·25	0·013	1·31	,,
	1·60	0·016	1·67	,,
	2·00	0·020	2·07	,,
	2·50	0·025	2·56	,,
60 × 30	1·25	0·011	1·12	,,
	1·60	0·014	1·42	,,
	2·00	0·017	1·75	,,
50 × 30	1·25	0·010	1·02	,,
	1·60	0·013	1·29	,,
	2·00	0·016	1·60	,,
Channels with lips				
Size:				
100 × 100	2·00	0·051	5·24	,,
	2·50	0·063	6·50	,,
	3·15	0·082	8·36	,,
	4·00	0·103	10·48	,,
80 × 80	1·60	0·033	3·33	,,
	2·00	0·041	4·14	,,
	2·50	0·052	5·32	,,
	3·15	0·065	6·62	,,
60 × 60	1·25	0·019	1·94	,,
	1·60	0·024	2·45	,,
	2·00	0·031	3·20	,,
	2·50	0·039	3·95	,,
50 × 50	1·25	0·016	1·64	,,
	1·60	0·020	2·08	,,
	2·00	0·025	2·57	,,
40 × 40	1·25	0·013	1·35	,,
	1·60	0·017	1·70	,,
	2·00	0·020	2·09	,,
30 × 30	1·25	0·009	0·95	,,
	1·60	0·012	1·20	,,

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Channels with lips				
Size:				
200 × 80	1·60	0·047	4·84	m
	2·00	0·059	6·02	"
	2·50	0·075	7·67	"
	3·15	0·094	9·59	"
	4·00	0·118	12·05	"
180 × 80	1·60	0·045	4·59	"
	2·00	0·056	5·71	"
	2·50	0·071	7·28	"
	3·15	0·089	9·10	"
	4·00	0·112	11·42	"
160 × 80	1·60	0·043	4·34	"
	2·00	0·053	5·39	"
	2·50	0·068	6·89	"
	3·15	0·084	8·60	"
	4·00	0·106	10·79	"
140 × 70	1·60	0·038	3·84	"
	2·00	0·047	4·76	"
	2·50	0·058	5·91	"
	3·15	0·075	7·61	"
	4·00	0·094	9·54	"
120 × 60	1·25	0·025	2·52	"
	1·60	0·031	3·21	"
	2·00	0·041	4·14	"
	2·50	0·050	5·12	"
	3·15	0·063	6·38	"
100 × 50	1·25	0·021	2·13	"
	1·60	0·027	2·71	"
	2·00	0·033	3·35	"
	2·50	0·043	4·34	"
80 × 40	1·25	0·017	1·74	"
	1·60	0·022	2·20	"
	2·00	0·027	2·72	"
60 × 30	1·25	0·012	1·25	"
	1·60	0·015	1·57	"
50 × 30	1·25	0·011	1·15	"
	1·60	0·014	1·45	"
Hat sections				
Size:				
100 × 100	2·50	0·068	6·89	"
	3·15	0·089	9·05	"
	4·00	0·115	11·73	"
80 × 80	2·00	0·043	4·39	"
	2·50	0·056	5·71	"
	3·15	0·072	7·36	"
60 × 60	1·60	0·026	2·63	"
	2·00	0·034	3·45	"
	2·50	0·043	4·34	"
50 × 50	1·60	0·022	2·25	"
	2·00	0·028	2·88	"
40 × 40	1·25	0·013	1·36	"
	1·60	0·018	1·83	"
100 × 50	1·60	0·034	3·51	"
	2·00	0·044	4·45	"
	2·50	0·054	5·51	"
80 × 40	1·25	0·021	2·15	"
	1·60	0·028	2·83	"
	2·00	0·034	3·51	"
60 × 30	1·25	0·016	1·64	"
	1·60	0·020	2·08	"
50 × 25	1·25	0·013	1·35	"
100 × 150	3·15	0·101	10·28	"
	4·00	0·134	13·68	"

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN		per
		kN	kg	per
(1)	(2)	(3)	(4)	(5)
Hat sections Size:				
80 × 120	3·15	0·089	9·08	m
	4·00	0·113	11·48	,,
60 × 90	2·50	0·050	5·12	,,
	3·15	0·067	6·82	,,
	4·00	0·084	8·59	,,
50 × 75	2·00	0·033	3·37	,,
	2·50	0·043	4·44	,,
	3·15	0·055	5·64	,,
40 × 60	1·60	0·021	2·14	,,
	2·00	0·028	2·82	,,
	2·50	0·035	3·55	,,
Rectangular box sections Size:				
200 × 100	1·60	0·072	7·35	,,
	2·00	0·0[illegible]0	9·16	,,
180 × 90	1·60	0·065	6·60	,,
	2·00	0·081	8·22	,,
160 × 80	1·60	0·057	5·85	,,
	2·00	0·071	7·28	,,
140 × 70	1·60	0·050	5·09	,,
	2·00	0·062	6·34	,,
120 × 60	1·60	0·043	4·34	,,
	2·00	0·053	5·39	,,
100 × 50	1·25	0·028	2·82	,,
	1·60	0·035	3·58	,,
80 × 40	1·25	0·022	2·23	,,
	1·60	0·028	2·83	,,
60 × 30	1·25	0·016	1·64	,,
	1·60	0·020	2·08	,,
50 × 30	1·25	0·014	1·44	,,
	1·60	0·018	1·83	,,
Square box section Size:				
200 × 200	1·60	0·097	9·86	,,
	2·00	0·121	12·30	,,
180 × 180	1·60	0·087	8·86	,,
	2·00	0·108	11·04	,,
160 × 160	1·60	0·764	77·85	,,
	2·00	0·096	9·79	,,
140 × 140	1·60	0·067	6·85	,,
	2·00	0·084	8·53	,,
120 × 120	1·60	0·057	5·85	,,
	2·00	0·071	7·28	,,
100 × 100	1·25	0·037	3·80	,,
	1·60	0·047	4·84	,,
80 × 80	1·25	0·030	3·01	,,
	1·60	0·038	3·84	,,
60 × 60	1·25	0·022	2·23	,,
	1·60	0·028	2·83	,,
50 × 50	1·25	0·018	1·84	,,
	1·60	0·023	2·33	,,
Rolled steel tee bars (*see* IS : 1173-1978*) Designation				
ISNT 20	—	0·009	0·9	,,
ISNT 30	—	0·014	1·4	,,
ISNT 40	—	0·034	3·5	,,
ISNT 50	—	0·044	4·5	,,
ISNT 60	—	0·053	5·4	,,
ISNT 80	—	0·094	9·6	,,
ISNT 100	—	0·147	15·0	,,
ISNT 150	—	0·223	22·8	,,

*Specification for hot-rolled and slit steel tee bars (*second revision*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Designation				
ISHT 75	—	0·150	15·3	m
ISHT 100	—	0·196	20·0	,,
ISHT 125	—	0·269	27·4	,,
ISHT 150	—	0·288	29·4	,,
ISST 100	—	0·079	8·1	,,
ISST 150	—	0·154	15·7	,,
ISST 200	—	0·279	28·4	,,
ISST 250	—	0·368	37·5	,,
ISLT 50	—	0·040	4·0	,,
ISLT 75	—	0·070	7·1	,,
ISLT 100	—	0·125	12·7	,,
ISJT 75	—	0·034	3·5	,,
ISJT 87·5	—	0·039	4·0	,,
ISJT 100	—	0·049	5·0	,,
ISJT 112·5	—	0·063	6·4	,,
Steel sheet piling sections (*see* IS : 2314-1963*)				
Designation				
ISPS 1 021 Z	—	0.483	49·25	,,
ISPS 1 625 U	—	0·641	65·37	,,
ISPS 2 222 U	—	0·811	82·70	,,
ISPS 100 F	—	0·541	55·20	,,
47. *Stone*				
Agate	—	25·50	2 600	m³
Aggregate	—	15·70 to 18·85	1 600 to 1 920	
Basalt	—	27·95 to 29·05	2 850 to 2 960	,,
Cast	—	21·95	2 240	,,
Chalk	—	21·50	2 190	,,
Dolomite	—	28·25	2 880	,,
Emery	—	39·25	4 000	,,
Flint	—	25·40	2 590	,,
Gneiss	—	23·55 to 26·40	2 400 to 2 690	,,
Granite	—	25·90 to 27·45	2 640 to 2 800	,,
Gravel:				
Loose	—	15·70	1 600	,,
Moderately rammed, dry	—	18·85	1 920	,,
Green stone	—	28·25	2 880	,,
Gypsum	—	21·95 to 23·55	2 240 to 2 400	,,
Laterite	—	20·40 to 23·55	2 080 to 2 400	,,
Lime stone	—	23·55 to 25·90	2 400 to 2 640	,,
Marble	—	26·70	2 720	,,
Pumice	—	7·85 to 11·00	800 to 1 120	,,
Quartz rock	—	25·90	2 640	,,
Sand stone	—	21·95 to 23·54	2 240 to 2 400	,,
Slate	—	27·45	2 800	,,
Soap stone	—	26·45	2 700	,,
48. *Tar, Coal*				
Crude (*see* IS : 212-1983†)	—	9·90	1 010	,,
Naphtha, light (*see* IS : 213-1968‡)	—	9·90	1 010	,,
Naphtha, heavy	—	9·90	1 010	,,
Road tar (*see* IS : 215-1961§)	—	9·90	1 010	,,
Pitch (*see* IS : 216-1961‖)	—	9·90	1 010	,,
49. *Thermal Insulation*				
Unbonded glass wool	—	12·75 to 23·55	1 300 to 2 400	,,
Unbonded rock and slag wool	—	11·30 to 19·60	1 150 to 2 000	,,
Expanded polystyrene	—	1·45 to 2·95	150 to 300	,,
Cellular concrete				
Grade A	—	Up to 29·40	Up to 3 000	,,
Grade B	—	29·50 to 39·20	3 010 to 4 000	,,
Grade C	—	39·30 to 49·00	4 010 to 5 000	,,
Preformed calcium silicate insulation (for temperature up to 650°C)	—	19·60 to 34·30	2 000 to 3 500	,,

*Specification for steel sheet piling sections.
†Specification for crude coal tar for general use (*second revision*).
‡Specification for coal-based napntha (*first revision*).
§Specification for road tar (*revised*).
‖Specification for coal tar pitch (*revised*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
50. *Terra Cotta*	—	18·35 to 23·25	1 870 to 2 370	m^3
51. *Terrazzo*				
Paving	10	0·24	24	m^2
Cast partitions	40	0·93	95	,,
52 *Tiles*				
Mangalore pattern (*see* IS : 654-1972*)	—	0·02 to 0·03	2 to 3	Tile
Polystyrene wall tiles (*see* IS : 3463-1966†)	99 × 99	0·013	1·35	m^2
	148·5 × 148·5	0·013	1·35	,,
53. *Timber*				
Typical Indian timbers (*see* IS : 399-1963‡)				
Aglaia	—	8·34	850	m^3
Aini	—	5·83	595	,,
Alder	—	3·63	370	,,
Amari	—	6·13	625	,,
Amla	—	7·85	800	,,
Amra	—	4·41	450	,,
Anjan	—	8·33	850	,,
Arjun	—	7·99	815	,,
Ash	—	7·06	720	,,
Axlewood	—	8·82	900	,,
Babul	—	7·70	785	,,
Baen	—	7·70	785	,,
Bahera	—	7·99	815	,,
Bakota	—	4·21	430	,,
Balasu	—	7·55	770	,,
Ballagi	—	11·13	1 135	,,
Banati	—	4·41	450	,,
Benteak	—	6·62	675	,,
Ber	—	6·91	705	,,
Bhendi	—	7·55	770	,,
Bijasal	—	7·85	800	,,
Birch	—	6·13	625	,,
Black chuglam	—	7·85	800	,,
Black locust	—	8·34	850	,,
Blue gum	—	8·34	850	,,
Blue pine	—	5·05	515	,,
Bola	—	6·42	655	,,
Bonsum	—	5·20	530	,,
Bullet wood	—	8·78	895	,,
Casuarina	—	8·34	850	,,
Cettis	—	6·42	655	,,
Champ	—	4·85	495	,,
Chaplash	—	5·05	515	,,
Chatian	—	4·07	415	,,
Chikrassy	—	6·62	675	,,
Chilauni	—	6·42	655	,,
Chilla	—	7·85	800	,,
Chir	—	5·64	575	,,
Chuglam:				
Black	—	7·85	800	,,
White (silver grey-wood)	—	6·91	705	,,
Cinnamon	—	6·42	655	,,
Cypress	—	5·05	515	,,
Debdaru	—	6·28	640	,,
Deodar	—	5·35	545	,,
Devdam	—	7·06	720	,,
Dhaman:				
Grewia tiliofolia	—	7·70	785	,,
Grewia vestita	—	7·40	755	,,
Dhup	—	6·42	655	,,
Dilenia	—	6·13	625	,,

*Specification for clay roofing tiles, Mangalore pattern (*second revision*).

†Specification for polystyrene wall tiles.

‡Classification of commercial timbers and their zonal distribution (*revised*).

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
(1)	(2)	(3)	(4)	(5)
Dudhi	—	5·49	560	m^3
Ebony	—	8·19	835	,,
Elm	—	5·20	530	,,
Eucalyptus	—	8·33	850	,,
Figs	—	4·56	465	,,
Fir	—	4·14	450	,,
Frash	—	6·62	675	,,
Gamari	—	5·05	515	,,
Gardenia	—	7·40	755	,,
Garuga	—	5·98	610	,,
Geon	—	4·07	415	,,
Gluta	—	7·06	720	,,
Gokul	—	4·07	415	,,
Grewia sp.	—	7·55	770	,,
Gurjan	—	7·70	785	,,
Gutel	—	4·41	450	,,
Haldu	—	6·62	675	,,
Hathipaila	—	5·84	595	,,
Hiwar	—	7·70	785	,,
Hollock	—	5·98	610	,,
Hollong	—	7·21	735	,,
Hoom	—	7·21	735	,,
Horse chestnut	—	5·05	515	,,
Imli	—	8·97	915	,,
Indian Chestnut	—	6·28	640	,,
Indian Hemlock	—	3·92	400	,,
Indian Oak	—	8·48	865	,,
Indian Olive	—	10·35	1 065	,,
Irul	—	8·33	850	,,
Jack	—	5·83	595	,,
Jaman	—	7·70	785	,,
Jarul	—	6·13	625	,,
Jathikai	—	5·05	515	,,
Jhingan	—	5·63	575	,,
Jutili	—	7·85	800	,,
Kadam	—	4·85	495	,,
Kail	—	5·05	515	,,
Kaim	—	6·42	655	,,
Kambli	—	4·07	415	,,
Kanchan	—	6·62	675	,,
Kanjuj	—	5·84	595	,,
Karada	—	8·34	850	,,
Karal	—	7·99	815	,,
Karani	—	6·28	640	,,
Karar	—	5·34	545	,,
Kardahi	—	9·27	945	,,
Karimgotta	—	3·92	400	,,
Kasi	—	5·83	595	,,
Kasum	—	10·84	1 105	,,
Kathal	—	5·85	595	,,
Keora	—	6·13	625	,,
Khair	—	9·90	1 010	,,
Khasipine	—	5·05	515	,,
Kindal	—	7·55	770	,,
Kokko	—	6·28	640	,,
Kongoo	—	9·76	995	,,
Kuchla	—	8·63	880	,,
Kumbi	—	7·70	785	,,
Kurchi	—	5·20	530	,,
Kurung	—	9·76	995	,,
Kusum	—	11·28	1 150	,,
Kuthan	—	4·71	480	,,
Lakooch	—	6·28	640	,,
Lambapatti	—	5·34	545	,,
Lampati	—	5·05	515	,,
Laurel	—	8·33	850	,,
Lendi	—	7·40	755	,,
Machilus:				
Gamblei	—	5·05	515	,,
Macrantha	—	5·20	530	,,
Maharukh	—	4·07	415	,,

(*Continued*)

TABLE 1 UNIT WEIGHT OF BUILDING MATERIALS — *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS		
		kN	kg	per
(1)	(2)	(3)	(4)	(5)
Mahogany	—	6·62	675	m³
Mahua	—	8·97	915	,,
Maina	—	5·64	575	,,
Makai	—	3·14	320	,,
Malabar neem	—	4·41	450	,,
Mango	—	6·77	690	,,
Maniawga	—	7·40	755	,,
Maple	—	5·64	575	,,
Mesua	—	9·76	995	,,
Milla	—	9·12	930	,,
Mokha	—	7·99	815	,,
Mulberry	—	6·62	675	,,
Mullilam	—	7·21	735	,,
Mundani	—	6·77	690	,,
Murtenga	—	7·70	785	,,
Myrabolan	—	9·27	945	,,
Narikel	—	5·49	560	,,
Nedunar	—	5·05	515	,,
Oak	—	8·48	865	,,
Padauk	—	7·06	720	,,
Padri	—	7·06	720	,,
Palang	—	5·98	610	,,
Pali	—	6·28	640	,,
Papita	—	3·28	335	,,
Parrotia	—	8·48	865	,,
Persian lilac	—	5·84	595	,,
Piney	—	6·13	625	,,
Ping	—	8·97	915	,,
Pinus insignis	—	6·13	625	,,
Pipli	—	5·83	595	,,
Pitraj	—	6·77	690	,,
Poon	—	6·42	655	,,
Poplar	—	4·41	450	,,
Pula	—	3·78	385	,,
Pyinma	—	5·98	610	,,
Rajbrikh	—	8·48	865	,,
Red sanders	—	10·84	1 105	,,
Rohini	—	11·33	1 155	,,
Rosewood (black wood)	—	8·19	835	,,
Rudrak	—	4·71	480	,,
Sal	—	8·48	865	,,
Salai	—	5·64	575	,,
Sandal wood	—	8·97	915	,,
Sandan	—	8·34	850	,,
Satin wood	—	9·41	960	,,
Saykaranji	—	7·40	755	,,
Seleng	—	4·85	495	,,
Semul	—	3·78	385	,,
Silver oak	—	6·28	640	,,
Siris	—	3·92	400	,,
Kala-siris	—	7·21	735	,,
Safed-siris	—	6·28	640	,,
Sisso	—	7·70	785	,,
Spruce	—	4·71	480	,,
Suji	—	2·65	270	,,
Sundri	—	9·41	960	,,
Talauma	—	5·64	575	,,
Tanaku	—	2·99	305	,,
Teak	—	6·28	640	,,
Toon	—	5·05	515	,,
Udal	—	2·50	255	,,
Upas	—	3·14	320	,,
Uriam	—	7·40	755	,,
Vakai	—	9·41	960	,,
Vellapine	—	5·83	595	,,
Walnut	—	5·64	575	,,
White bombwe	—	5·98	610	,,
White cedar	—	7·06	720	,,
White chuglam (silver grey-wood)	—	6·91	705	,,
White dhup	—	4·22	430	,,
Yon	—	8·33	850	,,

NOTE—The unit of timbers correspond to average unit weight of typical Indian timbers at 12 percent moisture content.

54. *Water*				
Fresh	—	9·81	1 000	m³
Salt	—	10·05	1 025	,,
55. *Wood-Wool Building Slabs*	10	0·059	6	,,

3. BUILDING PARTS AND COMPONENTS

3.1 The unit weights of building parts or components are specified in Table 2.

TABLE 2 UNIT WEIGHTS OF BUILDING PARTS OR COMPONENTS

Material	Nominal Size or Thickness mm	Weight/Mass kN	kg	per
1. *Ceilings*				
Plaster on tile or concrete	1·3 cm	0·25	25	m²
Plaster on wood lath	2·5 cm	0·39	40	,,
Suspended metal lath and cement plaster	2·5 cm	0·74	75	,,
Suspended metal lath and gypsum plaster	2·5 cm	0·49	50	,,
2. *Cement Concrete, Plain* (*see* 20 'Cement concentrate, plain' in Table 1)				
3. *Cement Concrete, Reinforced* (*see* 21 Cement concrete, reinforced' in Table 1)				
4. *Damp-Proofing* (*see* 28 'Felt bituminous for waterproofing and damp-proofing' in Table 1)				
5. *Earth Filling* (*see* 45 'Soils and gravels' in Table 1)				
6. *Finishing* (*see also* 'Floor finishes' given under 7 'Flooring' and 8 'Roofing' in Table 1)				
Aluminium foil	—	← Negligible →		
Plaster:				
Acoustic	10	0·08	8	m²
Anhydrite	10	0·21	21	,,
Barium sulphate	10	0·28	29	,,
Fibrous	10	0·09	9	,,
Gypsum or lime	10	0·19	19	,,
Hydraulic lime or cement	10	0·23	23	,,
Plaster ceiling on wire netting	10	0·26	27	,,
Note — When wood or metal lathing is used, add	—	0·06	6	,,
7. *Flooring*				
Asphalt flooring	10	0·22	22	,,
Note — For macadam finish, add	10	0·26	27	,,
Compressed cork	10	0·04	4	,,
Floors, structural:				
Hollow clay blocks including reinforcement and mortar jointing between blocks, but excluding any concrete topping	100	1·47	150	,,
	125	1·67	170	,,
	150	1·86	190	,,
	175	2·16	220	,,
	200	2·55	260	,,
Note — Add extra for concrete topping				
Hollow clay blocks including reinforcement and concrete ribs between blocks, but excluding any concrete topping	100	1·18	120	,,
	115	1·27	130	,,
	125	1·37	140	,,
	140	1·47	150	,,
	150	1·57	160	,,
	175	1·76	180	,,
	200	1·96	200	,,

Note — Add extra for concrete topping.

(Continued)

TABLE 2 UNIT WEIGHTS OF BUILDING PARTS OR COMPONENTS - *Contd*

MATERIAL	NOMINAL SIZE OR THICKNESS mm	WEIGHT/MASS kN	kg	per
Hollow concrete units including any concrete topping necessary for constructional purposes	100	1·67	170	m²
	125	1·96	200	,,
	150	2·16	220	,,
	175	2·35	240	,,
	200	2·65	270	,,
	230	3·14	320	,,
Floors, wood:				
Hard wood	22	0·16	16	,,
	28	0·20	20·5	,,
Soft wood	22	0·11	11	,,
	28	0·13	13·5	,,
Weight of mastic used in laying wood block flooring	—	0·015	1·5	,,
NOTE — All thicknesses are 'finished thicknesses'.				
Floor finishes:				
Clay floor tiles (*see* IS : 1478-1969*)	12·5 to 25·4	0·10 to 0·2	10 to 20	,,
NOTE — This weight is 'as laid' but excludes screeding.				
Magnesium oxychloride:				
Normal type (saw dust filler)	10	0·142	14·5	,,
Heavy duty type (mineral filler)	10	0·216	22	,,
Parquet flooring	—	0·08 to 0·12	8 to 12	,,
Rubber (*see* IS : 809-1970†)	3·2	0·048 to 0·062	4·9 to 6·3	,,
	4·8	0·070 to 0·09	7·1 to 9·5	,,
	6·4	0·093 to 0·130	9·5 to 13·2	,,
Terra cotta, filled 'as laid'	—	5·54 to 7·06	570 to 720	m³
Terrazzo paving 'as laid'	10	0·23	24	m²
8. *Roofing*				
Asbestos cement sheeting (*see* 'Asbestos cement sheeting' in Table 1).				
Allahabad tiles (single) including battens (*see* Note below)	—	0·83	85	,,
Allahabad tiles (double) including battens (*see* Note below)	—	1·67	170	,,
Country tiles (single) with battens (*see* Note below)	—	0·69	70	,,
Country tiles (double) with battens (*see* Note below)	—	1·18	120	,,
Mangalore tiles with battens (*see* Note below)	—	0·64	65	,,
Mangalore tiles bedded in mortar over flat tiles (*see* Note below)	—	1·08	110	,,
Mangalore tiles with flat tiles (*see* Note below)	—	0·78	80	,,
Copper sheet roofing including laps and rolls	0·56	0·08	8	,,
	0·72	0·10	10	,,
Flat Roofs:				
Clay tiles hollow (*see* 7 'Flooring' in this table)				
Concrete hollow precast (*see* 7 'Flooring' in this table)				
Galvanized iron sheeting (*see* 39 'Metal sheeting, protected' in Table 1)				
Glazed Roofing:				
Glazing with aluminium alloy bars for spans up to 3 m	6·4	0·19	19·5	,,
Glazing with lead-covered steel bars at 0·6 m centres	6·4	0·25 to 0·28	26 to 29	,,
States on battens	—	0·34 to 0·49	35 to 50	,,
Thatch with battens	—	0·34 to 0·49	35 to 50	,,

NOTE — Weights acting vertically on horizontal projection to be multiplied by cosine of roof angle to obtain weights normal to the roof surface.

*Specification for clay flooring tiles (*first revision*).
†Specification for rubber flooring materials for general purposes (*first revision*).

(*Continued*)

TABLE 2 UNIT WEIGHTS OF BUILDING PARTS OR COMPONENTS -- *Contd*

Material	Nominal Size or Thickness mm	Weight/Mass kN	kg	per
Roof finishes:				
Bitumen mecadam	10	0·22	22	m²
Felt roofing (*see* 28 'Felt, bituminous for water-proofing and damp-proofing' in Table 1)	10	0·008	0·8	,,
Glass silk, quilted	0·5	0·05	5	,,
Lead sheet	0·8	0·07	7	,,
Mortar screeding	10	0·21	21	,,
9. *Walling* (IS : 6072-1971*)				
Autoclaved reinforced cellular concrete wall slabs				
Class A	—	8·35 to 9·80	850 to 1 000	m³
Class B	—	7·35 to 8·35	750 to 850	,,
Class C	—	6·35 to 7·35	650 to 750	,,
Class D	—	5·40 to 6·35	550 to 650	,,
Class E	—	4·40 to 5·40	450 to 550	,,
Brick masonry (*see* 36 'Masonry, brick' in Table 1)				
Concrete blocks (*see* 11 'Block' in Table 1)				
Stone masonry (*see* 37 'Masonry, stone' in Table 1)				
Partitions:				
Brick wall	100	1·91	195	m²
Cinder concrete	75	1·13	115	,,
Galvanized iron sheet	—	0·15	15	,,
Hollow glass block (bricks)	100	0·88	90	,,
Hollow blocks per 200 mm of thickness:				
Ballast or stone concrete	20	0·201	20·5	,,
Clay	20	0·201	20·5	,,
Clinker concrete	20	0·220	22·5	,,
Coke breeze concrete	20	9·176	18	,,
Diatomaceous earth	20	0·093	9·5	,,
Gypsum	20	0·137	14	,,
Pumice concrete	20	0·177	18	,,
Slag concrete, air-cooled	20	0·196	20	,,
Slag concrete, foamed	20	0·186	19	,,
Lath and plaster	—	0·392	40	,,
Solid blocks per 20 mm of thickness:				
Ballast or stone	20	0·451	46	,,
Clinker concrete	20	0·300	30·5	,,
Coke breeze concrete	20	0·221	22·5	,,
Pumice concrete	20	0·221	22·5	,,
Slag concrete, foamed	20	0·250	25·5	,,
Terrazzo cast partitions	40	0·932	95	,,
Timber studding plastered	—	9·981	100	,,

NOTE — For unit weight of fixtures and fittings required to buildings including builder's hardware, reference may be made to appropriate Indian standards.

*Specification for autoclaved reinforced cellular concrete wall slabs.

4. STORE AND MISCELLANEOUS MATERIALS

4.1 Units weights of store and miscellaneous materials intended for dead load calculations and other general purposes are given in Appendix A.

APPENDIX A

[*Clauses* 1.1.1 (*Note*) *and* 4.1]

UNIT WEIGHTS OF STORE AND MISCELLANEOUS MATERIALS

Material	Weight/Mass		Angle of Friction, Degrees
	kN/m^3	kg/m^3	
1. *Agricultural and Food Products*			
Butter	8.45	860	—
Coffee in bags	5·50	560	—
Drinks in bottles, in boxes	7·35	750	—
Eggs, packed	2·95	300	—
Eats, oil	5·80	590	—
Fish meal	4·90	500	45
Flour in sacks up to 1 m height	2·20 to 5·90	225 to 600	—
Forage (bales)	1·25	125	—
Fruits	3·45	350	—
Grains:			
Barley	6·75	690	27
Corn, shelled	7·55	770	27
Flax seed	7·35	750	30
Oats	5·30	540	30
Rice	6 55	670	33
Soyabeans	7·35	750	30
Wheat	8·15	830	28
Wheat flour	6·85	700	30
Grain sheaves up to 4 m stack height	0·98	100	30
Grain sheaves over 4 m stack height	1·45	150	30
Grass and clover	3·45	350	—
Hay:			
Compressed	1·65	170	—
Loose up to about 3 m stack height	0·69	70	—
Honey	14·10	1 440	—
Hops:			
In sacks	1·65	170	—
In cylindrical hop bins	4 60	470	—
Sewn up or compressed in cylindrical shape in hop cloth	2·85	290	—
Malt:			
Crushed	3·90	400	20
Germinated	1·85	190	—
Meat and meat products	7·05	720	—
Milk	10·05	1 025	—
Molasses	4·40	450	—
Onion in bags	5·40	550	0
Oil cakes, crushed	5·80	590	0
Potatoes	7·05	720	30
Preserves (tins in cases)	4·90 to 7·85	500 to 800	—
Salt:			
Bags	7·05	720	—
Bulk	9·40	960	30
Seeds:			
Heaps	4·90 to 7·85	500 to 800	25
Sacks	3·90 to 6·85	400 to 700	—
Straw and chaff:			
Loose up to about 3 m stack height	0·45	45	—
Compressed	1·65	170	—
Sugar:			
Crystal	7·35	750	30
Cube sugar in boxes	7·85	800	—
Sugar beet, pressed out	7·85	800	—
Tobacco bundles	3·45	350	—
Vinegar	10·40	1 080	—

MATERIAL	WEIGHT/MASS		ANGLE OF FRICTION, DEGREES
	kN/m³	kg/m³	
2. *Chemicals and Allied Materials*			
Acid, hydrochloric	11·75	1 200	—
Acid, nitric 91%	14·80	1 510	—
Acid, sulphuric 87%	17·55	1 790	—
Alcohol	7·65	780	—
Alum, pearl, in barrel	5·20	530	—
Ammonia, liquid	8·85	900	—
Ammonium chloride, crystalline	8·15	830	30-40
Ammonium nitrate	7·05 to 9·80	720 to 1 000	25
Ammonium sulphate	7·05 to 9·00	720 to 920	32-45
Beeswax	9·40	960	—
Benzole	8·90	910	—
Benzene hexachloride	8·75	890	45
Bicarbonate of soda	6·40	650	30
Bone	18·65	1 900	—
Borax	17·15	1 750	—
Calcite	26·50	2 700	—
Camphor	9·70	990	—
Carbon disulphide	12·75	1 300	—
Casein	13·25	1 350	—
Caustic soda	13·85	1 410	—
Creosote	10·50	1 070	—
Dicalcium phosphate	6·65	680	45
Disodium phosphate	3·90 to 4·80	400 to 490	30-45
Iodine	48·55	4 950	—
Oils in bottles or barrels	5·70 to 8·90	580 to 910	—
Oil, linseed:			
In barrels	5·70	580	—
In drums	7·05	720	—
Oil, turpentine	8·50	865	—
Paints	9·40	960	—
Paraffin wax	7·85 to 9·40	800 to 960	—
Petroleum	9·90	1 010	—
Phosphorus	17·85	1 820	—
Plastics:			
Cellulose acetate	12·25 to 13·35	1 250 to 1 360	—
Cellulcse nitrate	13·25 to 15·70	1 350 to 1 600	—
Methyl methacrylate	11·60	1 185	—
Phenol formaldehyde	12·55	1 280	—
Polystryrene	10·40	1 060	—
Polyvinyl chloride (Perspex)	11·75 to 13·25	1 200 to 1 350	—
Resin bonded sheet	12·85 to 13·55	1 310 to 1 380	—
Urea formaldehyde	13·25 to 13·55	1 350 to 1 380	—
Potash	14·40	1 470	—
Potassium	8·65	880	—
Potassium nitrate	9·90	1 010	—
Red lead, dry	20·70	2 110	—
Red lead, paste	87·30	8 900	—
Rosin in barrels	6·75	690	—
Rubber:			
Raw	8·90 to 9·40	910 to 960	—
Vulcanized	8·90 to 9·10	910 to 930	—
Saltpetre	9·91	1 010	—
Sodium silicate in barrels	8·35	850	—
Sulphur	20·10	2 050	—
Talc	27·45	2 800	—
Varnishes	9·40	960	—
Vitriol, blue, in barrels	7·05	720	—
3. *Fuels*			
Brown coal	6·85	700	—
Brown coal briquettes heaped	7·85	800	35

Material	Weight/Mass kN/m³	kg/m³	Angle of Friction, Degrees
Brown coal briquettes, stacked	12·75	1 300	—
Charcoal	2·95	300	—
Coal:			
Untreated, mine-moist	9·80	1 000	35
In washeries	11·75	1 200	0
Dust	6·85	700	25
All other sorts	8·35	850	35
Coke:			
Furnace or gas	4·90	500	35
Brown coal, low-temperature	9·80	1 000	35
Hard, raw coal	8·35	850	35
Hard, raw coal, mine-damp	9·80	1 000	35
Diesel oil	9·40	960	0
Firewood, chopped	3·90	400	45
Petrol	6·75	690	0
Wood, in chips	1·95	200	45
Wood shavings, loose	1·45	150	35
Wood shavings, shaken down	2·45	250	35
4. *Manures*			
Animal manures:			
Loosely heaped	11·75	1 200	45
Stacked dung, up to about 2·5 m stack height	17·65	1 800	45
Artificial manures	11·75	1 200	24-30
5. *Metals and Alloys*			
Aluminium			
Cast	25·30 to 26·60	2 580 to 2 710	—
Wrought	25·90 to 27·45	2 640 to 2 800	—
Sheet per mm of thickness per m²	0·028	2·8	—
Antimony, pure:			
Amorphous	60·90	6 210	—
Solid	65·70	6 700	—
Bismuth:			
Liquid	98·07	10 000	—
Solid	95·02 to 97·09	9 690 to 9 900	—
Cadmium:			
Cast	83·75 to 84·05	8 540 to 8 570	—
Wrought	85·03	8 670	—
Calcium	15·60	1 590	—
Chromium	63·95 to 66·00	6 520 to 6 730	—
Cobalt:			
Cast	83·25 to 85·10	8 490 to 8 680	—
Wrought	88·45	9 020	—
Copper:			
Cast	86·20 to 87·65	8 790 to 8 940	—
Wrought	86·70 to 87·65	8 840 to 8 940	—
Sheet per mm of thickness	0·09	8·7	—
Gold:			
Cast	188·75 to 189·55	19 250 to 19 330	—
Wrought	189·55	19 330	—
Iron:			
Pig	70·60	7 200	—
Grey, cast	68·95 to 69·90	7 030 to 7 130	—
White, cast	74·35 to 75·70	7 580 to 7 720	—
Wrought	75·50	7 700	—

Material	Weight/Mass kN/m³	Weight/Mass kg/m³	Angle of Friction, Degrees
Lead:			
Cast	111·20	11 340	—
Liquid	105·00	10 710	—
Wrought	111·40	11 360	—
Sheet per mm of thickness	0·11	11	—
Magnesium	16·45 to 17·15	1 680 to 1 750	—
Manganese	72·55	7 400	—
Mercury	133·35	13 600	—
Nickel	81·20 to 87·20	8 280 to 8 890	—
Platinum	210·25	21 440	—
Silver:			
Cast	102·0 to 102·85	10 400 to 10 490	—
Liquid	93·15	9 500	—
Wrought	103·35 to 103·55	10 540 to 10 560	—
Sodium:			
Liquid	9·10	930	—
Solid	9·30	950	—
Tungsten	188·30	19 200	—
Uranium	180·45	18 400	—
Zinc:			
Cast	68·95 to 70·20	7 030 to 7 160	—
Wrought	70·50	7 190	—
Sheet per mm of thickness	0·07	7	—
Alloys:			
Aluminium and copper			
Aluminium 10%, copper 90%	75·40	7 690	—
Aluminium 5%, copper 95%	82·00	8 360	—
Aluminium 3%, copper 97%	85·10	8 680	—
Aluminium 91%, zinc 9%	27·45	2 800	—
Babbit metal (tin 90%, lead 5%, copper 5%)	71·70	7 310	—
Wood's metal (bismuth 50%, lead 25%, cadmium 12·5%, tin 12·5%)	95·00	9 690	—
Brasses:			
Muntz metal (copper 60%, zinc 40%)	80·60	8 220	—
Red (copper 90%, zinc 10%)	84·25	8 590	—
White (copper 50%, zinc 50%)	80·30	8 190	—
Yellow (copper 70%, zinc 30%):			
Cast	82·75	8 440	—
Drawn	85·10	8 680	—
Rolled	83·85	8 550	—
Bronzes:			
Bell metal (copper 80%, tin 20%)	85·60	8 730	—
Gun metal (copper 90%, tin 10%)	86·10	8 780	—
Cadmium and tin	75·40	7 690	—
German Silver:			
Copper 52%, zinc 26%, nickel 22%	82·75	8 440	—
Copper 59%, zinc 30%, nickel 11%	81·70	8 330	—
Copper 63%, zinc 30%, nickel 7%	81·40	8 300	—
Gold and Copper:			
Gold 98%, copper 2%	184·75	18 840	—
Gold 50%, copper 10%	168·20	17 150	—

MATERIAL	WEIGHT/MASS kN/m³	kg m³	ANGLE OF FRICTION, DEGREES
Lead and Tin:			
Lead 87·5%, tin 12·5%	103·85	10 590	—
Lead 30·5%, tin 69·5%	81·10	8 270	—
Monel metal, cast (nickel 70%, copper 30%)	87·00	8 870	—
Steel:			
Cast	77·00	7 850	—
Wrought mild	76·80	7 830	—
Black plate per mm of thickness	0·08	8	—
Steel sections (*see* 46 'Steel sections in Table 1)			
6. *Miscellaneous Materials*			
Aggregate, coarse	10·80 to 15·70	1 100 to 1 600	30
Ashes, coal, dry, 12 mm and under	5·50 to 6·30	560 to 645	40
Ashes, coal, dry, 75 mm and under	5·50 to 6·30	560 to 645	38
Ashes, coal, wet, 12 mm and under	7·05 to 7·85	720 to 800	52
Ashes, coal, wet, 75 mm and under	7·05 to 7·85	720 to 800	50
Asphalt, crushed, 12 mm and under	7·05	720	30-45
Ammonium nitrate, prills	3·55 to 8·35	360 to 850	27
Bone	18·65	1 900	—
Books and files, stacked	8·35	851	—
Calcium ammonium nitrate	9·80	1 000	28
Copper sulphate, ground	11·75	1 200	30
Chalk	21·95	2 240	—
Chinaware, earthenware, stacked (including cavities)	10·80	1 100	—
Clinker, furnace, clean	7·85	800	30
Diammonium phosphate	7·85 to 8·50	800 to 865	29
Double salt (ammonium sulphate nitrate)	7·05 to 9·30	720 to 950	34
Filling cabinets and cupboards with contents, in records offices, libraries, archives	5·90	600	—
Flue dust, boiler house, dry	5·50 to 7·05	560 to 720	>30
Fly ash, pulverised	5·50 to 7·05	560 to 720	—
Glass:			
Glass, solid	23·50 to 26·70	2 400 to 2 720	—
Wool	0·16 to 1·18	16 to 120	—
In sheets	25·50	2 600	—
Glue	12·55	1 280	—
Gypsum, calcined, 12 mm and under	8·60 to 9·40	889 to 960	40
Gypsum, calcined, powdered	9·40 to 12·55	960 to 1 280	45
Gypsum, raw, 25 mm and under	14·10 to 15·70	1 440 to 1 600	30-45
Hides			
Dry, Salted } Only green	8·65	880	—
Ice	8·90	910	—
Leather put in rows	7·85	800	—
Lime, ground, 3 mm and under	9·40	960	>45
Lime, hydrated, 3 mm and under	6·30	640	30-45
Lime, hydrated, pulverized	5·00 to 6·30	510 to 640	30-45
Lime pebble	8·25 to 8·75	840 to 890	>45
Limestone, agricultural, 3 mm and under	10·60	1 080	30-45
Limestone, crushed	13·30 to 14·10	1 355 to 1 440	30-45
Limestone dust	8·65 to 14·90	880 to 1 520	38-45
Magnesite, caustic, in powder form	7·85	800	—
Magnesite, sinter and magnesite, granular	19·60	2000	—
Phosphate, rock, pulverized	9·40	960	40-52
Phosphate rock	11·75 to 13·35	1 200 to 1 360	30-45
Phosphate sand	14·10 to 15·70	1 440 to 1 600	30-45
Potassium carbonate	7·95	810	30-45
Potassium chloride, pellets	18·85 to 20·40	1 920 to 2 080	30-45
Potassium nitrate	4·85	495	>30
Potassium sulphate	6·55 to 7·45	670 to 760	45
Pyrites, pellets	18·85 to 20·40	1 920 to 2 080	30-45

MATERIAL	WEIGHT/MASS		ANGLE OF FRICTION, DEGREES
	kN/m³	kg/m³	
Pumice	5·80 to 9·90	590 to 1 010	—
Rubbish:			
Building	13·80	1 410	—
General	6·30	645	—
Salt, common, dry, coarse	6·30 to 10·00	640 to 1 020	30-45
Salt, common, dry, fine	11·00 to 12·55	1 120 to 1 280	30-45
Salt cake, dry, coarse	13·35	1 360	30
Salt cake, dry, pulverized	11·20 to 13·35	1 140 to 1 360	35
Sand, bank, damp	17·25 to 20·40	1 760 to 2 080	45
Sand, bank, dry	14·10 to 17·25	1 440 to 1 760	30
Sand, silica, dry	14·10 to 15·70	1 440 to 1 600	30-35
Saw dust, loose	1·57	160	30
Silica gel	4·40	450	30-45
Soda ash, heavy	8·65 to 10·20	880 to 1 040	35
Soda ash, light	4·70 to 6·00	480 to 610	37
Sodium nitrate, granular	11·00 to 12·55	1 120 to 1 280	24
Sulphur, crushed, 12 mm and under	7·85 to 8·25	800 to 840	35-45
Sulphur, 76 mm and under	8·65 to 13·35	880 to 1 360	32
Sulphur, powdered	7·85 to 9·40	800 to 960	30-45
Single superphosphate (S.S.P.), granulated	7·65 to 8·25	780 to 840	37
Slag, furnace, crushed	14·90	1 520	35
Steel goods:			
Cylinders, usually stored for carbonic acid, etc	13·80	1 410	—
Sheets, railway rails, etc, usually stored	44·00	4 490	—
Trisodium phosphate	9·40	960	30-45
Triple superphosphate	7·85 to 8·65	800 to 880	30-45
Turf	2·85 to 5·70	2 910 to 5 810	—
Urea, prills	6·40	650	23-26
7. *Ores*			
Antimony	29·80	3 040	—
Ferrous sulphide	26·50	2 700	—
Ferrous sulphide ore waste after roasting	13·85	1 400	—
Iron ore, compact storing	29·80	3 040	—
Magnesium ore	19·60	2 000	—
8. *Textiles, Paper and Allied Materials*			
Cellulose in bundles	7·35	750	—
Cotton, compressed	12·75	1 300	—
Flax, piled and compressed in bales	2·95	300	—
Furs	8·90	910	—
Jute in bundles	6·85	700	—
Paper:			
In bundles and rolls	6·85	700	—
Newspapers in bundles	3·90	400	—
Put in rows	10·80	1 100	—
Thread in bundles	4·90	500	—
Wood, compressed	12·75	1 300	—

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PART 2 IMPOSED LOADS

(Second Revision)

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PART 2 IMPOSED LOADS

(Second Revision)

(*Page* 17, *Appendix* A, *clause* **A-1**, *line* 5) — Delete the word 'design'.

(*Page* 17, *Appendix* A, *clause* **A-1**, *last sentence*) — Delete.

(*Page* 17, *Appendix* A, *clause* **A-1.1**, *line* 2) — Insert 'imposed' before 'floor'.

(*Page* 17, *Appendix* A, *clause* **A-1.1**) — Insert the following at the end:

'The discounted loading shown is only indicative of the principle. The actual design load for the column must be based on analysis.'

(*Page* 18, *Fig.* 1) — Substitute the following for the second heading:

'Imposed Floor
Load on Columns at
Different Floors, kN'

(*Page* 18, *Fig.* 1) — Substitute the following for the third heading:

'Discounted Imposed Loading
on Columns, kN'

(CED 37)

Indian Standard
CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 2 IMPOSED LOADS

(Second Revision)

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CONTENTS

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 2 IMPOSED LOADS

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 2) (Second Revision) was adopted by the Bureau of Indian Standards on 31 August 1987, after the draft finalized by the Structural Safety Sectional Committee had been approved by the Building Division Council.

0.2 A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety; and compliance with hygienic, sanitation, ventilation and day light standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in this Code by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, snow loads and other external loads, the structure would be required to bear. Strict conformity to loading standards recommended in this Code, it is hoped, will not only ensure the structural safety of the buildings which are being designed and constructed in the country and thereby reduce the hazards to life and property caused by unsafe structures, but also eliminate the wastage caused by assuming unnecessarily heavy loadings.

0.3 This Code was first published in 1957 for the guidance of civil engineers, designers and architects associated with the planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effects on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs, both curved and sloping, were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

0.3.1 With the increased adoption of the Code, a number of comments were received on the provisions on live load values adopted for different occupancies. Simultaneously live load surveys have been carried out in America and Canada to arrive at realistic live loads based on actual determination of loading (movable and immovable) in different occupancies. Keeping this in view and other developments in the field of wind engineering, the Sectional Committee responsible for the preparation of the Code has decided to prepare the second revision of IS : 875 in the following five parts :

Part 1 Dead loads

Part 2 Imposed loads

Part 3 Wind loads

Part 4 Snow loads

Part 5 Special loads and load combinations

Earthquake load is covered in a separate standard, namely IS : 1893-1984* which should be considered along with above loads.

0.3.2 This Code (Part 2) deals with imposed loads on buildings produced by the intended occupancy or use. In this revision, the following important changes have been made:

a) The use of the term 'live load' has been modified to 'imposed load' to cover not only the physical contribution due to persons but also due to nature of occupancy, the furniture and other equipments which are a part of the character of the occupancy.

b) The imposed loads on floors and roofs have been rationalized based on the codified data available in large number of latest foreign national standards, and other literature. Further, these values have been spelt out for the major occupancies as classified in the National Building Code of India as well as the various service areas appended to the major occupancies.

*Criteria for earthquake resistant design of structures (*fourth revision*).

c) The reduction of imposed loads for design of vertical supporting members in multi-storeyed buildings has been further increased from 40 to 50 percent.

d) Provision has been included for sign posting of loads on floors in view of the different loadings specified for different occupancies and to avoid possible misuse in view of conversion of occupancies.

e) The value of loads on parapets and balustrades have been revised with its effect taken both in the horizontal and vertical directions.

f) In the design of dwelling units planned and executed in accordance with IS : 8888-1979*, an imposed load of 1·5 kN/m² is allowed.

g) SI Units have been used in the Code.

0.3.3 The buildings and structural systems shall provide such structural integrity that the hazards associated with progressive collapse such as that due to local failure caused by severe overloads or abnormal loads not specifically covered therein are reduced to a level consistent with good engineering practice.

0.3.4 Whenever buildings are designed for future additions of floor at a later date, the number of storeys for which columns/walls, foundations, etc, have been structurally designed may be posted in a conspicuous place similar to posting of floor capacities and both could be placed together.

0.4 The Sectional Committee responsible for the preparation of this Code has taken into account the prevailing practices in regard to loading standards followed in this country by the various municipal authorities and has also taken note of the developments in a number of countries abroad. In the preparation of this Code, the following national standards have been examined :

a) BS 6399 : Part 1 : 1984 Design Loading for Buildings Part 1: Code of Practice for Dead and Imposed Loads. British Standards Institution.

b) AS : 1170, Part I-1983 — SAA Loading Code, Part I Dead and Live Loads. Australian Standards Institution.

c) NZS 4203-1976 New Zealand Standard General Structural Design and Design Loading for Building. Standards Association of New Zealand.

d) ANSI. A 58.1 — 1982 American Standard Building Code Requirements for Minimum Design Loads in Buildings and Other Structures.

e) National Building Code of Canada (1977) Supplement No. 4. Canadian Structural Design Manual.

f) DIN 1055 Sheet 3 — 1971 Design Loads for Buildings — Live Load (West German Loading Standards).

g) ISO 2103-1986 Loads due to use and occupancy in residential and public buildings.

h) ISO 2633-1974 Determination of Imposed Floor Loads in Production Buildings and Warehouses. International Organization for Standardization.

*Guide for requirements of low income housing.

1. SCOPE

1.1 This standard (Part 2) covers imposed loads* (live loads) to be assumed in the design of buildings. The imposed loads, specified herein, are minimum loads which should be taken into consideration for the purpose of structural safety of buildings.

1.2 This Code does not cover detailed provisions for loads incidental to construction and special cases of vibration, such as moving machinery, heavy acceleration from cranes, hoists and the like. Such loads shall be dealt with individually in each case.

2. TERMINOLOGY

2.0 For the purpose of this Code, the following definitions shall apply.

2.1 Imposed Load — The load assumed to be produced by the intended use or occupancy of a building, including the weight of movable partitions, distributed, concentrated loads, load due to impact and vibration, and dust load but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement, etc.

2.2 Occupancy or Use Group — The principal occupancy for which a building or part of a building is used or intended to be used; for the purpose of classification of a building according to occupancy, an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it. The occupancy classification is given from **2.2.1** to **2.2.8**.

2.2.1 *Assembly Buildings* — These shall include any building or part of a building where groups of people congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes, for example, theatres, motion picture houses, assembly halls, city halls,

*The word 'imposed load' is used through out instead of 'live load' which is synonymous.

marriage halls, town halls, auditoria, exhibition halls, museums, skating rinks, gymnasiums, restaurants (also used as assembly halls), places of worship, dance halls, club rooms, passenger stations and terminals of air, surface and other public transportation services, recreation piers and stadia, etc.

2.2.2 *Business Buildings* — These shall include any building or part of a building, which is used for transaction of business (other than that covered by **2.2.6**); for the keeping of accounts and records for similar purposes; offices, banks, professional establishments, court houses, and libraries shall be classified in this group so far as principal function of these is transaction of public business and the keeping of books and records.

2.2.2.1 *Office buildings* — The buildings primarily to be used as an office or for office purposes; 'office purposes' include the purpose of administration, clerical work, handling money, telephone and telegraph operating and operating computers, calculating machines; 'clerical work' includes writing, book-keeping, sorting papers, typing, filing, duplicating, punching cards or tapes, drawing of matter for publication and the editorial preparation of matter for publication.

2.2.3 *Educational Buildings* — These shall include any building used for school, college or day-care purposes involving assembly for instruction, education or recreation and which is not covered by **2.2.1**.

2.2.4 *Industrial Buildings* — These shall include any building or a part of a building or structure in which products or materials of various kinds and properties are fabricated, assembled or processed like assembly plants, power plants, refineries, gas plants, mills, dairies, factories, workshops, etc.

2.2.5 *Institutional Buildings* — These shall include any building or a part thereof, which is used for purposes, such as medical or other treatment in case of persons suffering from physical and mental illness, disease or infirmity; care of infants, convalescents of aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants. It includes hospitals, sanitoria, custodial institutions or penal institutions like jails, prisons and reformatories.

2.2.6 *Mercantile Buildings* — These shall include any building or a part of a building which is used as shops, stores, market for display and sale of merchandise either wholesale or retail. Office, storage and service facilities incidental to the sale of merchandise and located in the same building shall be included under this group.

2.2.7 *Residential Buildings* — These shall include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities (except buildings under **2.2.5**). It includes one or multi-family dwellings, apartment houses (flats), lodging or rooming houses, restaurants, hostels, dormitories and residential hotels.

2.2.7.1 *Dwellings* — These shall include any building or part occupied by members of single/multi-family units with independent cooking facilities. These shall also include apartment houses (flats).

2.2.8 *Storage Buildings* — These shall include any building or part of a building used primarily for the storage or sheltering of goods, wares or merchandize, like warehouses, cold storages, freight depots, transity sheds, store houses, garages, hangers, truck terminals, grain elevators, barns and stables.

3. IMPOSED LOADS ON FLOORS DUE TO USE AND OCCUPANCY

3.1 Imposed Loads — The imposed loads to be assumed in the design of buildings shall be the greatest loads that probably will be produced by the intended use or occupancy, but shall not be less than the equivalent minimum loads specified in Table 1 subject to any reductions permitted by **3.2**.

Floors shall be investigated for both the uniformly distributed load (UDL) and the corresponding concentrated load specified in Table 1 and designed for the most adverse effects but they shall not be considered to act simultaneously. The concentrated loads specified in Table 1 may be assumed to act over an area of 0·3 × 0·3 m. However, the concentrated loads need not be considered where the floors are capable of effective lateral distribution of this load.

All other structural elements shall be investigated for the effects of uniformly distributed loads on the floors specified in Table 1.

NOTE 1 — Where in Table 1, no values are given for concentrated load, it may be assumed that the tabulated distributed load is adequate for design purposes.

NOTE 2 — The loads specified in Table 1 are equivalent uniformly distributed loads on the plan area and provide for normal effect of impact and acceleration. They do not take into consideration special concentrated loads and other loads.

NOTE 3 — Where the use of an area or floor is not provided in Table 1, the imposed load due to the use and occupancy of such an area shall be determined from the analysis of loads resulting from:

a) weight of the probable assembly of persons;

b) weight of the probable accumulation of equipment and furnishing;

c) weight of the probable storage materials; and

d) impact factor, if any.

TABLE 1 IMPOSED FLOOR LOADS FOR DIFFERENT OCCUPANCIES

(*Clauses* 3.1, 3.1.1 *and* 4.1.1)

SL No.	OCCUPANCY CLASSIFICATION	UNIFORMLY DISTRIBUTED LOAD (UDL)	CONCENTRATED LOAD
(1)	(2)	(3)	(4)
		kN/m²	kN
i)	RESIDENTIAL BUILDINGS		
	a) Dwelling houses:		
	1) All rooms and kitchens	2·0	1·8
	2) Toilet and bath rooms	2·0	—
	3) Corridors, passages, staircases including fire escapes and store rooms	3·0	4·5
	4) Balconies	3.0	1·5 per metre run concentrated at the outer edge
	b) Dwelling units planned and executed in accordance with IS : 8888-1979* only:		
	1) Habitable rooms, kitchens, toilet and bathrooms	1·5	1·4
	2) Corridors, passages and staircases including fire escapes	1·5	1·4
	3) Balconies	3·0	1·5 per metre run concentrated at the outer edge
	c) Hotels, hostels, boarding houses, lodging houses, dormitories, residential clubs:		
	1) Living rooms, bed rooms and dormitories	2·0	1·8
	2) Kitchens and laundries	3·0	4·5
	3) Billiards room and public lounges	3·0	2·7
	4) Store rooms	5·0	4·5
	5) Dining rooms, cafeterias and restaurants	4·0	2·7
	6) Office rooms	2·5	2·7
	7) Rooms for indoor games	3·0	1·8
	8) Baths and toilets	2·0	—
	9) Corridors, passages, staircases including fire escapes, lobbies — as per the floor serviced (excluding stores and the like) but not less than	3·0	4·5
	10) Balconies	Same as rooms to which they give access but with a minimum of 4·0	1·5 per metre run concentrated at the outer edge
	d) Boiler rooms and plant rooms — to be calculated but not less than	5·0	6·7

(*Continued*)

TABLE 1 IMPOSED FLOOR LOADS FOR DIFFERENT OCCUPANCIES — *Contd*

SL No.	OCCUPANCY CLASSIFICATION	UNIFORMLY DISTRIBUTED LOAD (UDL)	CONCENTRATED LOAD
(1)	(2)	(3)	(4)
		kN/m²	kN
	e) Garages:		
	1) Garage floors (including parking area and repair workshops) for passenger cars and vehicles not exceeding 2·5 tonnes gross weight, including access ways and ramps — to be calculated but not less than	2·5	9·0
	2) Garage floors for vehicles not exceeding 4·0 tonnes gross weight (including access ways and ramps) — to be calculated but not less than	5·0	9·0
ii)	EDUCATIONAL BUILDINGS		
	a) Class rooms and lecture rooms (not used for assembly purposes)	3·0	2·7
	b) Dining rooms, cafeterias and restaurants	3·0†	2·7
	c) Offices, lounges and staff rooms	2·5	2·7
	d) Dormitories	2·0	2·7
	e) Projection rooms	5·0	—
	f) Kitchens	3·0	4·5
	g) Toilets and bathrooms	2·0	—
	h) Store rooms	5·0	4·5
	j) Libraries and archives:		
	1) Stack room/stack area	6·0 kN/m² for a minimum height of 2·2 m + 2·0 kN/m² per metre height beyond 2·2 m	4·5
	2) Reading rooms (without separate storage)	4·0	4·5
	3) Reading rooms (with separate storage	3·0	4·5
	k) Boiler rooms and plant rooms — to be calculated but not less than	4·0	4·5
	m) Corridors, passages, lobbies, staircases including fire escapes — as per the floor serviced (without accounting for storage and projection rooms) but not less than	4·0	4·5
	n) Balconies	Same as rooms to which they give access but with a minimum of 4·0	1·5 per metre run concentrated at the outer edge
iii)	INSTITUTIONAL BUILDINGS		
	a) Bed rooms, wards, dressing rooms, dormitories and lounges	2·0	1·8
	b) Kitchens, laundries and laboratories	3·0	4·5

(*Continued*)

TABLE 1 IMPOSED FLOOR LOADS FOR DIFFERENT OCCUPANCIES — *Contd*

Sl No.	Occupancy Classification	Uniformly Distributed Load (UDL)	Concentrated Load
(1)	(2)	(3)	(4)
		kN/m²	kN
	c) Dining rooms, cafeterias and restaurants	3·0†	2·7
	d) Toilets and bathrooms	2·0	—
	e) X-ray rooms, operating rooms, general storage areas — to be calculated but not less than	3·0	4·5
	f) Office rooms and OPD rooms	2·5	2·7
	g) Corridors, passages, lobbies and staircases including fire escapes — as per the floor serviced but not less than	4·0	4·5
	h) Boiler rooms and plant rooms — to be calculated but not less than	5·0	4·5
	j) Balconies	Same as the rooms to which they give access but with a minimum of 4·0	1·5 per metre run concentrated at the outer edge
iv)	ASSEMBLY BUILDINGS		
	a) Assembly areas:		
	1) with fixed seats‡	4·0	—
	2) without fixed seats	5·0	3·6
	b) Restaurants (subject to assembly), museums and art galleries and gymnasia	4·0	4·5
	c) Projection rooms	5·0	—
	d) Stages	5·0	4·5
	e) Office rooms, kitchens and laundries	3·0	4·5
	f) Dressing rooms	2·0	1·8
	g) Lounges and billiards rooms	2·0	2·7
	h) Toilets and bathrooms	2·0	—
	j) Corridors, passages, staircases including fire escapes	4·0	4·5
	k) Balconies	Same as rooms to which they give access but with a minimum of 4·0	1·5 per metre run concentrated at the outer edge
	m) Boiler rooms and plant rooms including weight of machinery	7·5	4·5
	n) Corridors, passages subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like. Corridors, staircases and passages in grandstands	5·0	4·5
v)	BUSINESS AND OFFICE BUILDINGS (*see also* 3.1.2		
	a) Rooms for general use with separate storage	2·5	2·7
	b) Rooms without separate storage	4·0	4·5

(Continued)

TABLE 1 IMPOSED FLOOR LOADS FOR DIFFERENT OCCUPANCIES — *Contd*

SL No.	OCCUPANCY CLASSIFICATION	UNIFORMLY DISTRIBUTED LOAD (UDL)	CONCENTRATED LOAD
(1)	(2)	(3)	(4)
		kN/m²	kN*
	c) Banking halls	3·0	2·7
	d) Business computing machine rooms (with fixed computers or similar equipment)	3·5	4·5
	e) Records/files store rooms and storage space	5·0	4·5
	f) Vaults and strong room — to be calculated but not less than	5·0	4·5
	g) Cafeterias and dining rooms	3·0†	2·7
	h) Kitchens	3·0	2 7
	j) Corridors, passages, lobbies and staircases including fire escapes — as per the floor serviced (excluding stores) but not less than	4·0	4·5
	k) Bath and toilet rooms	2·0	—
	m) Balconies	Same as rooms to which they give access but with a minimum of 4·0	1·5 per metre run concentrated at the outer edge
	n) Stationary stores	4·0 for each metre of storage height	9·0
	p) Boiler rooms and plant rooms — to be calculated but not less than	5·0	6.7
	q) Libraries	*see* Sl No. (ii)	
vi)	MERCANTILE BUILDINGS		
	a) Retail shops	4·0	3·6
	b) Wholesale shops – to be calculated but not less than	6·0	4·5
	c) Office rooms	2·5	2·7
	d) Dining rooms, restaurants and cafeterias	3·0†	2.7
	e) Toilets	2·0	—
	f) Kitchens and laundries	3·0	4·5
	g) Boiler roooms and plant rooms — to be calculated but not less than	5·0	6·7
	h) Corridors, passages, staircases including fire escapes and lobbies	4·0	4·5
	j) Corridors, passages, staircases subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like	5·0	4·5
	k) Balconies	Same as rooms to which they give access but with a minimum of 4·0	1·5 per metre run concentrated at the outer edge

(*Continued*)

TABLE 1 IMPOSED FLOOR LOADS FOR DIFFERENT OCCUPANCIES — *Contd*

SL No.	OCCUPANCY CLASSIFICATION	UNIFORMLY DISTRIBUTED LOAD (UDL)	CONCENTRATED LOAD
(1)	(2)	(3)	(4)
		kN/m^2	kN
vii)	INDUSTRIAL BUILDINGS		
	a) Work areas without machinery/ equipment	2·5	4·5
	b) Work areas with machinery/equipment§		
	1) Light duty — To be calculated but not less than	5·0	4·5
	2) Medium duty — To be calculated but not less than	7·0	4·5
	3) Heavy duty — To be calculated but not less than	10·0	4·5
	c) Boiler rooms and plant rooms — to be calculated but not less than	5·0	6·7
	d) Cafeterias and dining rooms	3·0†	2·7
	e) Corridors, passages and staircases including fire escapes	4·0	4·5
	f) Corridors, passages, staircases subject to machine loads, wheeled vehicles — to be calculated but not less than	5·0	4·5
	g) Kitchens	3·0	4·5
	h) Toilets and bathrooms	2·0	—
viii)	STORAGE BUILDINGS ‖		
	a) Storage rooms (other than cold storage) warehouses — to be calculated based on the bulk density of materials stored but not less than	2·4 kN/m^2 per each metre of storage height with a minimum of 7·5 kN/m^2	7·0
	b) Cold storage — to be calculated but not less than	5·0 kN/m^2 per each metre of storage height with a minimum of 15 kN/m^2	9·0
	c) Corridors, passages and staircases including fire escapes — as per the floor serviced but not less than	4·0	4·5
	d) Corridors, passages subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like	5·0	4·5
	e) Boiler rooms and plant rooms	7·5	4·5

*Guide for requirements of low income housing.

†Where unrestricted assembly of persons is anticipated, the value of UDL should be increased to 4·0 kN/m^2.

‡'With fixed seats' implies that the removal of the seating and the use of the space for other purposes is improbable. The maximum likely load in this case is, therefore, closely controlled.

§The loading in industrial buildings (workshops and factories) varies considerably and so three loadings under the terms 'light', 'medium' and 'heavy' are introduced in order to allow for more economical designs but the terms have no special meaning in themselves other than the imposed load for which the relevant floor is designed. It is, however, important particularly in the case of heavy weight loads, to assess the actual loads to ensure that they are not in excess of 10 kN/m^2; in case where they are in excess, the design shall be based on the actual loadings.

For various mechanical handling equipment which are used to transport goods, as in warehouses, workshops, store rooms, etc, the actual load coming from the use of such equipment shall be ascertained and design should cater to such loads.

NOTE 4 — While selecting a particular loading, the possible change in use or occupancy of the building should be kept in view. Designers should not necessarily select in every case the lower loading appropriate to the first occupancy. In doing this, they might introduce considerable restrictions in the use of the building at a later date and thereby reduce its utility.

NOTE 5 — The loads specified herein which are based on estimations, may be considered as the characteristic loads for the purpose of limit state method of design till such time statistical data are established based on load surveys to be conducted in the country.

NOTE 6 — When an existing building is altered by an extension in height or area, all existing structural parts affected by the addition shall be strengthened, where necessary, and all new structural parts shall be designed to meet the requirements for building thereafter erected.

NOTE 7 — The loads specified in the Code does not include loads incidental to construction. Therefore, close supervision during construction is essential to ensure that overloading of the building due to loads by way of stacking of building materials or use of equipment (for example, cranes and trucks) during construction or loads which may be induced by floor to floor propping in multi-storeyed construction, does not occur. However, if construction loads were of short duration, permissible increase in stresses in the case of working stress method or permissible decrease in load factors in limit state method, as applicable to relevant design codes, may be allowed for.

NOTE 8 — The loads in Table 1 are grouped together as applicable to buildings having separate principal occupancy or use. For a building with multiple occupancies, the loads appropriate to the occupancy with comparable use shall be chosen from other occupancies.

NOTE 9 — Regarding loading on machine rooms including storage space used for repairing lift machines, designers should go by the recommendations of lift manufacturers for the present. Regarding the loading due to false ceiling the same should be considered as an imposed load on the roof/floor to which it is fixed.

3.1.1 *Load Application* — The uniformly distributed loads specified in Table 1 shall be applied as static loads over the entire floor area under consideration or a portion of the floor area whichever arrangement produces critical effects on the structural elements as provided in respective design codes.

In the design of floors, the concentrated loads are considered to be applied in the positions which produce the maximum stresses and where deflection is the main criterion, in the positions which produce the maximum deflections. Concentrated load, when used for the calculation of bending and shear are assumed to act at a point. When used for the calculation of local effects, such as crushing or punching, they are assumed to act over an actual area of application of 0·3 × 0·3 m.

3.1.2 *Loads Due to Light Partitions* — In office and other buildings where actual loads due to light partitions cannot be assessed at the time of planning, the floors and the supporting structural members shall be designed to carry, in addition to other loads, a uniformly distributed load per square metre of not less than 33⅓ percent of weight per metre run of finished partitions, subject to a minimum of 1 kN/m^2, provided total weight of partition walls per square metre of the wall area does not exceed 1·5 kN/m^2 and the total weight per metre length is not greater than 4·0 kN.

3.2 Reduction in Imposed Loads on Floors

3.2.1 *For Floor Supporting Structural Members* — Except as provided for in **3.2.1.1**, the following reductions in assumed total imposed loads on floors may be made in designing columns, load bearing walls, piers, their supports and foundations.

Number of Floors (Including the Roof) to be Carried by Member under Consideration	*Reduction in Total Distributed Imposed Load on all Floors to be Carried by the Member under Consideration (Percent)*
1	0
2	10
3	20
4	30
5 to 10	40
Over 10	50

3.2.1.1 No reduction shall be made for any plant or machinery which is specifically allowed for, or in buildings for storage purposes, warehouses and garages. However, for other buildings where the floor is designed for an imposed floor load of 5·0 kN/m^2 or more, the reductions shown in **3.2.1** may be taken, provided that the loading assumed is not less than it would have been if all the floors had been designed for 5·0 kN/m^2 with no reductions.

NOTE — In case if the reduced load in the lower floor is lesser than the reduced load in the upper floor, then the reduced load of the upper floor will be adopted.

3.2.1.2 An example is given in Appendix A illustrating the reduction of imposed loads in a multi-storeyed building in the design of column members.

3.2.2 *For Beams in Each Floor Level* — Where a single span of beam, girder or truss supports not less than 50 m^2 of floor at one general level, the imposed floor load may be reduced in the design of the beams, girders or trusses by 5 percent for each 50 m^2 area supported subject to a maximum reduction of 25 percent. However, no reduction shall be made in any of the following types of loads:

a) Any superimposed moving load,

b) Any actual load due to machinery or similar concentrated loads,

c) The additional load in respect of partition walls, and

d) Any impact or vibration.

NOTE — The above reduction does not apply to beams, girders or trusses supporting roof loads.

3.3 Posting of Floor Capacities — Where a floor or part of a floor of a building has been designed to sustain a uniformly distributed load exceeding 3·0 kN/m² and in assembly, business, mercantile, industrial or storage buildings, a permanent notice in the form as shown in the label, indicating the actual uniformly distributed and/or concentrated loadings for which the floor has been structurally designed shall be posted in a conspicuous place in a position adjacent to such floor or on such part of a floor.

DESIGNED IMPOSED FLOOR LOADING
DISTRIBUTED............kN/m²
CONCENTRATED......kN

LABEL INDICATING DESIGNED IMPOSED FLOOR LOADING

NOTE 1 — The lettering of such notice shall be embossed or cast suitably on a tablet whose least dimension shall be not less than 0·25 m and located not less than 1·5 m above floor level with lettering of a minimum size of 25 mm.

NOTE 2 — If a concentrated load or a bulk load has to occupy a definite position on the floor, the same could also be indicated in the label above.

4. IMPOSED LOADS ON ROOFS

4.1 Imposed Loads on Various Types of Roofs — On flat roofs, sloping roofs and curved roofs, the imposed loads due to use or occupancy of the buildings and the geometry of the types of roofs shall be as given in Table 2.

4.1.1 Roofs of buildings used for promenade or incidental to assembly purposes shall be designed for the appropriate imposed floor loads given in Table 1 for the occupancy.

4.2 Concentrated Load on Roof Coverings — To provide for loads incidental to maintenance, unless otherwise, specified by the Engineer-in-Charge, all roof coverings (other than glass or transparent sheets made of fibre glass) shall be capable of carrying an incidental load of 0·90 kN concentrated on an area of 12·5 cm² so placed as to produce maximum stresses in the covering. The intensity of the concentrated load may be reduced with the approval of the Engineer-in-Charge, where it is ensured that the roof coverings would not be transversed without suitable aids. In any case, the roof coverings shall be capable of carrying the loads in accordance with 4.1, 4.3, 4.4 and snow load/wind load.

4.3 Loads Due to Rain — On surfaces whose positioning, shape and drainage systems are such as to make accumulation of rain water possible, loads due to such accumulation of water and the imposed loads for the roof as given in Table 2 shall be considered separately and the more critical of the two shall be adopted in the design.

4.4 Dust Load — In areas prone to settlement of dust on roofs (example, steel plants, cement plants), provision for dust load equivalent to probable thickness of accumulation of dust may be made.

4.5 Loads on Members Supporting Roof Coverings — Every member of the supporting structure which is directly supporting the roof covering(s) shall be designed to carry the more severe of the following loads except as provided in 4.5.1 :

a) The load transmitted to the members from the roof covering(s) in accordance with 4.1, 4.3 and 4.4; and

b) An incidental concentrated load of 0·90 kN concentrated over a length of 12·5 cm placed at the most unfavourable positions on the member.

NOTE — Where it is ensured that the roofs would be traversed only with the aid of planks and ladders capable of distributing the loads on them to two or more supporting members, the intensity of concentrated load indicated in (b) may be reduced to 0·5 kN with the approval of the Engineer-in-Charge.

4.5.1 In case of sloping roofs with slope greater than 10°, members supporting the roof purlins, such as trusses, beams, girders, etc, may be designed for two-thirds of the imposed load on purlins or roofing sheets.

5. IMPOSED HORIZONTAL LOADS ON PARAPETS AND BALUSTRADES

5.1 Parapets, Parapet Walls and Balustrades — Parapets, parapet walls and balustrades together with the members which give them structural support shall be designed for the minimum loads given in Table 3. These are expressed as horizontal forces acting at handrail or coping level. These loads shall be considered to act vertically also but not simultaneously with the horizontal forces. The values given in Table 3 are minimum values and where values for actual loadings are available, they shall be used instead.

5.2 Grandstands and the Like—Grandstands, stadia, assembly platforms, reviewing stands and the like shall be designed to resist a horizontal force applied to seats of 0·35 kN per linear metre along the line of seats and 0·15 kN per linear metre perpendicular to the line of the seats. These loadings need not be applied simultaneously. Platforms without seats shall be designed to resist a minimum horizontal force of 0·25 kN/m² of plan area.

6. LOADING EFFECTS DUE TO IMPACT AND VIBRATION

6.0 The crane loads to be considered under imposed loads shall include the vertical loads, eccentricity effects induced by vertical loads, impact factors, lateral and longitudinal braking forces acting across and along the crane rails respectively.

6.1 Impact Allowance for Lifts, Hoists and Machinery — The imposed loads specified in 3.1 shall be assumed to include adequate allowance for ordinary impact conditions. However, for structures carrying loads which induce impact or vibration, as far as possible, calculations shall be made for increase in the imposed load, due to impact or vibration. In the absence of sufficient data for

TABLE 2 IMPOSED LOADS ON VARIOUS TYPES OF ROOFS

(*Clause* 4.1)

Sl No.	Type of Roof	Uniformly Distributed Imposed Load Measured on Plan Area	Minimum Imposed Load Measured on Plan
(1)	(2)	(3)	(4)
i)	Flat, sloping or curved roof with slopes up to and including 10 degrees		
	a) Access provided	1·5 kN/m²	3·75 kN uniformly distributed over any span of one metre width of the roof slab and 9 kN uniformly distributed over the span of any beam or truss or wall
	b) Access not provided except for maintenance	0·75 kN/m²	1·9 kN uniformly distributed over any span of one metre width of the roof slab and 4·5 kN uniformly distributed over the span of any beam or truss or wall
ii)	Sloping roof with slope greater than 10 degrees	For roof membrane sheets or purlins-0·75 kN/m² less 0·02 kN/m² for every degree increase in slope over 10 degrees	Subject to a minimum of 0·4 kN/m²
iii)	Curved roof with slope of line obtained by joining springing point to the crown with the horizontal, greater than 10 degrees	$(0·75 - 0·52\,\gamma^2)$ kN/m² where $\gamma = h/l$; h = the height of the highest point of the structure measured from its springing; and l = chord width of the roof if singly curved and shorter of the two sides if doubly curved. Alternatively, where structural analysis can be carried out for curved roofs of all slopes in a simple manner applying the laws of statistics, the curved roof shall be divided into minimum 6 equal segments and for each segment imposed load shall be calculated appropriate to the slope of the chord of each segment as given in (i) and (ii) above	Subject to a minimum of 0·4 kN/m²

NOTE 1 — The loads given above do not include loads due to snow, rain, dust collection, etc. The roof shall be designed for imposed loads given above or for snow/rain load, whichever is greater.

NOTE 2 — For special types of roofs with highly permeable and absorbent material, the contingency of roof material increasing in weight due to absorption of moisture shall be provided for.

TABLE 3 HORIZONTAL LOADS ON PARAPETS, PARAPET WALLS AND BALUSTRADES

(*Clause* 5.1)

SL No.	USAGE AREA	INTENSITY OF HORIZONTAL LOAD, kN/m RUN
(1)	(2)	(3)
i)	Light access stairs gangways and the like not more than 600 mm wide	0·25
ii)	Light access stairs, gangways and the like, more than 600 mm wide; stairways, landings, balconies and parapet walls (private and part of dwellings)	0·35
iii)	All other stairways, landings and balconies, and all parapets and handrails to roofs except those subject to overcrowding covered under (iv)	0·75
iv)	Parapets and balustrades in place of assembly, such as theatres, cinemas, churches, schools, places of entertainment, sports, buildings likely to be overcrowded	2·25

NOTE — In the case of guard parapets on a floor of multi-storeyed car park or crash barriers provided in certain buildings for fire escape, the value of imposed horizontal load (together with impact load) may be determined.

such calculation, the increase in the imposed loads shall be as follows:

Structures	*Impact Allowance Min*
For frames supporting lifts and hoists	100 percen
For foundations, footings and piers supporting lifts and hoisting apparatus	40 percent
For supporting structures and foundations for light machinery, shaft or motor units	20 percent
For supporting structures and foundations for reciprocating machinery or power units	50 percent

6.2 Concentrated Imposed Loads with Impact and Vibration — Concentrated imposed loads with impact and vibration which may be due to installed machinery shall be considered and provided for in the design. The impact factor shall not be less than 20 percent which is the amount allowable for light machinery.

6.2.1 Provision shall also be made for carrying any concentrated equipment loads while the equipment is being installed or moved for servicing and repairing.

6.3 Impact Allowances for Crane Girders — For crane gantry girders and supporting columns, the following allowances shall be deemed to cover all forces set up by vibration, shock from slipping or slings, kinetic action of acceleration, and retardation and impact of wheel loads:

Type of Load	*Additional Load*
a) Vertical loads for electric overhead cranes	25 percent of maximum static loads for crane girders for all classes of cranes
	25 percent for columns supporting Class III and Class IV cranes
	10 percent for columns supporting Class I and Class II cranes
	No additional load for design of foundations
b) Vertical loads for hand operated cranes	10 percent of maximum wheel loads for crane girders only

(Continued)

c) Horizontal forces transverse to rails:

1) For electric overhead cranes with trolley having rigid mast for suspension of lifted weight (such as soaker crane, stripper crane, etc)	—10 percent of weight of crab and the weight lifted by the cranes, acting on any one crane track rail, acting in either direction and equally distributed amongst all the wheels on one side of rail track For frame analysis this force shall be applied on one side of the frame at a time in either direction.
2) For all other electric overhead cranes and hand operated cranes	—5 percent of weight of crab and the weight lifted by the cranes, acting on anyone crane track rail, acting in either direction and equally distributed amongst the wheels on one side of rail track For the frame analysis, this force shall be applied on one side of the frame at a time in either direction
d) Horizontal traction forces along the rails for overhead cranes, either electrically operated or hand operated	—5 percent of all static wheel loads

Forces specified in (c) and (d) shall be considered as acting at the rail level and being appropriately transmitted to the supporting system. Gantry girders and their vertical supports shall be designed on the assumption that either of the horizontal forces in (c) and (d) may act at the same time as the vertical load.

NOTE—*See* IS : 807-1976* for classification (Classes 1 to 4) of cranes.

6.3.1 *Overloading Factors in Crane Supporting Structures* — For all ladle cranes and charging cranes, where there is possibility of overloading from production considerations, an overloading factor of 10 percent of the maximum wheel loading shall be taken.

6.4 Crane Load Combinations — In the absence of any specific indications, the load combinations shall be as indicated in the following sub-clauses.

6.4.1 *Vertical Loads* — In an aisle, where more than one crane is in operation or has provision for more than one crane in future, the following load combinations shall be taken for vertical loading:

a) Two adjacent cranes working in tandem with full load and with overloading according to 6.3(a); and

b) For long span gantries, where more than one crane can come in the span, the girder shall be designed for one crane fully loaded with overloading according to 6.3(a) plus as many loaded cranes as can be accommodated on the span but without taking into account overloading according to 6.3(a) to give the maximum effect.

6.4.2 *Lateral Surge* — For design of columns and foundations, supporting crane girders, the following crane combinations shall be considered:

a) *For single-bay frames* — Effect of one crane in the bay giving the worst effect shall be considered for calculation of surge force, and

b) *For multi-bay frames* — Effect of two cranes working one each in any of two bays in the cross-section to give the worst effect shall be considered for calculation of surge force.

6.4.3 *Tractive Force*

6.4.3.1 Where one crane is in operation with no provision for future crane, tractive force from only one crane shall be taken

6.4.3.2 Where more than one crane is in operation or there is provision for future crane, tractive force from two cranes giving maximum effect shall be considered.

NOTE — Lateral surge force and longitudinal tractive force acting across and along the crane rail respectively, shall not be assumed to act simultaneously. However, if there is only one crane in the bay, the lateral and longitudinal forces may act together simultaneously with vertical loads.

7. OTHER LOADS

7.1 Dead Load — Dead load includes the weight of all permanent components of a building including walls, partitions, columns, floors, roofs, finishes

*Code of practice for design, manufacture, erection and testing (structural portion) of cranes and hoists (*first revision*).

and fixed permanent equipment and fittings that are an integral part of the structure. Unit weight of building materials shall be in accordance with IS : 875 (Part 1)-1988.

7.2 **Wind Load** — The wind load on buildings/ structures shall be in accordance with IS : 875 (Part 3)-1988.

7.3 **Seismic Load** — Seismic load on buildings/ structures shall be in accordance with IS : 1893-1984*.

7.4 **Snow Load** — Snow loading on buildings shall be in accordance with IS : 875 (Part 4)-1988.

7.5 **Special Loads and Load Combinations** — Special loads and load combinations shall be in accordance with IS : 875 (Part 5)-1988.

*Criteria for earthquake resistant design of structures (*fourth revision*).

APPENDIX A

(*Clause* 3.2.1.2)

ILLUSTRATIVE EXAMPLE SHOWING REDUCTION OF UNIFORMLY DISTRIBUTED IMPOSED FLOOR LOADS IN MULTI-STOREYED BUILDINGS FOR DESIGN OF COLUMNS

A-1. The total imposed loads from different floor levels (including the roof) coming on the central column of a multi-storeyed building (with mixed occupancy) is shown in Fig. 1. Calculate the reduced imposed load for the design of column members at different floor levels as given in 3.2.1. Floor loads do not exceed 5·0 kN/m².

A-1.1 Applying reduction coefficients in accordance with **3.2.1**, total reduced floor loads on the column at different levels is indicated along with Fig. 1.

Floor No. from Top Including Roof	Actual Floor Load Coming on Columns at Different Floors, kN	Loads for which Columns are to be Designed, kN
1	30	30
2	40	(30 + 40) (1 — 0·1) = 63
3	50	(30 + 40 + 50) (1 — 0·2) = 96
4	50	(30 + 40 + 50 + 50) (1 — 0·3) = 119
5	40	(30 + 40 + 50 + 50 + 40) (1 — 0·4) = 126
6	45	(30 + 40 + 50 + 50 + 40 + 45) (1 — 0·4) = 153
7	50	(30 + 40 + 50 + 50 + 40 + 45 + 50) (1 — 0·4) = 183
8	50	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50) (1 — 0·4) = 213
9	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40) (1 — 0·4) = 237
10	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40) (1 — 0·4) = 261
11	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40) (1 — 0·5) = 237·5 < 261 ∴ adopt 261 for design
12	55	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55) (1 — 0·5) = 265
13	55	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55) (1 — 0·5) = 292·5
14	70	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55 + 70) (1 — 0·5) = 327·5
15	80	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55 + 70 + 80) (1 — 0·5) = 367·5

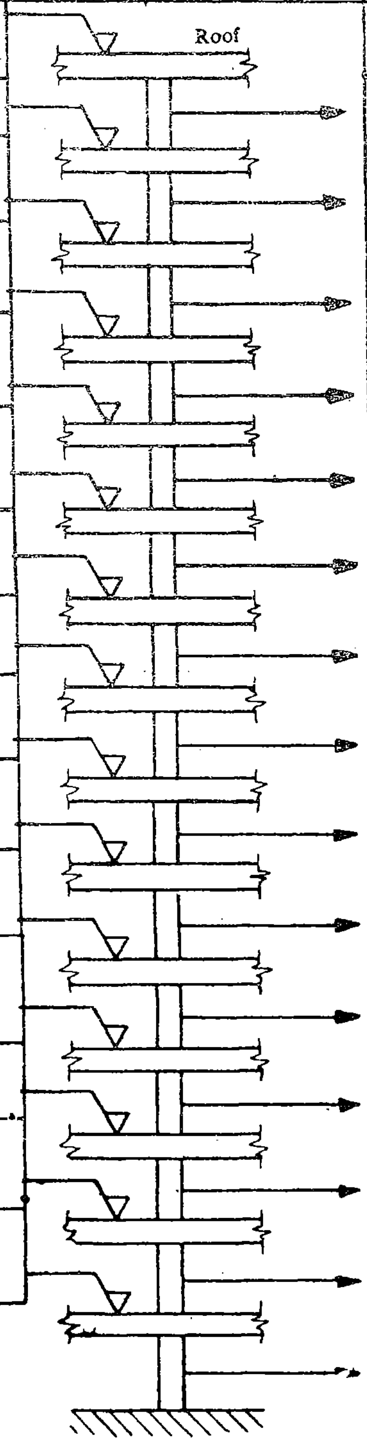

Fig. 1 Loading Details

IS 875 (Part 3) (1987): Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures. Part 3: Wind Loads (Second Revision). UDC 624.042.41 : 006.76

IS : 875 (Part 3) - 1987

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 3 WIND LOADS

(Second Revision)

Fifth Reprint JULY 1997

UDC 624·042·41

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

Gr 14 *February* 1989

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AMENDMENT NO. 3 MARCH 2006
TO
IS 875 (PART 3) : 1987 CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 3 WIND LOADS

(Second Revision)

(*Page* 8, *clause* 5.3, *Note*) — Insert the following at the end:

'For buildings and structures located in cyclone prone areas reference may be made to IS 15498 : 2004 Guidelines for improving the cyclonic resistance of low rise houses and other buildings/structures.'

(*Page* 11, *Table* 1) — Insert 'permanent walls' at the end of third item under Class of structure.

(*Page* 13, *clause* 5.5) — Substitute the following for the existing clause:

'**5.5 Cyclonic Wind Velocity** — Cyclonic storms form far away from the sea coast and the wind speed reduces gradually as the cyclone storm moves towards inland from the shore. Cyclonic storms generally extend up to about 60 km after striking the coast. For buildings and structures located in cyclone prone areas, reference to be made to IS 15498 : 2004. The enhancement factors for cyclonic wind speed as given in IS 15498 : 2004 shall be taken into consideration.'

(*Page* 52, *clause* **8.3**) — Substitute the following for '$V_h = V_z$ = hourly mean wind speed at height z,:

'V_h = hourly mean wind speed at height h,'

(CED 37)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 2 MARCH 2002
TO
IS 875 (PART 3) : 1987 CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 3 WIND LOADS

(Second Revision)

Substitute 'V_Z' *for* 'V_d' at all places.

(*Tables* 5, 6, 7 *and* 8) — Insert the following Note at the end of each table:

'NOTE — *W* and *L* are overall length and width including overhangs, *w* and *l* are dimensions between the walls excluding overhangs.'

(*Tables* 9, 10, 11, 12, 13 *and* 14, *first column*) — Substitute the following matter in the last row for the specific values of θ given therein:

'for all values of θ '

[*Page* 27, *clause* 6.2.2.7(a)] — Insert at the end 'downwards'.

[*Page* 27, *clause* 6.2.2.8(a)] — Substitute '-0.8' *for* '0.8'.

[*Page* 27, *clause* 6.2.2.8(b)] — Substitute '-0.5' *for* '0.5'.

(*Page* 27, *clause* 6.2.2.9) — Substitute '$P = 0.785\ D^2\ (C_{pi} - C_{pe})\ p_d$' for the existing formula.

(*Page* 32, *Table* 19) — Substitute '$P = 0.785\ D^2\ (C_{pi} - C_{pe})\ p_d$' for the existing formula.

(*Page* 46, *Table* 27, *third row*) — Substitute '$D\ V_d < 6\ m^2/s$' for the existing.

(*Page* 46, *Table* 28, *col* 2, *second row*) — Substitute '1.8' *for* '1.0'.

(*Page* 46, *clause* 6.3.3.3, *formula, last line*) — Substitute

$$\gamma = \frac{(\text{Area of the frame in a supercritical flow})}{A_e}$$ for the existing.

[*Page* 47, *clause* 7.1(a), *third line*] — Substitute 'or' *for* 'and'.

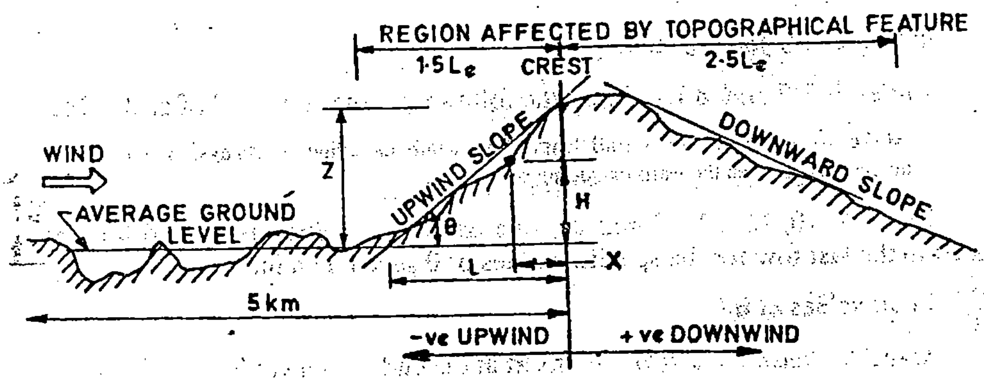
[*Page* 48, *clause* 7.1(b), *first line*] — Delete 'closed'.

(*Page* 48, *clause* 7.1, *fourth and fifth line*) — Substitute 'satisfies' *for* 'does not satisfy'.

(*Page* 55, *clause* C-1, *second line*) — Substitute 'and' *for* 'add'.

(*Page* 56, *clause* C-2, *last line*) — Insert ',' between 'crest' and 'relative'.

(*Page* 56, *Fig.* 13A) — Substitute the following figure for the existing:



13A General Notations

(*Page* 56, *Fig.* 13B) — Substitute 'Hill and Ridge' *for* 'Cliff and Excarpment'.

(*Page* 56, *Fig.* 13C) — Substitute 'Cliff and Escarpment' *for* 'Hill and Ridge'.

(*Page* 58, *clause* D-1, *eighth line*) — Substitute 'm^2/s' *for* 'm^2s'

(CED 57)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 1 DECEMBER 1997
TO
IS 875 (Part 3) : 1987 CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 3 WIND LOADS

(Second Revision)

(*Page* 15, *Table* 4, *first column*) — Substitute

$$\text{'}\frac{h}{w} \geq 6\text{' for '}\frac{h}{w} \geqslant \infty\text{'}$$

(*Page* 40, *Table* 23, *first column, first row*) — Substitute '*See also* Appendix D' *for* '*See also* Appendix C'.

(*Page* 47, *Table* 32, *col* 2) — Substitute

'$DV_d \geq 6\ m^2/s$' *for* '$DV_d \leqslant 6\ m^2/s$'.

(CED 37)

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 3 WIND LOADS

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 3) (Second Revision) was adopted by the Bureau of Indian Standards on 13 November 1987, after the draft finalized by the Structural Safety Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in loading codes by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, wind loads and other external loads, the structure would be required to bear. Strict conformity to loading standards, it is hoped, will not only ensure the structural safety of the buildings and structures which are being designed and constructed in the country and thereby reduce the hazards to life and property caused by unsafe structures, but also eliminate the wastage caused by assuming unnecessarily heavy loadings without proper assessment.

0.3 This standard was first published in 1957 for the guidance of civil engineers, designers and architects associated with the planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of the buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effect on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs, both curved and sloping were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

0.3.1 With the increased adoption of this Code, a number of comments were received on provisions on live load values adopted for different occupancies. Simultaneously, live load surveys have been carried out in America and Canada to arrive at realistic live loads based on actual determination of loading (movable and immovable) in different occupancies. Keeping this in view and other developments in the field of wind engineering, the Structural Safety Sectional Committee decided to prepare the second revision of IS : 875 in the following five parts:

Part 1 Dead loads

Part 2 Imposed loads

Part 3 Wind loads

Part 4 Snow loads

Part 5 Special loads and load combinations

Earthquake load is covered in a separate standard, namely, IS : 1893-1984* which should be considered along with the above loads.

0.3.2 This Part (Part 3) deals with wind loads to be considered when designing buildings, structures and components thereof. In this revision, the following important modifications have been made from those covered in the 1964 version of IS : 875:

a) The earlier wind pressure maps (one giving winds of shorter duration and another excluding winds of shorter duration)

*Criteria for earthquake resistant design of structures (*fourth revision*).

have been replaced by a single wind map giving basic maximum wind speed in m/s (peak gust velocity averaged over a short time interval of about 3 seconds duration). The wind speeds have been worked out for 50 years return period based on the up-to-date wind data of 43 dines pressure tube (DPT) anemograph stations and study of other related works available on the subject since 1964. The map and related recommendations have been provided in the code with the active cooperation of Indian Meteorological Department (IMD). Isotachs (lines of equal velocity) have not been given as in the opinion of the committee, there is still not enough extensive meteorological data at close enough stations in the country to justify drawing of isotachs.

b) Modification factors to modify the basic wind velocity to take into account the effects of terrain, local topography, size of structure, etc, are included.

c) Terrain is now classified into four categories based on characteristics of the ground surface irregularities.

d) Force and pressure coefficients have been included for a large range of clad and unclad buildings and for individual structural elements.

e) Force coefficients (drag coefficients) are given for frames, lattice towers, walls and hoardings.

f) The calculation of force on circular sections is included incorporating the effects of Reynolds number and surface roughness.

g) The external and internal pressure coefficients for gable roofs, lean-to roofs, curved roofs, canopy roofs (butterfly type structures) and multi-span roofs have been rationalised.

h) Pressure coefficients are given for combined roofs, roofs with sky light, circular silos, cylindrical elevated structures, grandstands, etc.

j) Some requirements regarding study of dynamic effects in flexible slender structures are included.

k) Use of gust energy method to arrive at the design wind load on the whole structure is now permitted.

0.3.3 The Committee responsible for the revision of wind maps while reviewing available meteorological wind data and response of structures to wind, felt the paucity of data on which to base wind maps for Indian conditions on statistical analysis. The Committee, therefore, recommends to all individuals and organizations responsible for putting-up of tall structures to provide instrumentation in their existing and new structures (transmission towers, chimneys, cooling towers, buildings, etc) at different elevations (at least at two levels) to continuously measure and monitor wind data. The instruments are required to collect data on wind direction, wind speed and structural response of the structure due to wind (with the help of accelerometer, strain gauges, etc). It is also the opinion of the committee that such instrumentation in tall structures will not in any way affect or alter the functional behaviour of such structures. The data so collected will be very valuable in evolving more accurate wind loading of structures.

0.4 The Sectional Committee responsible for the preparation of this standard has taken into account the prevailing practice in regard to loading standards followed in this country by the various authorities and has also taken note of the developments in a number of other countries. In the preparation of this code, the following overseas standards have also been examined:

a) BSCP 3 : 1973 Code of basic data for design of buildings: Chapter V Loading, Part 2 Wind loads.

b) AS 1170, Part 2-1983 SAA Loading code Part 2 — Wind forces.

c) NZS 4203-1976 Code of practice for general structural design loading for buildings.

d) ANSI A58.1-1972 American Standard Building code requirements for minimum design loads in buildings and other structures.

e) Wind resistant design regulations, A World List. Association for Science Documents Information, Tokyo.

0.5 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*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard gives wind forces and their effects (static and dynamic) that should be taken into account when designing buildings, structures and components thereof.

1.1.1 It is believed that ultimately wind load estimation will be made by taking into account the random variation of wind speed with time but available theoretical methods have not matured sufficiently at present for use in the code. For this reason, static wind method of load estimation which implies a steady wind speed, which has proved to be satisfactory for normal, short and heavy structures, is given in **5** and **6**. However, a beginning has been made to take account of the random nature of the wind speed by requiring that the along-wind or drag load on structures which are prone to wind induced oscillations, be also determined by the gust factor method (*see* **8**) and the more severe of the two estimates be taken for design.

A large majority of structures met with in practice do not however, suffer wind induced oscillations and generally do not require to be examined for the dynamic effects of wind, including use of gust factor method. Nevertheless, there are various types of structures or their components such as some tall buildings, chimneys, latticed towers, cooling towers, transmission towers, guyed masts, communication towers, long span bridges, partially or completely solid faced antenna dish, etc, which require investigation of wind induced oscillations. The use of **7** shall be made for identifying and analysing such structures.

1.1.2 This code also applies to buildings or other structures during erection/construction and the same shall be considered carefully during various stages of erection/construction. In locations where the strongest winds and icing may occur simultaneously, loads on structural members, cables and ropes shall be calculated by assuming an ice covering based on climatic and local experience.

1.1.3 In the design of special structures, such as chimneys, overhead transmission line towers, etc, specific requirements as specified in the respective codes shall be adopted in conjunction with the provisions of this code as far as they are applicable. Some of the Indian Standards available for the design of special structurers are:

IS : 4998 (Part 1)-1975 Criteria for design of reinforced concrete chimneys: Part 1 Design criteria (*first revision*)

IS : 6533-1971 Code of practice for design and construction of steel chimneys

IS : 5613 (Part 1/Sec 1)-1970 Code of practice for design, installation and maintenance of overhead power lines: Part 1 Lines up to and including 11 kV, Section 1 Design

IS : 802 (Part 1)-1977 Code of practice for use of structural steel in overhead transmission line towers: Part 1 Loads and permissible stresses (*second revision*)

IS : 11504-1985 Criteria for structural design of reinforced concrete natural draught cooling towers

NOTE 1 — This standard does not apply to buildings or structures with unconventional shapes, unusual locations, and abnormal environmental conditions that have not been covered in this code. Special investigations are necessary in such cases to establish wind loads and their effects. Wind tunnel studies may also be required in such situations.

NOTE 2 — In the case of tall structures with unsymmetrical geometry, the designs may have to be checked for torsional effects due to wind pressure.

2. NOTATIONS

2.1 The following notations shall be followed unless otherwise specified in relevant clauses:

A = surface area of a structure or part of a structure;

A_e = effective frontal area;

A_z = an area at height z;

b = breadth of a structure or structural member normal to the wind stream in the horizontal plane;

C_f = force coefficient/drag coefficient;

C_{fn} = normal force coefficient;

C_{ft} = transverse force coefficient;

C'_f = frictional drag coefficient;

C_p = pressure coefficient;

C_{pe} = external pressure coefficient;

C_{pi} = internal pressure coefficient;

d = depth of a structure or structural member parallel to wind stream;

D = diameter of cylinder;

F = force normal to the surface;

F_n = normal force;

F_t = transverse force;

F' = frictional force;

h = height of structure above mean ground level;

h_x = height of development of a velocity profile at a distance x down wind from a change in terrain category;

k_1, k_2, k_3 = multiplication factors;

K = multiplication factor;

l = length of the member or greater horizontal dimension of a building;

p_d = design wind pressure;

p_z = design wind pressure at height Z;
p_e = external pressure;
p_i = internal pressure;
R_e = reynolds number;
S = strouhal number;
V_b = regional basic wind speed;
V_z = design wind velocity at height z;
$\bar{V}_z$ = hourly mean wind speed at height z;
w = lesser horizontal dimension of a building, or a structural member;
w' = bay width in multi-bay buildings;
x = distance down wind from a change in terrain category;
θ = wind angle from a given axis;
α = inclination of the roof to the horizontal;
β = effective solidity ratio;
η = shielding factor or shedding frequency;
ϕ = solidity ratio;
z = a height or distance above the ground; and
ϵ = average height of the surface roughness.

3. TERMINOLOGY

3.1 For the purpose of this code, the following definitions shall apply.

3.1.1 *Angle of Attack* — Angle between the direction of wind and a reference axis of the structure.

3.1.2 *Breadth* — Breadth means horizontal dimension of the building measured normal to the direction of wind.

NOTE — Breadth and depth are dimensions measured in relation to the direction of the wind, whereas length and width are dimensions related to the plan.

3.1.3 *Depth* — Depth means the horizontal dimension of the building measured in the direction of the wind.

3.1.4 *Developed Height* — Developed height is the height of upward penetration of the velocity profile in a new terrain. At large fetch lengths, such penetration reaches the gradient height, above which the wind speed may be taken to be constant. At lesser fetch lengths, a velocity profile of a smaller height but similar to that of the fully developed profile of that terrain category has to be taken, with the additional provision that the velocity at the top of this shorter profile equals that of the unpenetrated earlier velocity profile at that height.

3.1.5 *Effective Frontal Area* — The projected area of the structure normal to the direction of the wind.

3.1.6 *Element of Surface Area* — The area of surface over which the pressure coefficient is taken to be constant.

3.1.7 *Force Coefficient* — A non-dimensional coefficient such that the total wind force on a body is the product of the force coefficient, the dynamic pressure of the incident design wind speed and the reference area over which the force is required.

NOTE — When the force is in the direction of the incident wind, the non-dimensional coefficient will be called as 'drag coefficient'. When the force is perpendicular to the direction of incident wind, the non-dimensional coefficient will be called as 'lift coefficient'.

3.1.8 *Ground Roughness* — The nature of the earth's surface as influenced by small scale obstructions such as trees and buildings (as distinct from topography) is called ground roughness.

3.1.9 *Gust* — A positive or negative departure of wind speed from its mean value, lasting for not more than, say, 2 minutes over a specified interval of time.

Peak Gust — Peak gust or peak gust speed is the wind speed associated with the maximum amplitude.

Fetch Length — Fetch length is the distance measured along the wind from a boundary at which a change in the type of terrain occurs. When the changes in terrain types are encountered (such as, the boundary of a town or city, forest, etc), the wind profile changes in character but such changes are gradual and start at ground level, spreading or penetrating upwards with increasing fetch length.

Gradient Height — Gradient height is the height above the mean ground level at which the gradient wind blows as a result of balance among pressure gradient force, coriolis force and centrifugal force. For the purpose of this code, the gradient height is taken as the height above the mean ground level, above which the variation of wind speed with height need not be considered.

Mean Ground Level — The mean ground level is the average horizontal plane of the area enclosed by the boundaries of the structure.

Pressure Coefficient — Pressure coefficient is the ratio of the difference between the pressure acting at a point on a surface and the static pressure of the incident wind to the design wind pressure, where the static and design wind pressures are determined at the height of the point considered after taking into account the geographical location, terrain conditions and shielding effect. The pressure coefficient is also equal to $[1-(V_p/V_z)^2]$, where V_p is the actual wind speed at any point on the structure at a height corresponding to that of V_z.

NOTE — Positive sign of the pressure coefficient indicates pressure acting towards the surface and negative sign indicates pressure acting away from the surface.

Return Period — Return period is the number of years, the reciprocal of which gives the probability of extreme wind exceeding a given wind speed in any one year.

Shielding Effect — Shielding effect or shielding refers to the condition where wind has to pass along some structure(s) or structural element(s) located on the upstream wind side, before meeting the structure or structural element under consideration. A factor called 'shielding factor' is used to account for such effects in estimating the force on the shielded structures.

Suction — Suction means pressure less than the atmospheric (static) pressure and is taken to act away from the surface.

Solidity Ratio — 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 boundary of the frame normal to the wind direction.

NOTE — Solidity ratio is to be calculated for individual frames.

Terrain Category — Terrain category means the characteristics of the surface irregularities of an area which arise from natural or constructed features. The categories are numbered in increasing order of roughness.

Velocity Profile — The variation of the horizontal component of the atmospheric wind speed at different heights above the mean ground level is termed as velocity profile.

Topography — The nature of the earth's surface as influenced the hill and valley configurations.

4. GENERAL

4.1 Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind, vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 metres above ground.

4.2 Very strong winds (greater than 80 km/h) are generally associated with cyclonic storms, thunderstorms, dust storms or vigorous monsoons. A feature of the cyclonic storms over the Indian area is that they rapidly weaken after crossing the coasts and move as depressions/lows inland. The influence of a severe storm after striking the coast does not, in general exceed about 60 kilometres, though sometimes, it may extend even up to 120 kilometres. Very short duration hurricanes of very high wind speeds called Kal Baisaki or Norwesters occur fairly frequently during summer months over North East India.

4.3 The wind speeds recorded at any locality are extremely variable and in addition to steady wind at any time, there are effects of gusts which may last for a few seconds. These gusts cause increase in air pressure but their effect on stability of the building may not be so important; often, gusts affect only part of the building and the increased local pressures may be more than balanced by a momentary reduction in the pressure elsewhere. Because of the inertia of the building, short period gusts may not cause any appreciable increase in stress in main components of the building although the walls, roof sheeting and individual cladding units (glass panels) and their supporting members such as purlins, sheeting rails and glazing bars may be more seriously affected. Gusts can also be extremely important for design of structures with high slenderness ratios.

4.4 The liability of a building to high wind pressures depends not only upon the geographical location and proximity of other obstructions to air flow but also upon the characteristics of the structure itself.

4.5 The effect of wind on the structure as a whole is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply.

4.6 The stability calculations as a whole shall be done considering the combined effect, as well as separate effects of imposed loads and wind loads on vertical surfaces, roofs and other part of the building above general roof level.

4.7 Buildings shall also be designed with due attention to the effects of wind on the comfort of people inside and outside the buildings.

5. WIND SPEED AND PRESSURE

5.1 Nature of Wind in Atmosphere — In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to a maximum at a height called the gradient height. There is usually a slight change in direction (Ekman effect) but this is ignored in the code. The variation with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this average value. The average value depends on the averaging time employed in analysing the meteorological data and this averaging time varies from a few seconds to several minutes. The magnitude of fluctuating component of the wind speed which is called gust, depends on the averaging time. In general, smaller the averaging interval, greater is the magnitude of the gust speed.

5.2 Basic Wind Speed — Figure 1 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 1 have been worked out for a 50 year return period. Basic wind speed for some important cities/towns is also given in Appendix A.

5.3 Design Wind Speed (V_z) — The basic wind speed (V_b) for any site shall be obtained from Fig. 1 and shall be modified to include the following effects to get design wind velocity at any height (V_z) for the chosen structure:

a) Risk level;

b) Terrain roughness, height and size of structure; and

c) Local topography.

It can be mathematically expressed as follows:

$$V_z = V_b \, k_1 \, k_2 \, k_3$$

where

V_z = design wind speed at any height z in m/s;

k_1 = probability factor (risk coefficient) (*see* **5.3.1**);

k_2 = terrain, height and structure size factor (*see* **5.3.2**); and

k_3 = topography factor (*see* **5.3.3**).

NOTE — Design wind speep up to 10 m height from mean ground level shall be considered constant.

5.3.1 *Risk Coefficient (k_1 Factor)* — Figure 1 gives basic wind speeds for terrain Category 2 as applicable at 10 m above ground level based on 50 years mean return period. The suggested life period to be assumed in design and the corresponding k_1 factors for different class of structures for the purpose of design is given in Table 1. In the design of all buildings and structures, a regional basic wind speed having a mean return period of 50 years shall be used except as specified in the note of Table 1.

5.3.2 *Terrain, Height and Structure Size Factor (k_2 Factor)*

5.3.2.1 *Terrain* — Selection of terrain categories shall be made with due regard to the effect of obstructions which constitute the ground surface roughness. The terrain category used in the design of a structure may vary depending on the direction of wind under consideration. Wherever sufficient meteorological information is available about the nature of wind direction, the orientation of any building or structure may be suitably planned.

Terrain in which a specific structure stands shall be assessed as being one of the following terrain categories:

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

NOTE — This category includes open sea-coasts and flat treeless plains.

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

NOTE — This is the criterion for measurement of regional basic wind speeds and includes airfields, open parklands and undeveloped sparsely built-up outskirts of towns and suburbs. Open land adjacent to sea coast may also be classified as Category 2 due to roughness of large sea waves at high winds.

c) *Category* 3 — Terrain with numerous closely spaced obstructions having the size of building-structures up to 10 m in height with or without a few isolated tall structures.

NOTE 1 — This category includes well wooded areas, and shrubs, towns and industrial areas full or partially developed.

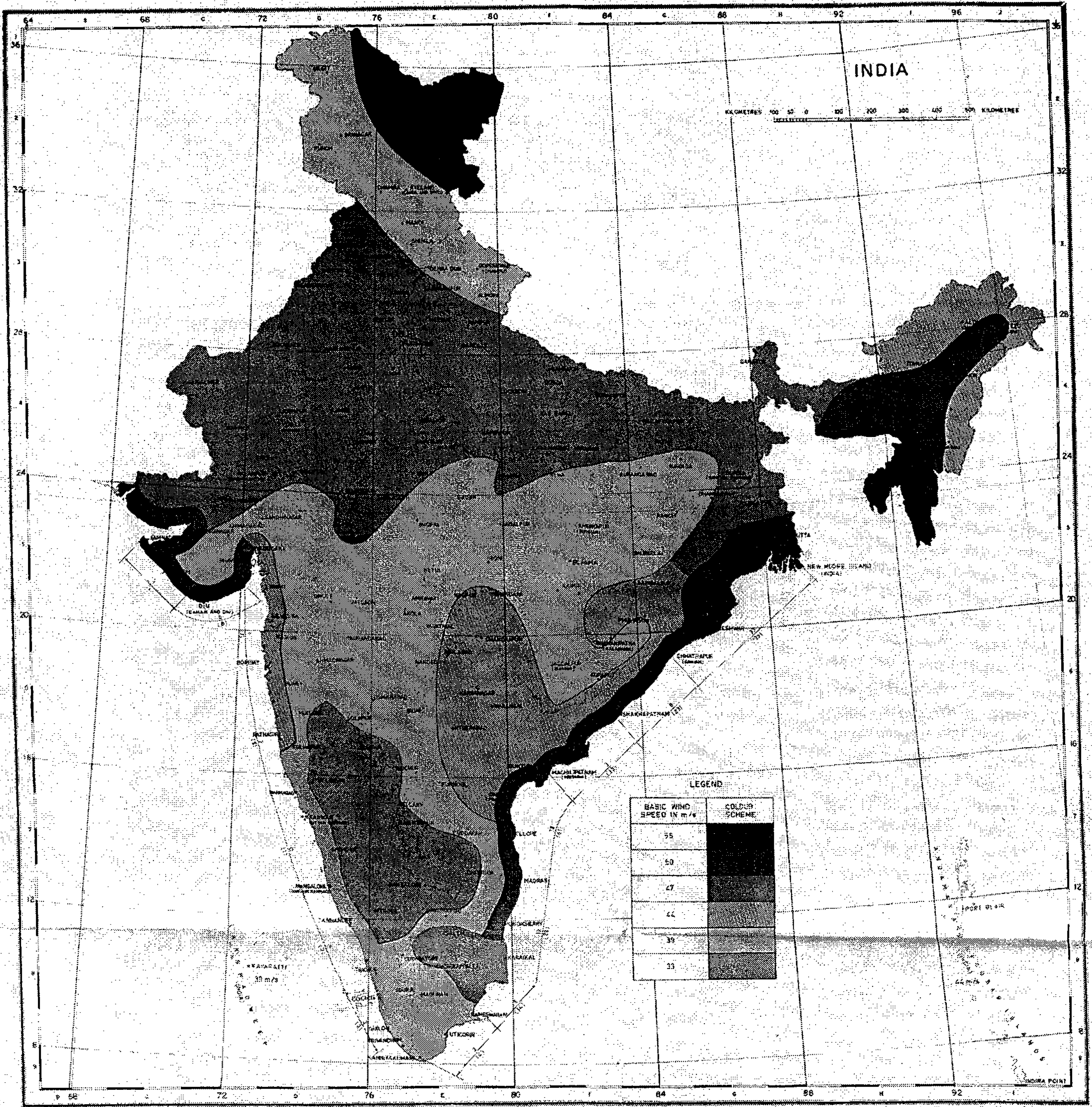
NOTE 2 — It is likely that the next higher category than this will not exist in most design situations and that selection of a more severe category will be deliberate.

NOTE 3 — Particular attention must be given to performance of obstructions in areas affected by fully developed tropical cyclones. Vegetation which is likely to be blown down or defoliated cannot be relied upon to maintain Category 3 conditions. Where such situation may exist, either an intermediate category with velocity multipliers midway between the values for Category 2 and 3 given in Table 2, or Category 2 should be selected having due regard to local conditions.

d) *Category* 4 — Terrain with numerous large high closely spaced obstructions.

NOTE — This category includes large city centres, generally with obstructions above 25 m and well developed industrial complexes.

5.3.2.2 *Variation of wind speed with height for different sizes of structures in different terrains (k_2 factor)* — Table 2 gives multiplying factors (k_2) by which the basic wind speed given in Fig. 1 shall be multiplied to obtain the wind speed at different heights, in each terrain category for different sizes of buildings/structures.



Based upon Survey of India map with the permission of the Surveyor General of India.

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.

The boundary of Meghalaya shown on this map is as Interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but has yet to be verified.

NOTE 1 — The occurrence of a tornado is possible in virtually any part of India. They are particularly more severe in the northern parts of India. The recorded number of these tornados is too small to assign any frequency. The devastation caused by a tornado is due to exceptionally high winds about its periphery, and the sudden reduction in atmospheric pressure at its centre, resulting in an explosive outward pressure on the elements of the structure. The regional basic wind speeds do not include any specific allowance for tornados. It is not the usual practice to allow for the effect of tornados unless special requirements are called for as in the case of important structures such as, nuclear power reactors and satellite communication towers.

NOTE 2 — The total number of cyclonic storms that have struck different sections of east and west coasts are included in Fig. 1, based on available records for the period from 1877 to 1982. The figures above the lines (between the stations) indicate the total number of severe cyclonic storms with or without a core of hurricane winds (speeds above 87 km/h) and the figures in the brackets below the lines indicate the total number of cyclonic storms. Their effect on land is already reflected in the basic wind speeds specified in Fig. 1. These have been included only as an additional information.

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

The buildings/structures are classified into the following three different classes depending upon their size:

Class A — Structures and/or their components such as cladding, glazing, roofing, etc, having maximum dimension (greatest horizontal or vertical dimension) less than 20 m.

Class B — Structures and/or their components such as cladding, glazing, roofing, etc, having maximum dimension (greatest horizontal or vertical dimension) between 20 and 50 m.

Class C — Structures and/or their components such as cladding, glazing, roofing, etc, having maximum dimension (greatest horizontal or vertical dimension) greater than 50 m.

TABLE 1 RISK COEFFICIENTS FOR DIFFERENT CLASSES OF STRUCTURES IN DIFFERENT WIND SPEED ZONES

(*Clause* 5.3.1)

Class of Structure	Mean Probable Design Life of Structure in Years	k_1 Factor for Basic Wind Speed (m/s) of 33	39	44	47	50	55
All general buildings and structures	50	1·0	1·0	1·0	1·0	1·0	1·0
Temporary sheds, structures such as those used during construction operations (for example, formwork and falsework), structures during construction stages and boundary walls	5	0·82	0·76	0·73	0·71	0·70	0·67
Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings	25	0·94	0·92	0·91	0·90	0·90	0·89
Important buildings and structures such as hospitals communication buildings / towers, power plant structures	100	1·05	1·06	1·07	1·07	1·08	1·08

Note — The factor k_1 is based on statistical concepts which take account of the degree of reliability required and period of time in years during which these will be exposure to wind, that is, life of the structure. Whatever wind speed is adopted for design purposes, there is always a probability (however small) that it may be exceeded in a storm of exceptional violence; the greater the period of years over which these will be exposure to the wind, the greater is the probability. Higher return periods ranging from 100 to 1 000 years (implying lower risk level) in association with greater periods of exposure may have to be selected for exceptionally important structures, such as, nuclear power reactors and satellite communication towers. Equation given below may be used in such cases to estimate k_1 factors for different periods of exposure and chosen probability of exceedance (risk level). The probability level of 0·63 is normally considered sufficient for design of buildings and structures against wind effects and the values of k_1 corresponding to this risk level are given above.

$$k_1 = \frac{X_{N,P}}{X_{50,\,0\cdot63}} = \frac{A - B\left[ln\left\{ -\frac{1}{N}\, ln\left(1 - P_N\right)\right\}\right]}{A + 4B}$$

where

N = mean probable design life of structure in years;

P_N = risk level in N consecutive years (probability that the design wind speed is exceeded at least once in N successive years), nominal value = 0·63;

$X_{N,P}$ = extreme wind speed for given values of N and P_N; and

$X_{50,\,0\cdot63}$ = extreme wind speed for N = 50 years and P_N = 0·63.

A and B are coefficients having the following values for different basic wind speed zones:

Zone	*A*	*B*
33 m/s	83·2	9·2
39 m/s	84·0	14·0
44 m/s	88·0	18·0
47 m/s	88·0	20·5
50 m/s	88·8	22·8
55 m/s	90·8	27·3

TABLE 2 k_2 FACTORS TO OBTAIN DESIGN WIND SPEED VARIATION WITH HEIGHT IN DIFFERENT TERRAINS FOR DIFFERENT CLASSES OF BUILDINGS/STRUCTURES

(*Clause* 5.3.2.2)

HEIGHT	TERRAIN CATEGORY 1 CLASS			TERRAIN CATEGORY 2 CLASS			TERRAIN CATEGORY 3 CLASS			TERRAIN CATEGORY 4 CLASS		
m	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
10	1·05	1·03	0·99	1·00	0·98	0·93	0·91	0·88	0·82	0·80	0·76	0·67
15	1·09	1·07	1·03	1·05	1·02	0·97	0·97	0·94	0·87	0·80	0·76	0·67
20	1·12	1·10	1·06	1·07	1·05	1·00	1·01	0·98	0·91	0·80	0·76	0·67
30	1·15	1·13	1·09	1·12	1·10	1·04	1·06	1·03	0·96	0·97	0·93	0·83
50	1·20	1·18	1·14	1·17	1·15	1·10	1·12	1·09	1·02	1·10	1·05	0·95
100	1·26	1·24	1·20	1·24	1·22	1·17	1·20	1·17	1·10	1·20	1·15	1·05
150	1·30	1·28	1·24	1·28	1·25	1·21	1·24	1·21	1·15	1·24	1·20	1·10
200	1·32	1·30	1·26	1·30	1·28	1·24	1·27	1·24	1·18	1·27	1·22	1·13
250	1·34	1·32	1·28	1·32	1·31	1·26	1·29	1·26	1·20	1·28	1·24	1·16
300	1·35	1·34	1·30	1·34	1 32	1·28	1·31	1·28	1·22	1·30	1·26	1·17
350	1·37	1·35	1·31	1·36	1·34	1·29	1·32	1·30	1·24	1·31	1·27	1·19
400	1·38	1·36	1·32	1·37	1·35	1·30	1·34	1·31	1·25	1·32	1·28	1·20
450	1·39	1·37	1·33	1·38	1·36	1·31	1·35	1·32	1·26	1·33	1·29	1·21
500	1·40	1·38	1·34	1·39	1·37	1·32	1·36	1·33	1·28	1·34	1·30	1·22

NOTE 1 — *See* 5.3.2.2 for definitions of Class A, Class B and Class C structures.

NOTE 2 — Intermediate values may be obtained by linear interpolation, if desired. It is permissible to assume constant wind speed between 2 heights for simplicity.

5.3.2.3 *Terrain categories in relation to the direction of wind* — The terrain category used in the design of a structure may vary depending on the direction of wind under consideration. Where sufficient meteorological information is available, the basic wind speed may be varied for specific wind direcion.

5.3.2.4 *Changes in terrain categories* — The velocity profile for a given terrain category does not develop to full height immediately with the commencement of that terrain category but develop gradually to height (h_x) which increases with the fetch or upwind distance (x).

a) *Fetch and developed height relationship* — The relation between the developed height (h_x) and the fetch (x) for wind-flow over each of the four terrain categories may be taken as given in Table 3.

b) For structures of heights greater than the developed height (h_x) in Table 3, the velocity profile may be determined in accordance with the following:

i) The less or least rough terrain, or

ii) The method described in Appendix B.

5.3.3 *Topography* (k_3 *Factor*) — The basic wind speed V_b given in Fig. 1 takes account of the general level of site above sea level. This does not allow for local topographic features such as hills, valleys, cliffs, escarpments, or ridges which can significantly affect wind speed in their vicinity. The effect of topography is to accelerate wind near the summits of hills or crests of cliffs, escarpments or ridges and decelerate the wind in valleys or near the foot of cliffs, steep escarpments, or ridges.

TABLE 3 FETCH AND DEVELOPED HEIGHT RELATIONSHIP

(*Clause* 5.3.2.4)

FETCH (x) km	DEVELOPED HEIGHT, h_x IN METRES			
	Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
(1)	(2)	(3)	(4)	(5)
0·2	12	20	35	60
0·5	20	30	35	95
1	25	45	80	130
2	35	65	110	190
5	60	100	170	300
10	80	140	250	450
20	120	200	350	500
50	180	300	400	500

5.3.3.1 The effect of topography will be significant at a site when the upwind slope (θ) is greater than about 3°, and below that, the value of k_3 may be taken to be equal to 1·0. The value of k_3 is confined in the range of 1·0 to 1·36 for slopes greater than 3°. A method of evaluating the value of k_3 for values greater than 1·0 is given in Appendix C. It may be noted that the value of k_3 varies with height above ground level, at a maximum near the ground, and reducing to 1·0 at higher levels.

5.4 Design Wind Pressure — The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$p_z = 0{\cdot}6\ V_z^2$$

where

p_z = design wind pressure in N/m² at height z, and

V_z = design wind velocity in m/s at height z.

NOTE — The coefficient 0·6 (in SI units) in the above formula depends on a number of factors and mainly on the atmospheric pressure and air temperature. The value chosen corresponds to the average appropriate Indian atmospheric conditions.

5.5 Off Shore Wind Velocity — Cyclonic storms form far away from the sea coast and gradually reduce in speed as they approach the sea coast. Cyclonic storms generally extend up to about 60 kilometres inland after striking the coast. Their effect on land is already reflected in basic wind speeds specified in Fig. 1. The influence of wind speed off the coast up to a distance of about 200 kilometres may be taken as 1·15 times the value on the nearest coast in the absence of any definite wind data.

6. WIND PRESSURES AND FORCES ON BUILDINGS/STRUCTURES

6.1 General — The wind load on a building shall be calculated for:

a) The building as a whole,

b) Individual structural elements as roofs and walls, and

c) Individual cladding units including glazing and their fixings.

6.2 Pressure Coefficients — The pressure coefficients are always given for a particular surface or part of the surface of a building. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (C_p) and the design wind pressure at the height of the surface from the ground. The average values of these pressure coefficients for some building shapes are given in **6.2.2** and **6.2.3**.

Average values of pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building, the total load should be calculated for each of the critical directions shown from all quadrants. Where considerable variation of pressure occurs over a surface, it has been subdivided and mean pressure coefficients given for each of its several parts.

In addition, areas of high local suction (negative pressure concentration) frequently occurring near the edges of walls and roofs are separately shown. Coefficients for the local effects should only be used for calculation of forces on these local areas affecting roof sheeting, glass panels, individual cladding units including their fixtures. They should not be used for calculating force on entire structural elements such as roof, walls or structure as a whole.

NOTE 1 — The pressure coefficients given in different tables have been obtained mainly from measurements on models in wind tunnels, and the great majority of data available has been obtained in conditions of relatively smooth flow. Where sufficient field data exists as in the case of rectangular buildings, values have been obtained to allow for turbulent flow.

NOTE 2 — In recent years, wall glazing and cladding design has been a source of major concern. Although of less consequence than the collapse of main structures, damage to glass can be hazardous and cause considerable financial losses.

NOTE 3 — For pressure coefficients for structures not covered here, reference may be made to specialist literature on the subject or advise may be sought from specialists in the subject.

6.2.1 *Wind Load on Individual Members* — When calculating the wind load on individual strcutural elements such as roofs and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite faces of such elements or units. For clad structures, it is, therefore, necessary to know the internal pressure as well as the external pressure. Then the wind load, F, acting in a direction normal to the individual structural element or cladding unit is:

$$F = (C_{pe} - C_{pi}) A p_d$$

where

C_{pe} = external pressure coefficient,

C_{pi} = internal pressure coefficient,

A = surface area of structural element or cladding unit, and

p_d = design wind pressure.

NOTE 1 — If the surface design pressure varies with height, the surface areas of the structural element may be sub-divided so that the specified pressures are taken over appropriate areas.

NOTE 2 — Positive wind load indicates the force acting towards the structural element and negative away from it.

6.2.2 *External Pressure Coefficients*

6.2.2.1 *Walls* — The average external pressure coefficient for the walls of clad buildings of rectangular plan shall be as given in Table 4. In addition, local pressure concentration coefficients are also given.

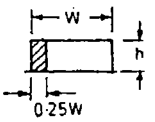
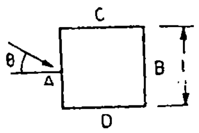
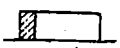
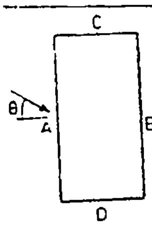
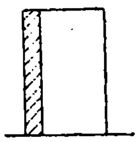
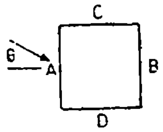
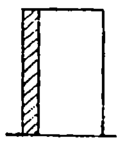
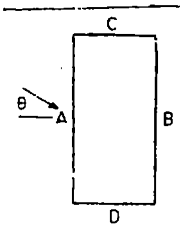
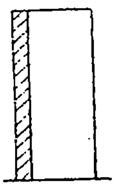
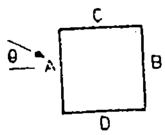
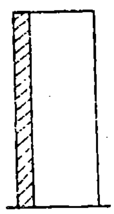
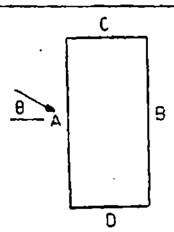
6.2.2.2 *Pitched roofs of rectangular clad buildings* — The average external pressure coefficients and pressure concentration coefficients for pitched roofs of rectangular clad building shall be as given in Table 5. Where no pressure concentration coefficients are given, the average coefficients shall apply. The pressure coefficients on the underside of any overhanging roof shall be taken in accordance with **6.2.2.7**.

NOTE 1 — The pressure concentration shall be assumed to act outward (suction pressure) at the ridges, eaves, cornices and 90 degree corners of roofs (*see* **6.2.2.7**).

NOTE 2 — The pressure concentration shall not be included with the net external pressure when computing overall loads.

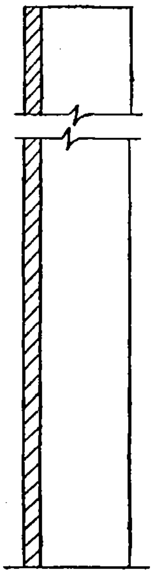
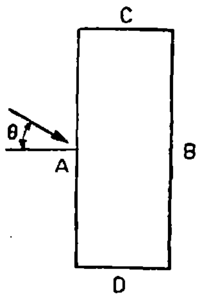
TABLE 4 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR WALLS OF RECTANGULAR CLAD BUILDINGS

(*Clause* 6.2.2.1)

Building Height Ratio	Building Plan Ratio	Elevation	Plan	Wind Angle θ	C_{pe} for Surface A	B	C	D	Local C_{pe}
				degrees					
$\frac{h}{w} < \frac{1}{2}$	$1 < \frac{l}{w} < \frac{3}{2}$			0 90	+0·7 −0·5	−0·2 −0·5	−0·5 +0·7	−0·5 −0·2	−0·8
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+0·7 −0·5	−0·25 −0·5	−0·6 +0·7	−0·6 −0·1	−1·0
$\frac{1}{2} < \frac{h}{w} \leqslant \frac{3}{2}$	$1 < \frac{l}{w} < \frac{3}{2}$			0 90	+0·7 −0·6	−0·25 −0·6	−0·6 +0·7	−0·6 −0·25	−1·1
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+0·7 −0·5	−0·3 −0·5	−0·7 +0·7	−0·7 −0·1	−1·1
$\frac{3}{2} < \frac{h}{w} < 6$	$1 < \frac{l}{w} \leqslant \frac{3}{2}$			0 90	+0·8 −0·8	−0·25 −0·8	−0·8 +0·8	−0·8 −0·25	−1·2
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+0·7 −0·5	−0·4 −0·5	−0·7 +0·8	−0·7 −0·1	−1·2

(*Continued*)

TABLE 4 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR WALLS OF RECTANGULAR CLAD BUILDINGS — *Contd*

Building Height Ratio	Building Plan Ratio	Elevation	Plan	Wind Angle θ	C_{pe} for Surface A	B	C	D	Local C_{pe}
$\frac{h}{w} > \infty$	$\frac{l}{w} = \frac{3}{2}$			0	+0·95	−1·85	−0·9	−0·9	−1·25
				90	−0·8	−0·8	+0·9	−0·85	
	$\frac{l}{w} = 1·0$			0	+0·95	−1·25	−0·7	−0·7	−1·25
				90	−0·7	−0·7	+0·95	−1·25	
	$\frac{l}{w} = 2$			0	+0·85	−0·75	−0·75	−0·75	−1·25
				90	−0·75	−0.75	+0·85	−0·75	

NOTE — h is the height to eaves or parapet, l is the greater horizontal dimension of a building and w is the lesser horizontal dimension of a building.

6.2.2.3 *Monoslope roofs of rectangular clad buildings* — The average pressure coefficient and pressure concentration coefficient for monoslope (lean-to) roofs of rectangular clad buildings shall be as given in Table 6.

6.2.2.4 *Canopy roofs with* $\left(\frac{l}{4} < \frac{h}{w} < 1 \text{ and } 1 < \frac{L}{w} < 3\right)$ — The pressure coefficients are given in Tables 7 and 8 separately for mono-pitch and double pitch canopy roofs such as open-air parking garages, shelter areas, outdoor areas, railway platforms, stadiums and theatres. The coefficients take account of the combined effect of the wind exerted on and under the roof for all wind directions; the resultant is to be taken normal to the canopy. Where the local coefficients overlap, the greater of the two given values should be taken. However, the effect of partial closures of one side and or both sides, such as those due to trains, buses and stored materials shall be foreseen and taken into account.

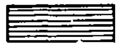
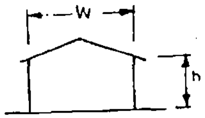
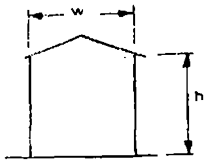
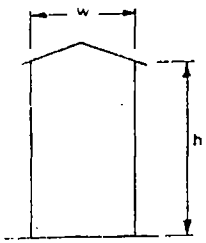
The solidity ratio ϕ is equal to the area of obstructions under the canopy divided by the gross area under the canopy, both areas normal to the wind direction. $\phi = 0$ represents a canopy with no obstructions underneath. $\phi = 1$ represents the canopy fully blocked with contents to the downwind eaves. Values of C_p for intermediate solidities may be linearly interpolated between these two extremes, and apply upwind of the position of maximum blockage only. Downwind of the position of maximum blockage the coefficients for $\phi = 0$ may be used.

In addition to the pressure forces normal to the canopy, there will be horizontal loads on the canopy due to the wind pressure on any fascia and to friction over the surface of the canopy. For any wind direction, only the greater of these two forces need be taken into account. Fascia loads should be calculated on the area of the surface facing the wind, using a force coefficient of 1·3. Frictional drag should be calculated using the coefficients given in **6.3.1**.

NOTE — Tables 9 to 14 may be used to get internal and external pressure coefficients for pitches and troughed free roofs for some specific cases for which aspect ratios and roof slopes have been specified. However, while using Tables 9 to 14 any significant departure from it should be investigated carefully. No increase shall be made for local effects except as indicated.

TABLE 5 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR PITCHED ROOFS OF RECTANGULAR CLAD BUILDINGS

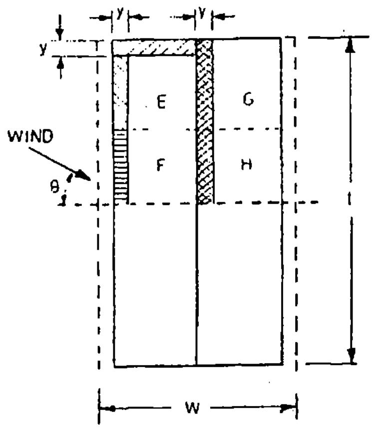
(*Clause* 6.2.2.2)

BUILDING HEIGHT RATIO		ROOF ANGLE α	WIND ANGLE θ 0°		WIND ANGLE θ 90°		LOCAL COEFFICIENTS			
			EF	GH	EG	FH				
		degrees								
$\frac{h}{w} \leqslant \frac{1}{2}$		0	−0·8	−0·4	−0·8	−0·4	−2·0	−2·0	−2·0	—
		5	−0·9	−0·4	−0·8	−0·4	−1·4	−1·2	−1·2	−1·0
		10	−1·2	−0·4	−0·8	−0·6	−1·4	−1·4		−1·2
		20	−0·4	−0·4	−0·7	−0·6	−1·0			−1·2
		30	0	−0·4	−0·7	−0·6	−0·8			−1·1
		45	+0·3	−0·5	−0·7	−0·6				−1·1
		60	+0·7	−0·6	−0·7	−0·6				−1·1
$\frac{1}{2} < \frac{h}{w} \leqslant \frac{3}{2}$		0	−0·8	−0·6	−1·0	−0·6	−2·0	−2·0	−2·0	—
		5	−0·9	−0·6	−0·9	−0·6	−2·0	−2·0	−1·5	−1·0
		10	−1·1	−0·6	−0·8	−0·6	−2·0	−2·0	−1·5	−1·2
		20	−0·7	−0·5	−0·8	−0·6	−1·5	−1·5	−1·5	−1·0
		30	−0·2	−0·5	−0·8	−0·8	−1·0			−1·0
		45	+0·2	−0·5	−0·8	−0·8				
		60	+0·6	−0·5	−0·8	−0·8				
$\frac{3}{2} < \frac{h}{w} < 6$		0	−0·7	−0·6	−0·9	−0·7	−2·0	−2·0	−2·0	—
		5	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·0
		10	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·2
		20	−0·8	−0·6	−0·8	−0·8	−1·5	−1·5	−1·5	−1·2
		30	−1·0	−0·5	−0·8	−0·7	−1·5			
		40	−0·2	−0·5	−0·8	−0·7	−1·0			
		50	+0·2	−0·5	−0·8	−0·7				
		60	+0·5	−0·5	−0·8	−0·7				

NOTE 1 — h is the height to eaves or parapet and w is the lesser horizontal dimension of a building.

NOTE 2 — Where no local coefficients are given, the overall coefficients apply.

NOTE 3 — For hipped roofs the local coefficient for the hip ridge may be conservatively taken as the appropriate ridge value.

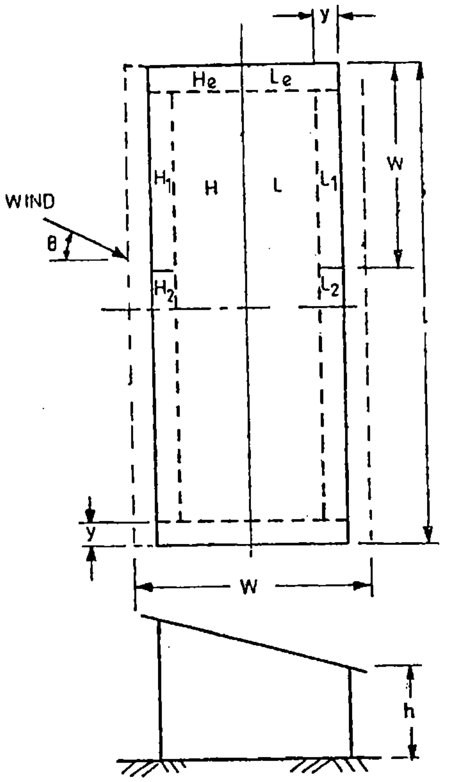


KEY PLAN

$y = h$ or $0.15\,w$, whichever is the lesser.

TABLE 6 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR MONOSLOPE ROOFS FOR RECTANGULAR CLAD BUILDINGS WITH $\frac{h}{w} < 2$

(*Clause* 6.2.2.3)



$y = h$ or $0{\cdot}15\,w$, whichever is the lesser.

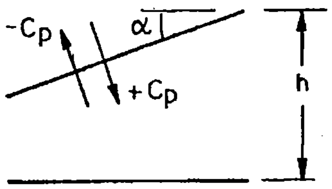
NOTE — Area *H* and area *L* refer to the whole quadrant.

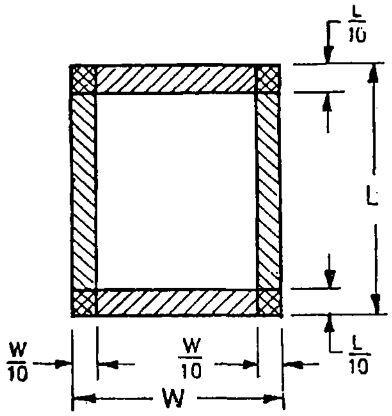
ROOF ANGLE α	WIND ANGLE θ										LOCAL C_{pe}					
	0°		45°		90°		135°		180°							
Degree	*H*	*L*	*H*	*L*	*H* & *L* (Applies to length *w*/2 from windward end)	*H* & *L* (Applies to remainder)	*H*	*L*	*H*	*L*	H_1	H_2	L_1	L_2	*He*	*Le*
5	−1·0	−0·5	−1·0	−0·9	−1·0	−0·5	−0·9	−1·0	−0·5	−1·0	−2·0	−1·5	−2·0	−1·5	−2·0	−2·0
10	−1·0	−0·5	−1·0	−0·8	−1·0	−0·5	−0·8	−1·0	−0·4	−1·0	−2·0	−1·5	−2·0	−1·5	−2·0	−2·0
15	−0·9	−0·5	−1·0	−0·7	−1·0	−0·5	−0·6	−1·0	−0·3	−1·0	−1·8	−0·9	−1·8	−1·4	−2·0	−2·0
20	−0·8	−0·5	−1·0	−0·6	−0·9	−0·5	−0·5	−1·0	−0·2	−1·0	−1·8	−0·8	−1·8	−1·4	−2·0	−2·0
25	−0·7	−0·5	−1·0	−0·6	−0·8	−0·5	−0·3	−0·9	−0·1	−0·9	−1·8	−0·7	−0·9	−0·9	−2·0	−2·0
30	−0·5	−0·5	−1·0	−0·6	−0·8	−0·5	−0·1	−0·6	0	−0·6	−1·8	−0·5	−0·5	−0·5	−2·0	−2·0

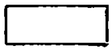
NOTE — *h* is the height to eaves at lower side, *l* is the greater horizontal dimension of a building and *w* is the lesser horizontal dimension of a building.

TABLE 7 PRESSURE COEFFICIENTS FOR MONOSLOPE FREE ROOFS

(*Clause* 6.2.2.4)



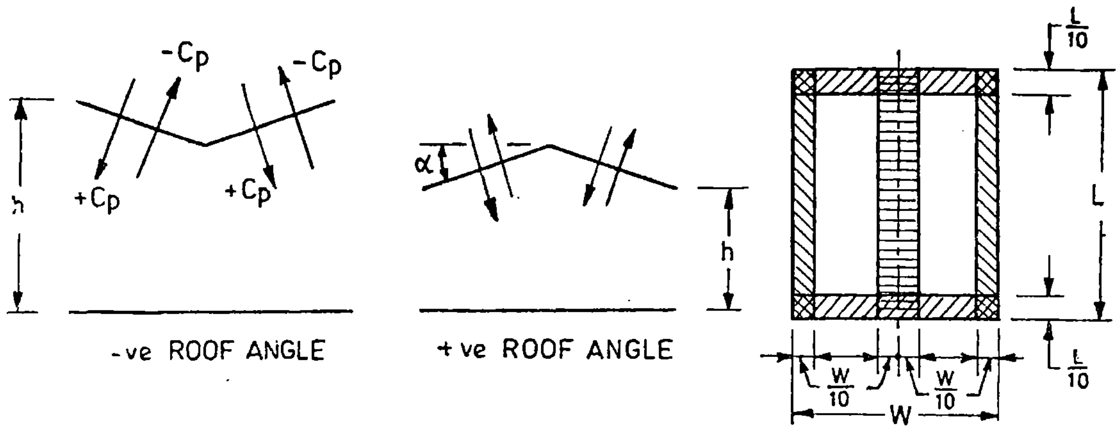


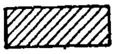
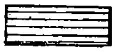
Roof Angle (Degrees)	Solidity Ratio	Maximum (Largest + ve) and Minimum (Largest − ve) Pressure Coefficients			
		Overall Coefficients	Local Coefficients		
					
0	All values of ϕ	+0·2	+0·5	+1·8	+1·1
5		+0·4	+0·8	+2·1	+1·3
10		+0·5	+1·2	+2·4	+1·6
15		+0·7	+1·4	+2·7	+1·8
20		+0·8	+1·7	+2·9	+2·1
25		+1·0	+2·0	+3·1	+2·3
30		+1·2	+2·2	+3·2	+2·4
0	ϕ=0	−0·5	−0·6	−1·3	−1·4
	ϕ=1	−1·0	−1·2	−1·8	−1·9
5	ϕ=0	−0·7	−1·1	−1·7	−1·8
	ϕ=1	−1·1	−1·6	−2·2	−2·3
10	ϕ=0	−0·9	−1·5	−2·0	−2·1
	ϕ=1	−1·3	−2·1	−2·6	−2·7
15	ϕ=0	−1·1	−1·8	−2·4	−2·5
	ϕ=1	−1·4	−2·3	−2·9	−3·0
20	ϕ=0	−1·3	−2·2	−2·8	−2·9
	ϕ=1	−1·5	−2·6	−3·1	−3·2
25	ϕ=0	−1·6	−2·6	−3·2	−3·2
	ϕ=1	−1·7	−2·8	−3·5	−3·5
30	ϕ=0	−1·8	−3·0	−3·8	−3·6
	ϕ=1	−1·8	−3·0	−3·8	−3·6

NOTE — For monopitch canopies the centre of pressure should be taken to act at 0·3 w from the windward edge.

TABLE 8 PRESSURE COEFFICIENTS FOR FREE STANDING DOUBLE SLOPED ROOFS

(*Clause* 6.2.2.4)

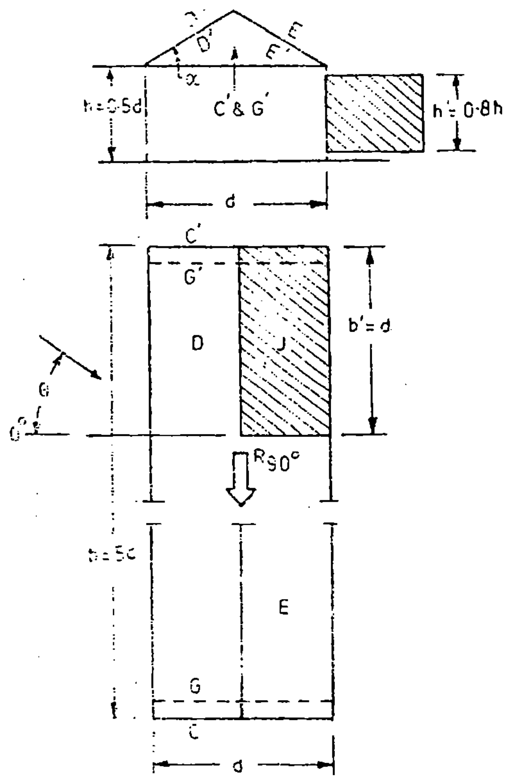


Roof Angle (Degrees)	Solidity Ratio	Maximum (Largest + ve) and Minimum (Largest − ve) Pressure Coefficients				
		Overall Coefficients	Local Coefficients			
						
−20	All values of ϕ	+0·7	+0·8	+1·6	+0·6	+1·7
−15		+0·5	+0·6	+1·5	+0·7	+1·4
−10		+0·4	+0·6	+1·4	+0·8	+1·1
−5		+0·3	+0·5	+1·5	+0·8	+0·8
+5		+0·3	+0·6	+1·8	+1·3	+0·4
+10		+0·4	+0·7	+1·8	+1·4	+0·4
+15		+0·4	+0·9	+1·9	+1·4	+0·4
+20		+0·6	+1·1	+1·9	+1·5	+0·4
+25		+0·7	+1·2	+1·9	+1·6	+0·5
+30		+0·9	+1·3	+1·9	+1·6	+0·7
−20	ϕ=0	−0·7	−0·9	−1·3	−1·6	−0·6
	ϕ=1	−0·9	−1·2	−1·7	−1·9	−1·2
−15	ϕ=0	−0·6	−0·8	−1·3	−1·6	−0·6
	ϕ=1	−0·8	−1·1	−1·7	−1·9	−1·2
−10	ϕ=0	−0·6	−0·8	−1·3	−1·5	−0·6
	ϕ=1	−0·8	−1·1	−1·7	−1·9	−1·3
−5	ϕ=0	−0·5	−0·7	−1·3	−1·6	−0·6
	ϕ=1	−0·8	−1·5	−1·7	−1·9	−1·4
+5	ϕ=0	−0·6	−0·6	−1·4	−1·4	−1·1
	ϕ=1	−0·9	−1·3	−1·8	−1·8	−2·1
+10	ϕ=0	−0·7	−0·7	−1·5	−1·4	−1·4
	ϕ=1	−1·1	−1·4	−2·0	−1·8	−2·4
+15	ϕ=0	−0·8	−0·9	−1·7	−1·4	−1·8
	ϕ=1	−1·2	−1·5	−2·2	−1·9	−2·8
+20	ϕ=0	−0·9	−1·2	−1·8	−1·4	−2·0
	ϕ=1	−1·3	−1·7	−2·3	−1·9	−3·0
+25	ϕ=0	−1·0	−1·4	−1·9	−1·4	−2·0
	ϕ=1	−1·4	−1·9	−2·4	−2·1	−3·0
+30	ϕ=0	−1·0	−1·4	−1·9	−1·4	−2·0
	ϕ=1	−1·4	−2·1	−2·6	−2·2	−3·0

Each slope of a duopitch canopy should be able to withstand forces using both the maximum and the minimum coefficients, and the whole canopy should be able to support forces using one slope at the maximum coefficient with the other slope at the minimum coefficient. For duopitch canopies the centre of pressure should be taken to act at the centre of each slope.

TABLE 10 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED FREE ROOFS, $\alpha = 30°$ WITH EFFECTS OF TRAIN OR STORED MATERIALS

(*Clause* 6.2.2.4)

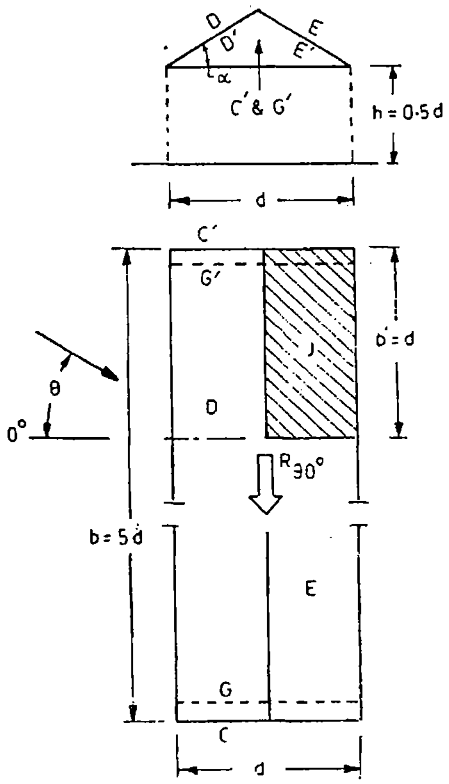


Roof slope $\alpha = 30°$
Effects of trains or stored materials:
$\theta = 0° - 45°$, or $135° - 180°$, D, D', E, E' full length
$\theta = 90°$, D, D', E, E' part length b', thereafter $C_p = 0$

θ	Pressure Coefficients, C_p							
					End Surfaces			
	D	D'	E	E'	C	C'	G	G'
0°	0·1	0·8	−0·7	0·9				
45°	−0·1	0·5	−0·8	0·5				
90°	−0·4	−0·5	−0·4	−0·5	−0·3	0·8	0·3	−0·4
180°	−0·3	−0·6	0·4	−0·6				
45°	For j : C_p top $= -1·5$; C_p bottom $= 0·5$							
90°	Tangentially acting friction: $R_{90°} = 0·05\ p_d bd$							

TABLE 9 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED ROOFS, $\alpha = 30°$

(*Clause* 6.2.2.4)

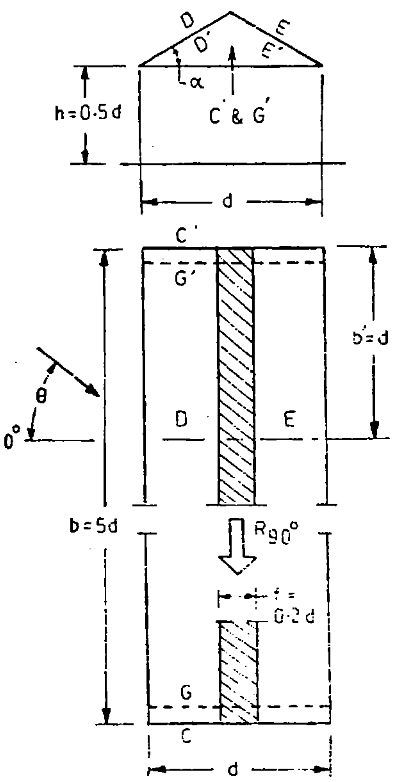


Roof slope $\alpha = 30°$
$\theta = 0° - 45°$, *D, D', E, E'* full length
$\theta = 90°$, *D, D', E, E'* part length *b'*, thereafter $C_p = 0$

θ	Pressure Coefficients, C_p							
					End Surfaces			
	D	*D'*	*E*	*E'*	*C*	*C'*	*G*	*G'*
0	0·6	−1·0	−0·5	−0·9				
45°	0·1	−0·3	−0·6	−0·3				
90°	−0·3	−0·4	−0·3	−0·4	−0·3	0·8	0·3	0·4
45°	For *j* : C_p top = −1·0; C_p bottom = −0·2							
90°	Tangentially acting friction: $R_{90°} = 0·05\, p_d bd$							

TABLE 11 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED FREE ROOFS, $\alpha = 10°$

(*Clause* 6.2.2.4)

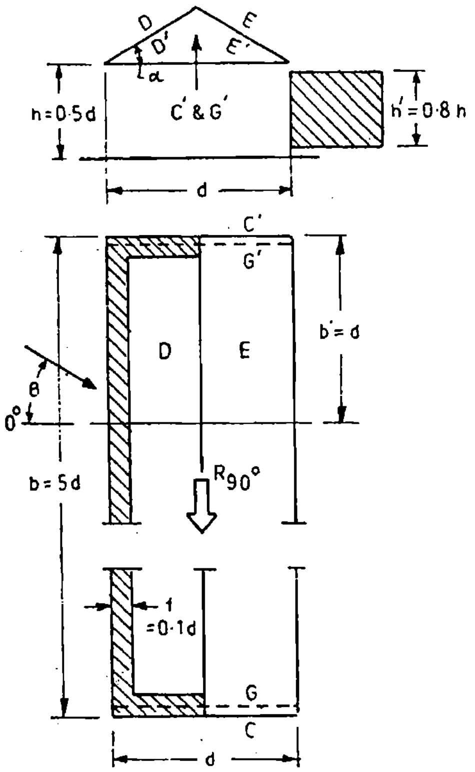


Roof slope $\alpha = 10°$
$\theta = 0° - 45°$, D, D', E, E' full length
$\theta = 90°$, D, D', E, E' part length b', thereafter $C_p = 0$

θ	Pressure Coefficients, C_p							
					End Surfaces			
	D	*D'*	*E*	*E'*	*C*	*C'*	*G*	*G'*
0°	−1·0	0 3	−0·5	0·2				
45°	−0·3	0·1	−0·3	0·1				
90°	−0 3	0	−0·3	0	−0·4	0·8	0·3	−0·6
0°	For *f*: C_p top = −1·0; C_p bottom = 0·4							
0° − 90°	Tangentially acting friction, $R_{90°} = 0·1\ p_d bd$							

TABLE 12 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED FREE ROOFS $\alpha = 10°$ WITH EFFECTS OF TRAIN OR STORED MATERIALS

(*Clause* 6.2.2.4)



Roof slope $\alpha = 10°$

Effects of trains or stored materials:

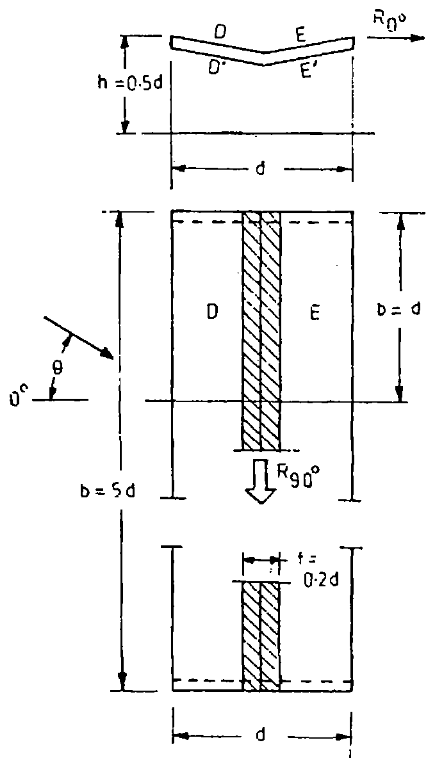
$\theta = 0° - 45°$, or $135° - 180°$, D, D', E, E' full length

$\theta = 90°$, D, D', E, E' part length b', thereafter $C_p = 0$

θ	Pressure Coefficients, C_p							
					End Surfaces			
	D	*D'*	*E*	*E'*	*C*	*C'*	*G*	*G'*
0°	−1·3	0·8	−0·6	0·7				
45°	−0·5	0·4	−0·3	0·3				
90°	−0·3	0	−0·3	0	−0·4	0·8	0·3	−0·6
180°	−0·4	−0·3	−0·6	−0·3				
0°	For *f*: C_p top = −1·6; C_p bottom = 0·9							
0° − 180°	Tangentially acting friction: $R_{90°} = 0·1\ p_d bd$							

TABLE 13 EXTERNAL PRESSURE COEFFICIENTS FOR TROUGHED FREE ROOFS, $\alpha = 10°$

(*Clause* 6.2.2.4)

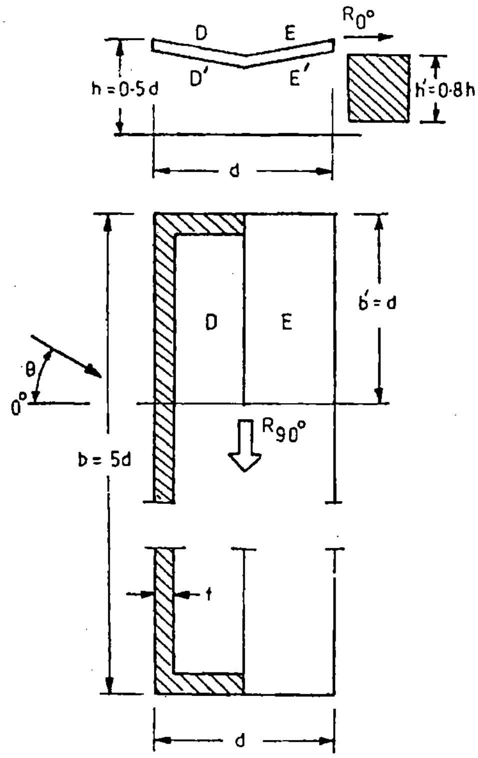


Roof slope $\alpha = 10°$
$\theta = 0° - 45°$, D, D', E, E' full length
$\theta = 90°$, D, D', E, E' part length b', thereafter $C_p = 0$

θ	Pressure Coefficients, C_p			
	D	*D'*	*E*	*E'*
0°	0·3	−0·7	0·2	−0·9
45°	0	−0·2	0·1	−0·3
90°	−0·1	0·1	−0·1	0·1
0°	For f: C_p top = 0·4; C_p bottom = −1·5			
0° − 90°	Tangentially acting friction $R_{90°} = 0·1\ p_d bd$			

TABLE 14 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR TROUGHED FREE ROOFS, $\alpha = 10°$ WITH EFFECTS OF TRAINS OR STORED MATERIALS

(*Clause* 6.2.2.4)



Roof slope $\alpha = 10°$
Effects of trains or stored materials:
$\theta = 0° - 45°$, or $135° - 180°$, *D*, *D'*, *E*, *E'* full length
$\theta = 90°$, *D*, *D'*, *E*, *E'*, part length *b'* thereafter $C_p = 0$

θ	Pressure Coefficients, C_p			
	D	*D'*	*E*	*E'*
0°	−0·7	0·8	−0·6	0·6
45°	−0·4	0·3	−0·2	0·2
90°	−0·1	0·1	−0·1	0·1
180°	−0·4	−0·2	−0·6	−0·3
0°	For *f*: C_p top = −1·1; C_p bottom = 0·9			
0°–180°	Tangentially acting friction: $R_{90°} = 0{\cdot}1\, p_d b d$			

6.2.2.5 *Curved roofs* — For curved roofs, the external pressure coefficients shall be as given in Table 15. Allowance for local effects shall be made in accordance with Table 5.

6.2.2.6 *Pitched and saw-tooth roofs of multi-span buildings* — For pitched and saw-tooth roofs of multi-span buildings, the external average pressure coefficients and pressure concentration coefficients shall be as given in Tables 16 and 17 respectively provided that all spans shall be equal and the height to the eaves shall not exceed the span.

NOTE — Evidence on multi-span buildings is fragmentary; any departure given in Tables 16 and 17 should be investigated separately.

6.2.2.7 *Pressure coefficients on overhangs from roofs* — The pressure coefficients on the top overhanging portion of the roofs shall be taken to be the same as that of the nearest top portion of the non-overhanging portion of the roofs. The pressure coefficients for the underside surface of the overhanging portions shall be taken as follows and shall be taken as positive if the overhanging portion is on the windward side:

a) 1·25 if the overhanging slopes,

b) 1·00 if the overhanging is horizontal, and

c) 0·75 if the overhanging slopes upwards.

For overhanging portions on sides other than the windward side, the average pressure coefficients on adjoining walls may be used.

6.2.2.8 *Cylindrical structures* — For the purpose of calculating the wind pressure distribution around a cylindrical structure of circular cross-section, the value of external pressure coefficients given in Table 18 may be used provided that the Reynolds number is greater than 10 000. They may be used for wind blowing normal to the axis of cylinders having axis normal to the ground plane (that is, chimneys and silos) and cylinders having their axis parallel to the ground plane (that is, horizontal tanks) provided that the clearance between the tank and the ground is not less than the diameter of the cylinder.

h is height of a vertical cylinder or length of a horizontal cylinder. Where there is a free flow of air around both ends, h is to be taken as half the length when calculating h/D ratio.

In the calculation of the resultant load on the periphery of the cylinder, the value of C_{pi} shall be taken into account. For open ended cylinders, C_{pi} shall be taken as follows:

a) 0·8 where h/D is not less than 0·3, and

b) 0·5 where h/D is less than 0·3.

6.2.2.9 *Roofs and bottoms of cylindrical elevated structures* — The external pressure coefficients for roofs and bottoms of cylindrical elevated structures shall be as given in Table 19 (*see also* Fig. 2).

The total resultant load (P) acting on the roof of the structure is given by the following formula:

$$P = 0{\cdot}785\ D^2\ (p_i - C_{pe}\, p_d)$$

The resultant of P for roofs lies at 0·1 D from the centre of the roof on the windword side.

6.2.2.10 *Combined roofs and roofs with a sky light* — The average external pressure coefficients for combined roofs and roofs with a sky light is shown in Table 20.

6.2.2.11 *Grandstands* — The pressure coefficients on the roof (top and bottom) and rear wall of a typical grandstand roof which is open on three sides is given in Table 21. The pressure coefficients are valid for a particular ratio of dimensions as specified in Table 21 but may be used for deviations up to 20 percent. In general, the maximum wind load occurs when the wind is blowing into the open front of the stand, causing positive pressure under the roof and negative pressure on the roof.

6.2.2.12 *Upper surface of round silos and tanks* — The pressure coefficients on the upper surface of round silos and tanks standing on ground shall be as given in Fig. 2.

6.2.2.13 *Spheres* — The external pressure coefficients for spheres shall be as given in Table 22.

6.2.3 *Internal Pressure Coefficients* — Internal air pressure in a building depends upon the degree of permeability of cladding to the flow of air. The internal air pressure may be positive or negative depending on the direction of flow of air in relation to openings in the buildings.

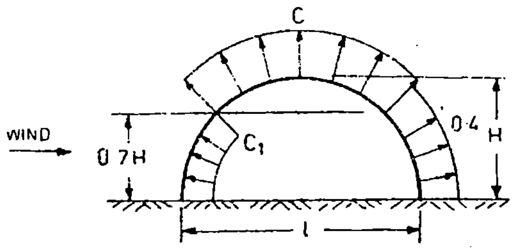
6.2.3.1 In the case of buildings where the claddings permit the flow of air with openings not more than about 5 percent of the wall area but where there are no large openings, it is necessary to consider the possibility of the internal pressure being positive or negative. Two design conditions shall be examined, one with an internal pressure coefficient of +0·2 and another with an internal pressure coefficient of −0·2.

The internal pressure coefficient is algebraically added to the external pressure coefficient and the analysis which indicates greater distress of the member shall be adopted. In most situations a simple inspection of the sign of external pressure will at once indicate the proper sign of the internal pressure coefficient to be taken for design.

NOTE — The term normal permeability relates to the flow of air commonly afforded by claddings not only through open windows and doors, but also through the slits round the closed windows and doors and through chimneys, ventilators and through the joints between roof coverings, the total open area being less than 5 percent of area of the walls having the openings.

TABLE 15 EXTERNAL PRESSURE COEFFICIENTS FOR CURVED ROOFS

(*Clause* 6.2.2.5)

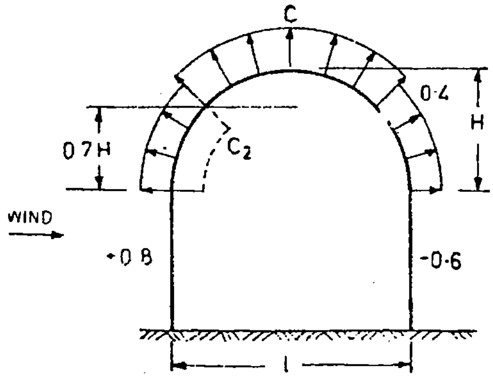


a) Roof springing from ground level

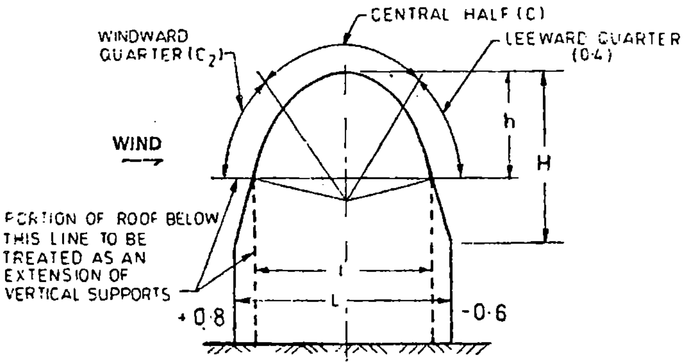
Values of C, C_1 and C_2

H/l	C	C_1	C_2
0·1	−0·8	+0·1	−0·8
0·2	−0·9	+0·3	−0·7
0 3	−1·0	+0·4	−0·3
0·4	−1·1	+0 6	+0·4
0·5	−1·2	+0·7	+0·7

NOTE — When the wind is blowing normal to gable ends, C_{pe} may be taken as equal to −0·7 for the full width of the roof over a length of $l/2$ from the gable ends and −0·5 for the remaining portion.



b) Roof on elevated structure



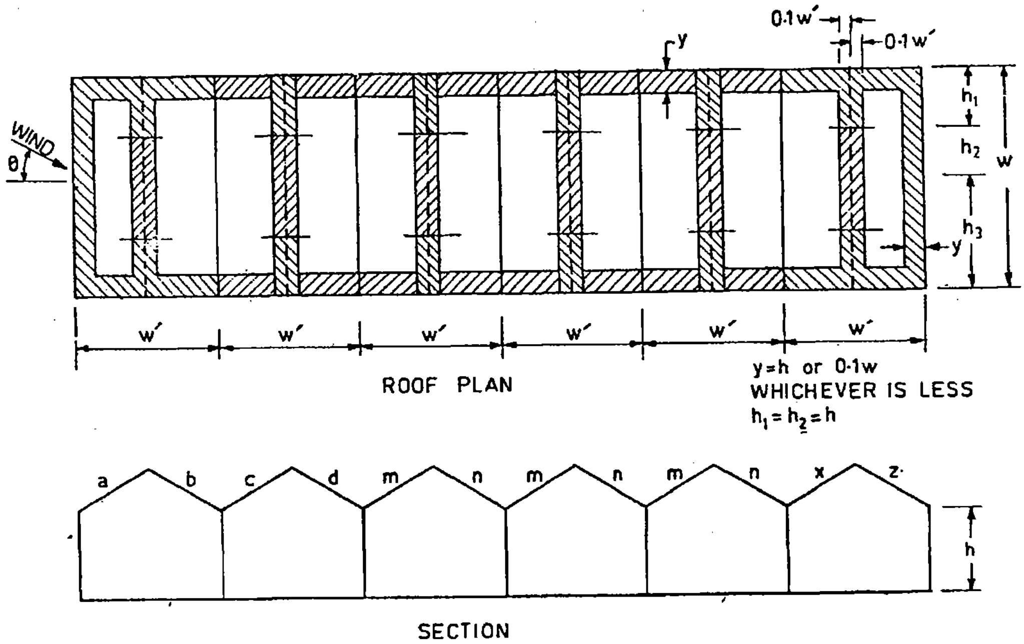
c) Doubly curved roofs

$\frac{H}{l} \ngtr 0·6$

$\frac{h}{L} > 0·6$

TABLE 16 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR PITCHED ROOFS OF MULTISPAN BUILDINGS (ALL SPANS EQUAL) WITH $h \not> w'$

(*Clause* 6.2.2.6)



Roof Angle	Wind Angle	First Span		First Intermediate Span		Other Intermediate Span		End Span		Local Coefficient	
α	θ	*a*	*b*	*c*	*d*	*m*	*n*	*x*	*z*	(cross-hatched \\\\)	(hatched //)
degrees	degrees										
5	0	−0·9	−0·6	−0·4	−0·3	−0·3	−0·3	−0·3	−0·3	−2·0	−1·5
10		−1·1	−0·6	−0·4	−0·3	−0·3	−0·3	−0·3	−0·4		
20		−0·7	−0·6	−0·4	−0·3	−0·3	−0·3	−0·3	−0·5		
30		−0·2	−0·6	−0·4	−0·3	−0·2	−0·3	−0·2	−0·5		
45		+0·3	−0·6	−0·6	−0·4	−0·2	−0·4	−0·2	−0·5		

Roof Angle α degrees	Wind Angle θ degrees	Distance h_1	Distance h_2	Distance h_3
Up to 45	90	−0·8	−0·6	−0·2

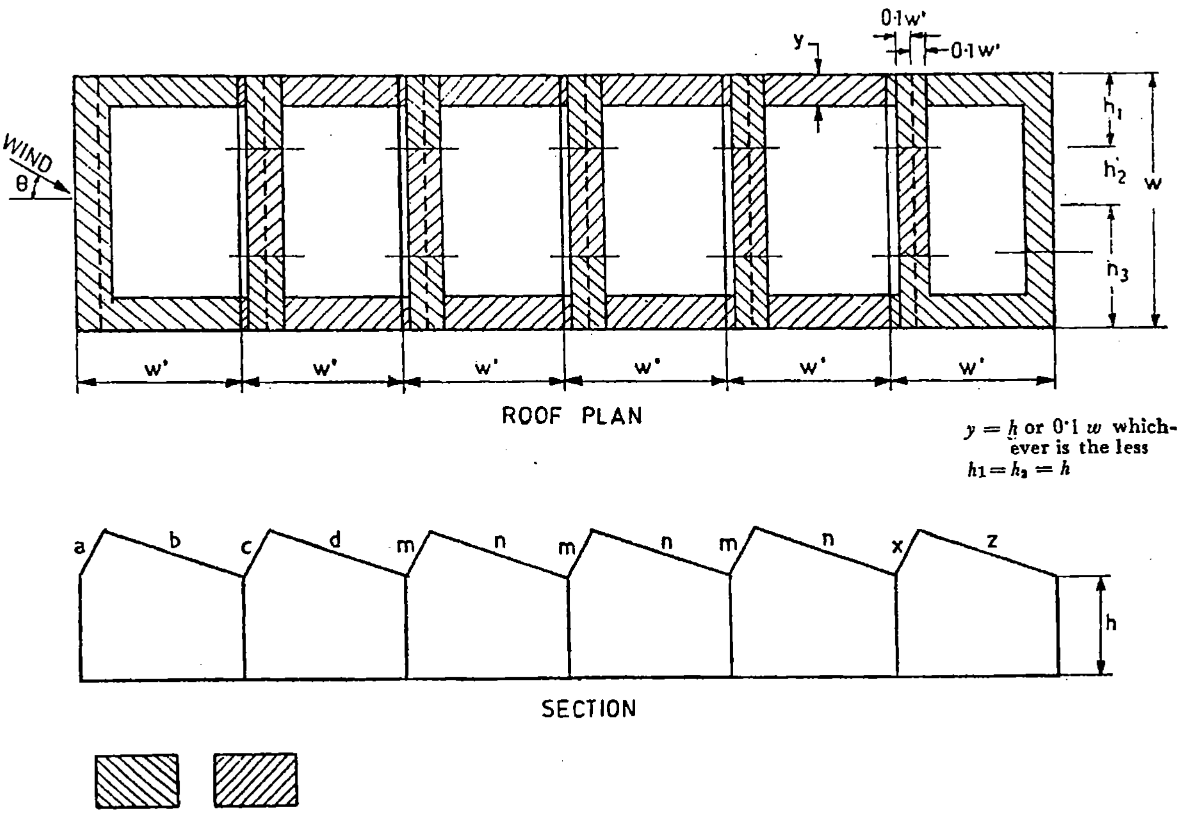
Frictional drag: When wind angle θ = 0°, horizontal forces due to frictional drag are allowed for in the above values; and

when wind angle θ = 90°, allow for frictional drag in accordance with 6.3.1.

NOTE — Evidence on these buildings is fragmentary and any departure from the cases given should be investigated separately.

TABLE 17 EXTERNAL PRESSURE COEFFICIENTS C_{pe} FOR SAW-TOOTH ROOFS OF MULTI-SPAN BUILDINGS (ALL SPANS EQUAL) WITH $h \ngtr w'$

(*Clause* 6.2.2.6)



Wind Angle θ	First Span a	First Span b	First Intermediate Span c	First Intermediate Span d	Other Intermediate Spans m	Other Intermediate Spans n	End Spans x	End Spans z	Local Coefficient (\\\\ hatching)	Local Coefficient (//// hatching)
degrees										
0	+0·6	−0·7	−0·7	−0·4	−0·3	−0·2	−0·1	−0·3	−2·0	−1·5
180	−0·5	−0·3	−0·3	−0·3	−0·4	−0·6	−0·6	−0·1		

Wind Angle θ degrees	Distance h_1	Distance h_2	Distance h_3
90	−0·8	−0·6	−0·2
270	Similarly, but handed		

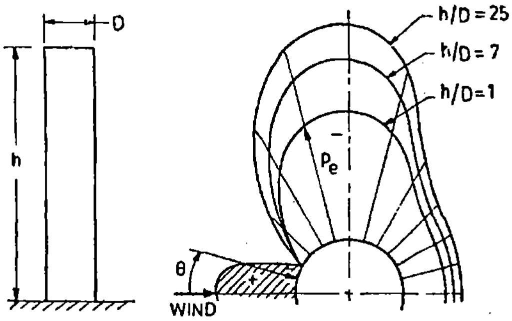
Frictional drag: When wind angle θ = 0°, horizontal forces due to frictional drag are allowed for in the above values; and

when wind angle θ = 90°, allow for frictional drag in accordance with 6.3.1.

NOTE — Evidence on these buildings is fragmentary and any departures from the cases given should be investigated separately.

TABLE 18 EXTERNAL PRESSURE DISTRIBUTION COEFFICIENTS AROUND CYLINDRICAL STRUCTURES

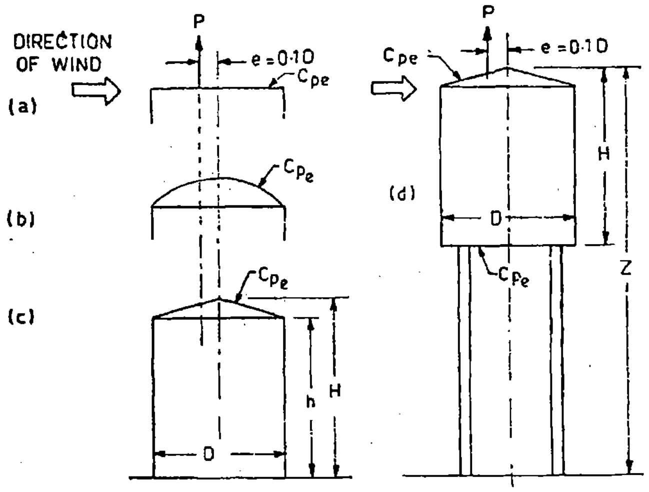
(*Clause* 6.2.2.8)



Position of Periphery, θ in Degrees	Pressure Coefficient, C_{pe}		
	$h/D = 25$	$h/D = 7$	$h/D = 1$
0	1·0	1·0	1·0
15	0·8	0·8	0·8
30	0·1	0·1	0·1
45	−0·9	−0·8	−0·7
60	−1·9	−1·7	−1·2
75	−2·5	−2·2	−1·6
90	−2·6	−2·2	−1·7
105	−1·9	−1·7	−1·2
120	−0·9	−0·8	−0·7
135	−0·7	−0·6	−0·5
150	−0·6	−0·5	−0·4
165	−0 6	−0·5	−0·4
180	−0·6	−0·5	−0·4

TABLE 19 EXTERNAL PRESSURE COEFFICIENTS FOR ROOFS AND BOTTOMS OF CYLINDRICAL BUILDINGS

(*Clause* 6.2.2.9)



COEFFICIENT OF EXTERNAL PRESSURE, C_{pe}

STRUCTURE ACCORDING TO SHAPE				
a, *b* and *c*		*d*		
H/*D*	Roof	(*z*/*H*) − 1	Roof	Bottom
0·5	−0·65	1·00	−0·75	−0·8
1·00	−1·00	1·25	−0·75	−0·7
2·00	−1·00	1·50	−0·75	−0·6

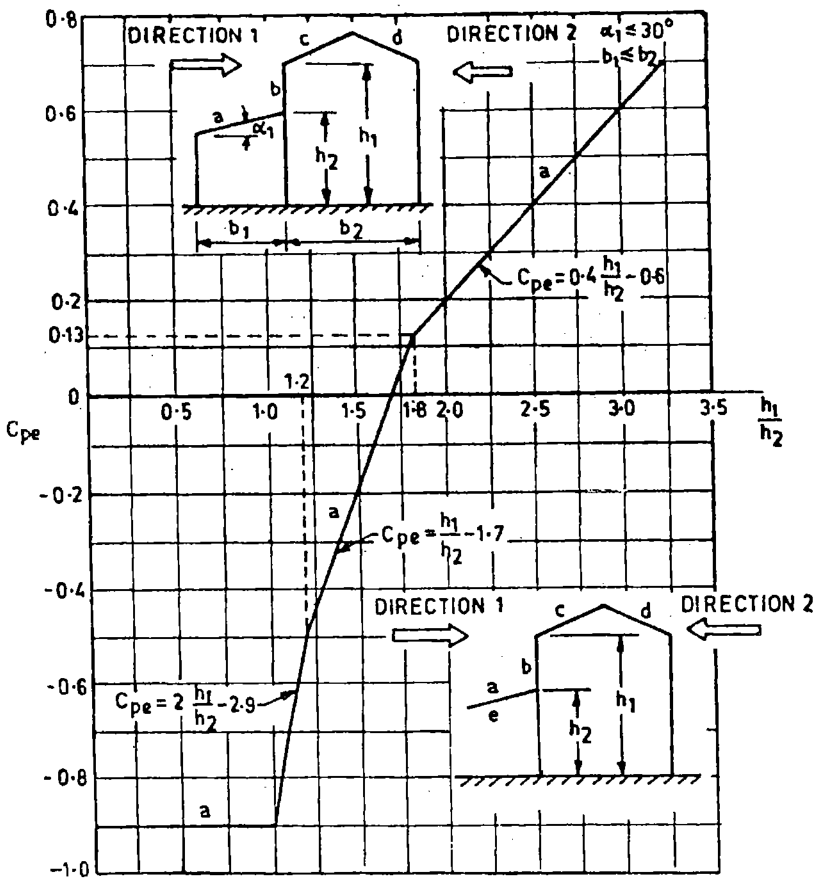
Total force acting on the roof of the structure, $P = 0{\cdot}785\ D^2\ (\ p_i - C_{pe}p_d\ )$

The resultant of P lies eccentrically, $e = 0{\cdot}1D$

TABLE 20 EXTERNAL PRESSURE COEFFICIENTS, C_{pe} FOR COMBINED ROOFS AND ROOFS WITH A SKY LIGHT

(*Clause* 6.2.2.10)

a) Combined Roofs



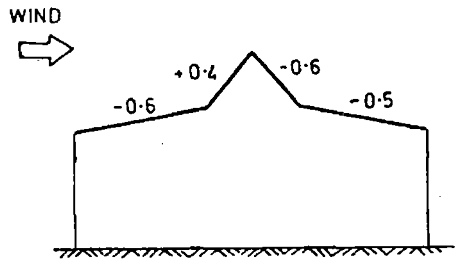
VALUES OF C_{pe}

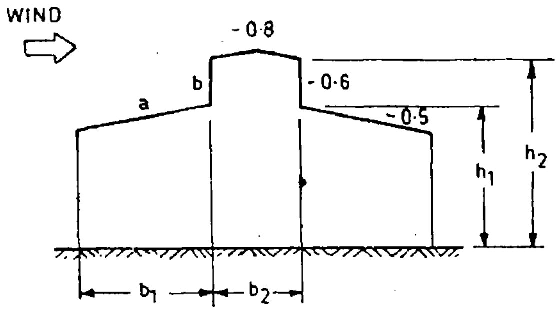
PORTION	DIRECTION 1	DIRECTION 2
a	From the Diagram	−0·4
b	$C_{pe} = -0.5, \frac{h_1}{h_2} \leqslant 1.5$ $C_{pe} = -0.7, \frac{h_1}{h_2} > 1.5$	
c and *d*	*See* Table 5	
e	*See* 6.2.2.7	

(*Continued*)

TABLE 20 EXTERNAL PRESSURE COEFFICIENTS, C_{pe} FOR COMBINED ROOFS AND ROOFS WITH A SKY LIGHT — *Contd*

b) Roofs with a Sky Light



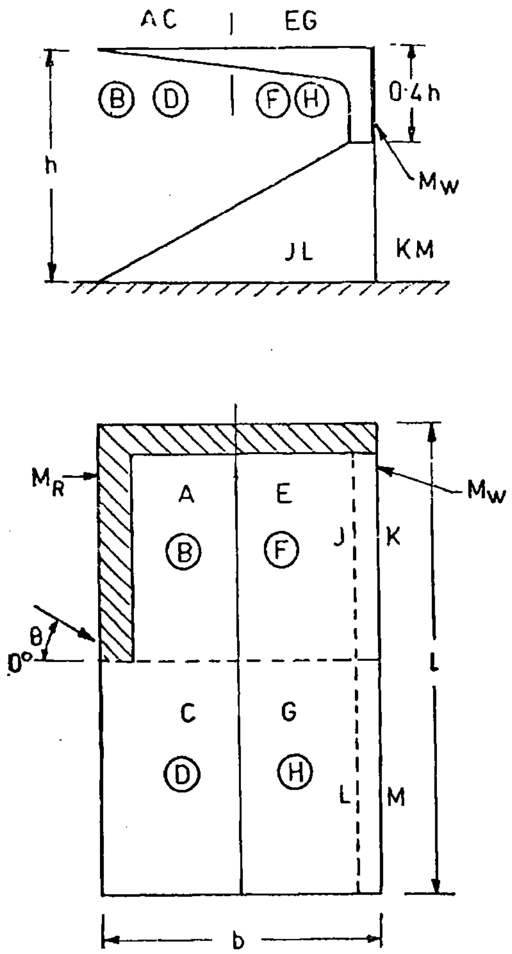


	$b_1 > b_2$		$b_1 \leqslant b_2$
PORTION	*a*	*b*	*a* and *b*
C_{pe}	−0·6	+0·7	*See* Table for combined roofs

TABLE 21 PRESSURE COEFFICIENTS AT TOP AND BOTTOM ROOF OF GRAND STANDS OPEN THREE SIDES (ROOF ANGLE UP TO 5°)

(*Clause* 6.2.2.11)

($h : b : l = 0{\cdot}8 : 1 : 2{\cdot}2$)



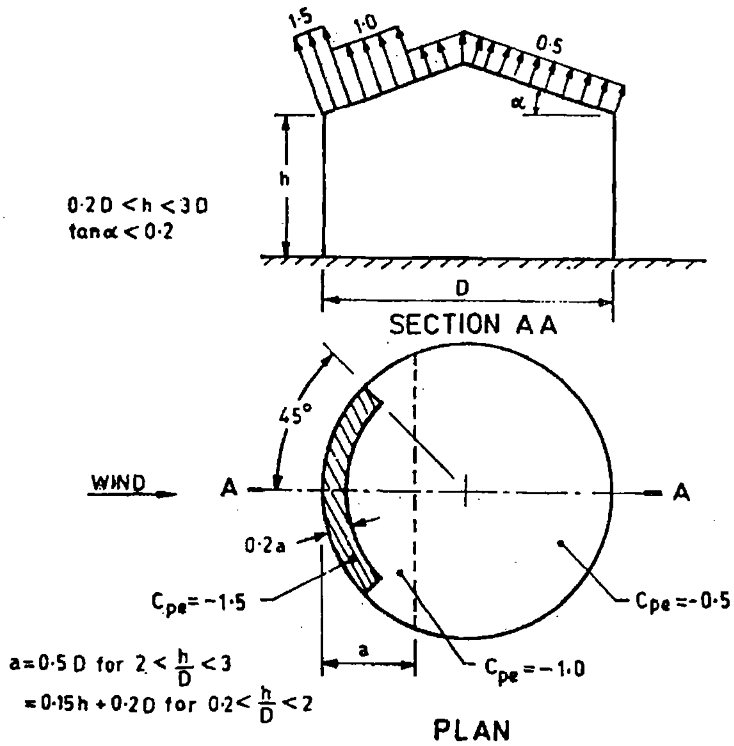
(Shaded area to scale)

FRONT AND BACK OF WALL

θ	*J*	*K*	*L*	*M*
0°	+0·9	−0·5	+0·9	−0·5
45°	+0·8	−0·6	+0·4	−0·4
135°	−1·1	+0·6	−1·0	+0·4
180°	−0·3	+0·9	−0·3	+0·9
60°	‘*Mw*’ − C_P of *K* = −1·0			
60°	‘*Mw*’ − C_P of *J* = +1·0			

TOP AND BOTTOM OF ROOF

θ	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
0°	−1·0	+0·9	−1·0	+0·9	−0·7	+0·9	+0·7	+0·9
45°	−1·0	+0·7	−0·7	+0·4	−0·5	+0·8	−0·5	+0·3
135°	−0·4	−1·1	−0·7	−1·0	−0·9	−1·1	−0·9	−1·0
180°	−0·6	−0·3	−0·6	−0·3	−0·6	−0·3	−0·6	−0·3
45°	‘M_R’ − C_P (top) = −2·0							
45°	‘M_R’ − C_P (bottom) = +1·0							



(For Force Coefficient Corresponding to Shell Portion, *see* Table 23).

FIG. 2 EXTERNAL PRESSURE COEFFICIENT ON THE UPPER ROOF SURFACE OF SINGULAR CIRCULAR STANDING ON THE GROUND

6.2.3.2 *Buildings with medium and large openings* — Buildings with medium and large openings may also exhibit either positive or negative internal pressure depending upon the direction of wind. Buildings with medium openings between about 5 to 20 percent of wall area shall be examined for an internal pressure coefficient of +0·5 and later with an internal pressure coefficient of −0·5, and the analysis which produces greater distress of the members shall be adopted. Buildings with large openings, that is, openings larger than 20 percent of the wall area shall be examined once with an internal pressure coefficient of +0·7 and again with an internal pressure coefficient of −0·7, and the analysis which produces greater distress on the members shall be adopted.

Buildings with one open side or opening exceeding 20 percent of wall area may be assumed to be subjected to internal positive pressure or suction similar to those for buildings with large openings. A few examples of buildings with one sided openings are shown in Fig. 3 indicating values of internal pressure coefficients with respect to the direction of wind.

6.2.3.3 In buildings with roofs but no walls, the roofs will be subjected to pressure from both inside and outside and the recommendations shall be as given in **6.2.2**.

6.3 Force Coefficients — The value of force coefficients apply to a building or structure as a whole, and when multiplied by the effective frontal area A_e of the building or structure and by design wind pressure, p_d gives the total wind load on that particular building or structure.

$$F = C_f \, A_e \, p_d$$

where F is the force acting in a direction specified in the respective tables and C_f is the force coefficient for the building.

NOTE 1 — The value of the force coefficient differs for the wind acting on different faces of a building or structure. In order to determine the critical load, the total wind load should be calculated for each wind direction.

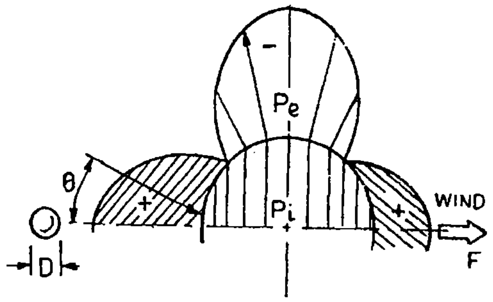
NOTE 2 — If surface design pressure varies with height, the surface area of the building/structure may be sub-divided so that specified pressures are taken over appropriate areas.

NOTE 3 — In tapered buildings/structures, the force coefficients shall be applied after sub-dividing the building/structure into suitable number of strips and the load on each strip calculated individually, taking the area of each strip as A_e.

NOTE 4 — For force coefficients for structures not covered above, reference may be made to specialist literature on the subject or advise may be sought from specialists in the subject.

TABLE 22 EXTERNAL PRESSURE DISTRIBUTION COEFFICIENTS AROUND SPHERICAL STRUCTURES

(*Clause* 6.2.2.13)



Position of Periphery, θ in Degrees	C_{pe}	Remarks
0	+1·0	C_f = 0·5 for $DV_d < 7$
15	+0·9	= 0·2 for $DV_d \not> 7$
30	+0·5	
45	−0·1	
60	−0·7	
75	−1·1	
90	−1·2	
105	−1·0	
120	−0·6	
135	−0·2	
150	+0·1	
165	+0·3	
180	+0·4	

6.3.1 *Frictional Drag* — In certain buildings of special shape, a force due to frictional drag shall be taken into account in addition to those loads specified in **6.2**. For rectangular clad buildings, this addition is necessary only where the ratio $\frac{d}{h}$ or $\frac{d}{b}$ is greater than 4. The frictional drag force, F', in the direction of the wind is given by the following formulae:

If $h \leqslant b$, $F' = C_f' (d - 4h) bp_d + C_f' (d - 4h) 2 hp_d$, and

if $h > b$, $F' = C_f' (d - 4b) bp_d + C_f' (d - 4b) 2 hp_d$.

The first term in each case gives the drag on the roof and the second on the walls. The value of C_f' has the following values:

C_f' = 0·01 for smooth surfaces without corrugations or ribs across the wind direction,

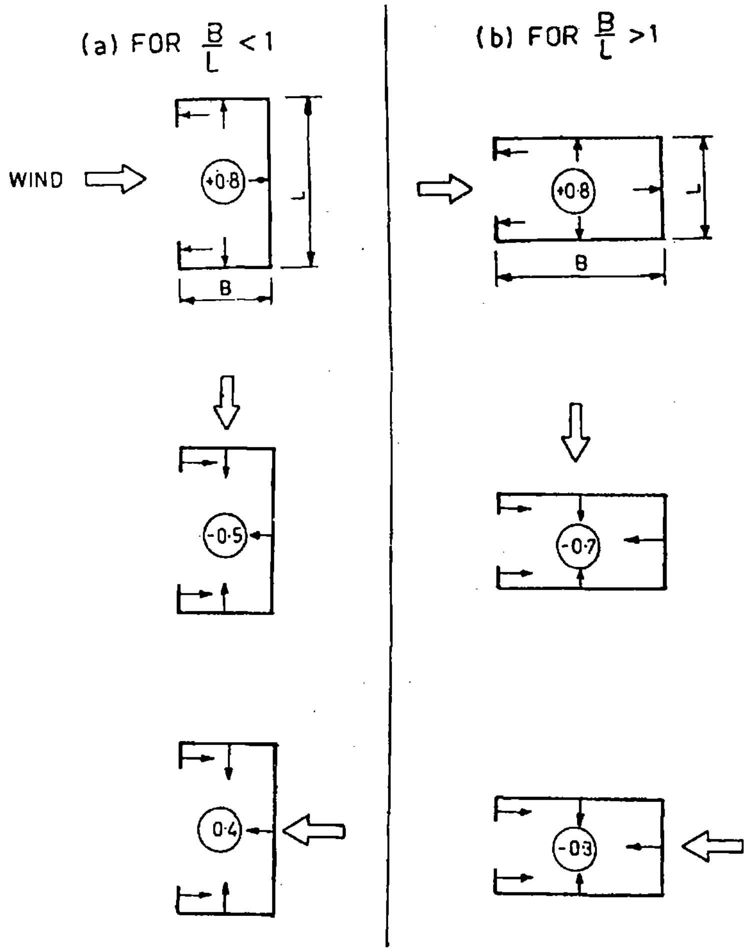
C_f' = 0·02 for surfaces with corrugations across the wind direction, and

C_f' = 0·04 for surfaces with ribs across the wind direction.

For other buildings, the frictional drag has been indicated, where necessary, in the tables of pressure coefficients and force coefficients.

6.3.2 *Force Coefficients for Clad Buildings*

6.3.2.1 *Clad buildings of uniform section* — The overall force coefficients for rectangular clad buildings of uniform section with flat roofs in uniform flow shall be as given in Fig. 4 and for other clad buildings of uniform section (without projections, except where otherwise shown) shall be as given in Table 23.



(C) For $\frac{B}{L} = 1$, use average values

Arrows indicate direction of wind.

FIG. 3 LARGE OPENING IN BUILDINGS (VALUES OF COEFFICIENTS OF INTERNAL PRESSURE) WITH TOP CLOSED

6.3.2.2 *Buildings of circular shapes* — Force coefficients for buildings circular cross-section shapes shall be as given in Table 23. However, more precise estimation of force coefficients for circular shapes of infinite length can be obtained from Fig. 5 taking into account the average height of surface roughness ε. When the length is finite, the values obtained from Fig. 5 shall be reduced by the multiplication factor K (*see also* Table 25 and Appendix D).

6.3.2.3 *Low walls and hoardings* — Force coefficients for low walls and hoardings less than 15 m high shall be as given in Table 24 provided the height shall be measured from the ground to the top of the walls or hoarding, and provided that for walls or hoardings above ground the clearance between the wall or hoarding and the ground shall be not less than 0·25 times the vertical dimension of the wall or hoarding.

To allow for oblique winds, the design shall also be checked for net pressure normal to the surface varying linearly from a maximum of 1·7 C_f at the up wind edge to 0·44 C_f at the down wind edge.

The wind load on appurtenances and supports for hoardings shall be accounted for separately by using the appropriate net pressure coefficients. Allowance shall be made for shielding effects of one element or another.

6.3.2.4 *Solid circular shapes mounted on a surface* — The force coefficients for solid circular shapes mounted on a surface shall be as given in Fig. 6.

6.3.3 *Force Coefficients for Unclad Buildings*

6.3.3.1 *General* — This section applies to permanently unclad buildings and to frameworks of buildings while temporarily unclad. In the case of buildings whose surfaces are well rounded, such as those with elliptic, circular or ovoid cross-sections, the total force can be more at wind speeds much less than the maximum due to transition in the nature of boundary layer on them. Although this phenomenon is well known in the case of circular cylinders, the same phenomenon exists in the case of many other well-rounded structures, and this possibility must be checked.

6.3.3.2 *Individual members*

a) The coefficients refer to the members of infinite length. For members of finite length, the coefficients should be multiplied by a factor K that depends on the ratio l/b where l is the length of the member and b is the width across the direction of wind. Table 25 gives the required values of K. The following special cases must be noted while estimating K.

   i) Where any member abuts onto a plate or wall in such a way that free flow of air around that end of the member is prevented, then the ratio of l/b shall be doubled for the purpose of determining K; and

   ii) When both ends of a member are so obstructed, the ratio l/b shall be taken as infinity for the purpose of determining K.

b) *Flat-sided members* — Force coefficients for wind normal to the longitudinal axis of flat-sided structural members shall be as given in Table 26.

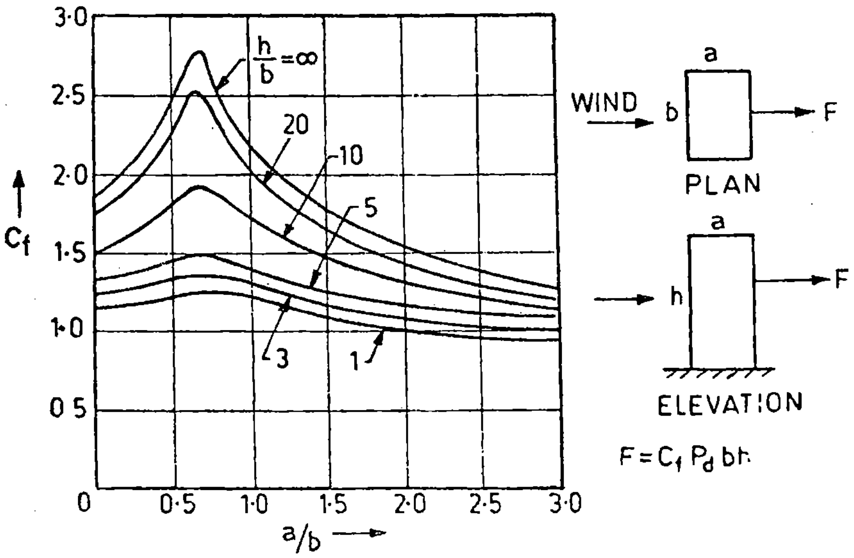
   The force coefficients are given for two mutually perpendicular directions relative to a reference axis on the structural member. They are designated as C_{fn} and C_{ft}, give the forces normal and transverse, respectively to the reference plane as shown in Table 26.

   Normal force, $F_n = C_{fn} p_d K l b$

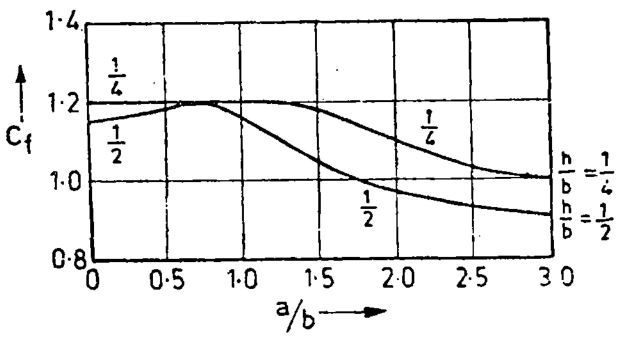
   Transverse force, $F_t = C_{ft} p_d K l b$

c) *Circular sections* — Force coefficients for members of circular section shall be as given in Table 23 (*see also* Appendix D).

d) Force coefficients for wires and cables shall be as given in Table 27 according to the diamater (D), the design wind speed (V_d) and the surface roughness.



4A Values of C_f *versus* $\frac{a}{b}$ for $\frac{h}{b} \geqslant 1$

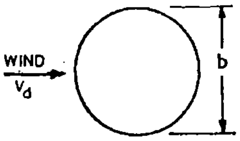
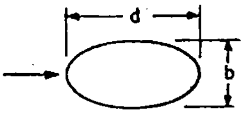
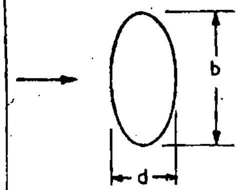
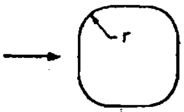
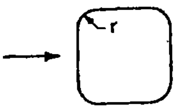
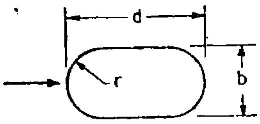
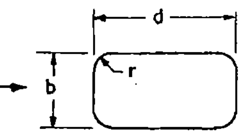
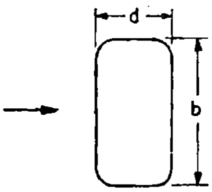


4B Values of C_f *versus* $\frac{a}{b}$ for $\frac{h}{b} < 1$

FIG. 4 FORCE COEFFICIENTS FOR RECTANGULAR CLAD BUILDINGS IN UNIFORM FLOW

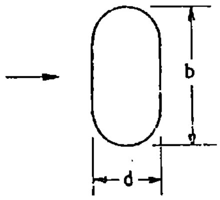
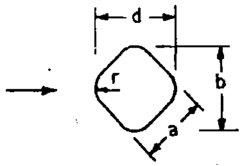
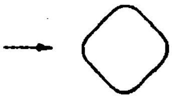
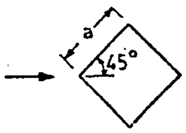
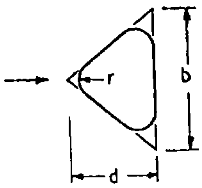
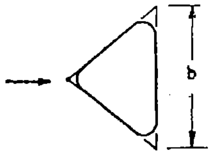
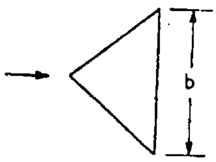
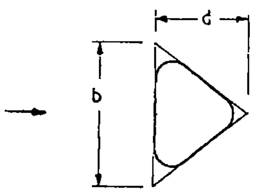
TABLE 23 FORCE COEFFICIENTS C_f FOR CLAD BUILDINGS OF UNIFORM SECTION (ACTING IN THE DIRECTION OF WIND)

[*Clauses* 6.3.2.1, 6.3.2.2 *and* 6.3.3.2(c)]

Plan Shape		$V_d b$ m²/s	C_f for Height/Breadth Ratio: Up to 1/2	1	2	5	10	20	∞
	All surfaces Rough or with projections	< 6 > 6	0·7	0·7	0·7	0·8	0·9	1·0	1·2
See also Apppendix C	Smooth	> 6	0·5	0·5	0·5	0·5	0·5	0·6	0·6
	Ellipse b/d = 1/2	< 10	0·5	0·5	0·5	0·5	0·6	0·6	0·7
		> 10	0·2	0·2	0·2	0·2	0·2	0·2	0·2
	Ellipse b/d = 2	< 8	0·8	0·8	0·9	1·0	1·1	1·3	1·7
		> 8	0·8	0·8	0·9	1·0	1·1	1·3	1·5
	b/d = 1 r/b = 1/3	< 4	0·6	0·6	0·6	0·7	0·8	0·8	1·0
		> 4	0·4	0·4	0·4	0·4	0·5	0·5	0·5
	b/d = 1 r/b = 1/6	< 10	0·7	0·8	0·8	0·9	1·0	1·0	1·3
		> 10	0·5	0·5	0·5	0·5	0·6	0·6	0·6
	b/d = 1/2 r/b = 1/2	< 3	0·3	0·3	0·3	0·3	0·3	0·3	0·4
		> 3	0·2	0·2	0·2	0·2	0·3	0·3	0·3
	b/d = 1/2 r/b = 1/6	All values	0·5	0·5	0·5	0·5	0·6	0·6	0·7
	b/d = 2 r/b = 1/12	All values	0·9	0·9	1·0	1·1	1·2	1·5	1·9

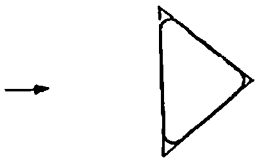
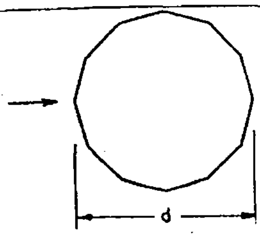
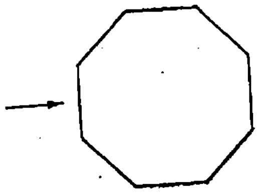
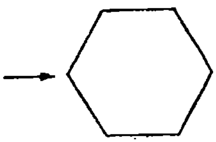
(*Continued*)

TABLE 23 FORCE COEFFICIENTS C_f FOR CLAD BUILDINGS OF UNIFORM SECTION (ACTING IN THE DIRECTION OF WIND) — *Contd*

PLAN SHAPE		$V_{d}b$ m²/s	C_f FOR HEIGHT/BREADTH RATIO Up to 1/2	1	2	5	10	20	∞
	b/d = 2, r/b = 1/4	< 6	0·7	0·8	0·8	0·9	1·0	1·2	1·6
		> 6	0·5	0·5	0·5	0·5	0·5	0·6	0·6
	r/a = 1/3	<10	0·8	0·8	0·9	1·0	1·1	1·3	1·5
		>10	0·5	0·5	0·5	0·5	0·5	0·6	0·6
	r/a = 1/12	All values	0·9	0·9	0·9	1·1	1·2	1·3	1·6
	r/a = 1/48	All values	0·9	0·9	0·9	1·1	1·2	1·3	1·6
	r/b = 1/4	<11	0·7	0·7	0·7	0·8	0·9	1·0	1·2
		>11	0·4	0·4	0·4	0·4	0·5	0·5	0·5
	r/b = 1/12	All values	0·8	0·8	0·8	1·0	1·1	1·2	1·4
	r/b = 1/48	All values	0·7	0·7	0·8	0·9	1·0	1·1	1·3
	r/b = 1/4	<8	0·7	0·7	0·8	0·9	1·0	1·1	1·3
		<8	0·4	0·4	0·4	0·4	0·5	0·5	0·5

(*Continued*)

TABLE 23 FORCE COEFFICIENTS C_f FOR CLAD BUILDINGS OF UNIFORM SECTION (ACTING IN THE DIRECTION OF WIND) — *Contd*

Plan Shape		$V_d b$ m²/s	C_f for Height/Breadth Ratio: Up to 1/2	1	2	5	10	20	∞
	1/48 < r/b < 1/12	All values	1·2	1·2	1·2	1·4	1·6	1·7	2·1
	12-sided polygon	< 12	0·7	0·7	0·8	0·9	1·0	1·1	1·3
		> 12	0·7	0·7	0·7	0·7	0·8	0·9	1·1
	Octagon	All values	1·0	1·0	1·1	1·2	1·2	1·3	1·4
	Hexagan	All values	1·0	1·1	1·2	1·3	1·4	1·4	1·5

Structures that, because of their size and design wind velocity, are in the supercritical flow regime may need further calculation to ensure that the greatest loads do not occur at some wind speed below the maximum when the flow will be subcritical.

The coefficients are for buildings without projections, except where otherwise shown.

In this table $V_d b$ is used as an indication of the airflow regime.

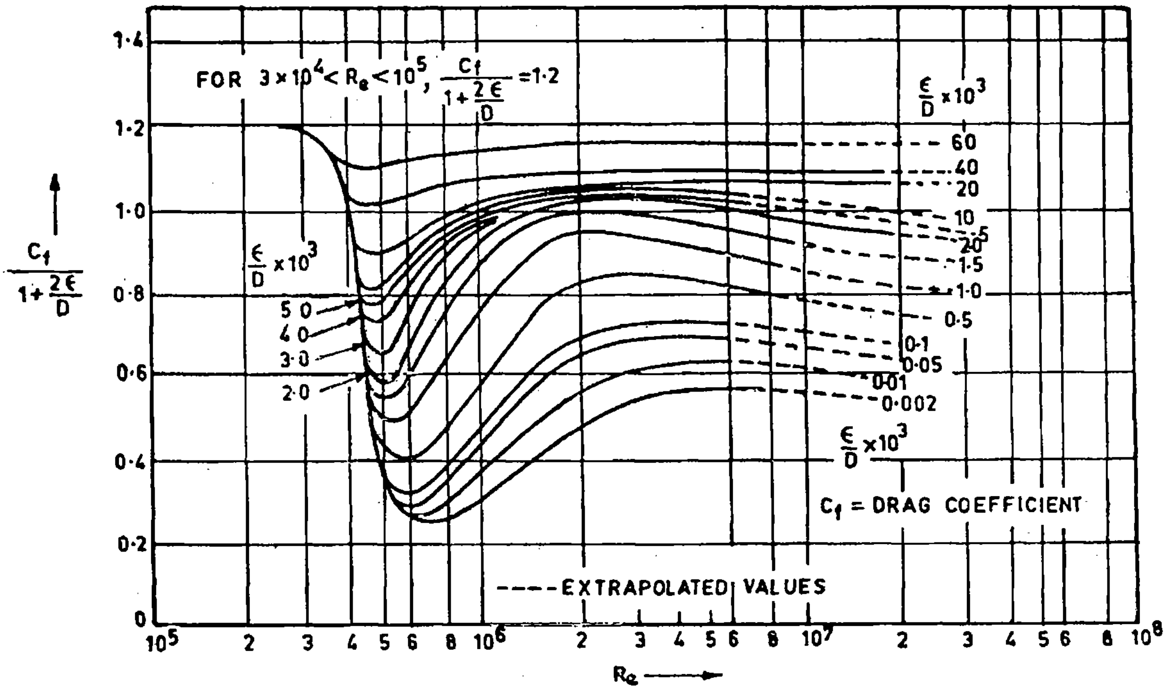
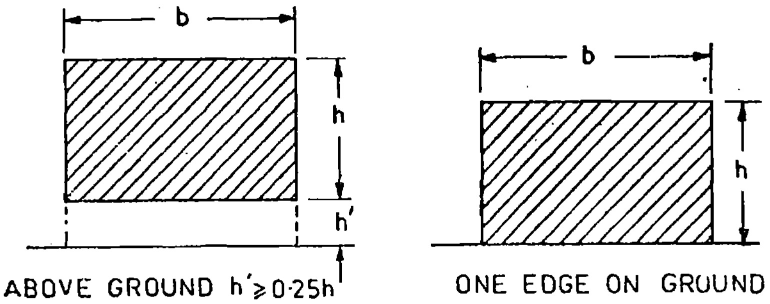


FIG. 5 VARIATION OF $\frac{C_f}{1 + \frac{2\epsilon}{D}}$ WITH R_e ($>3 \times 10^4$) FOR CIRCULAR SECTIONS

TABLE 24 FORCE COEFFICIENTS FOR LOW WALLS OR HOARDINGS (< 15m HIGH)

(*Clause* 6.3.2.3)



Wind normal to face

WIDTH TO HEIGHT RATIO, b/h		DRAG COEFFICIENT, C_f
Wall Above Ground	Wall on Ground	
From 0·5 to 6	From 1 to 12	1·2
10	20	1·3
16	32	1·4
20	40	1·5
40	80	1·75
60	120	1·8
80 or more	160 or more	2·0

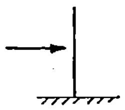
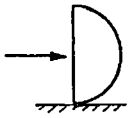
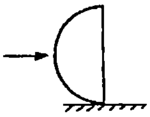
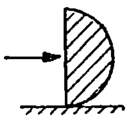
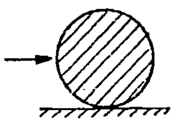
SIDE ELEVATION	DESCRIPTION OF SHAPE	C_f
	CIRCULAR DISC	1·2
	HEMISPHERICAL BOWL	1·4
	HEMISPHERICAL BOWL	0·4
	HEMISPHERICAL SOLID	1·2
	SPHERICAL SOLID	0·5 FOR $V_dD < 7$ 0·2 FOR $V_dD \geq 7$

FIG. 6 FORCE COEFFICIENTS FOR SOLID SHAPES MOUNTED ON A SURFACE

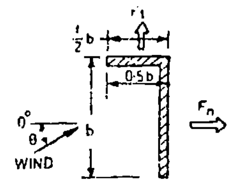
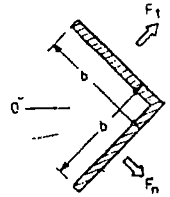
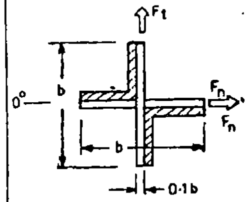
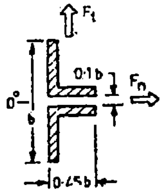
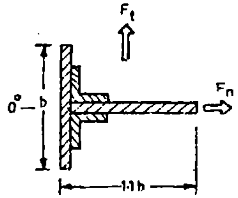
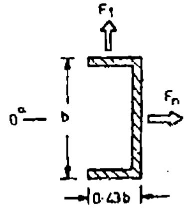
TABLE 25 REDUCTION FACTOR *K* FOR INDIVIDUAL MEMBERS

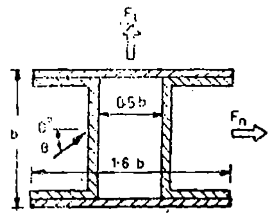
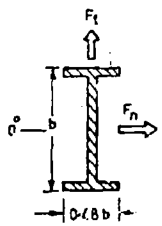
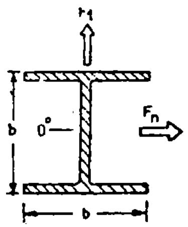
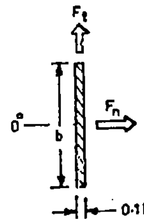
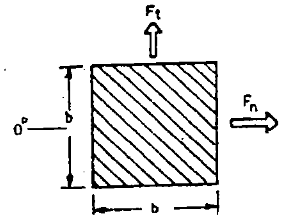
[*Clauses* 6.3.2.2 *and* 6.3.3.2(a)]

l/b or l/D	2	5	10	20	40	50	100	∞
Circular cylinder, subcritical flow	0·58	0·62	0·68	0·74	0·82	0·87	0·98	1·00
Circular cylinder, supercritical flow ($DV_d \geq 6 m^2/s$)	0·80	0·80	0·82	0·90	0·98	0·99	1·00	1·00
Flat plate perpendicular to wind ($DV_d \geq 6 m^2/s$)	0·62	0·66	0·69	0·81	0·87	0·90	0·95	1·00

TABLE 26 FORCE COEFFICIENTS (C_f) FOR INDIVIDUAL STRUCTURAL MEMBERS OF INFINITE LENGTH

[*Clause* 6.3.3.2(b)]

												
θ	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}
degrees												
0	+1·9	+0·95	+1·8	+1·8	+1·75	+0·1	+1·6	0	+2·0	0	+2·05	0
45	+1·8	+0·8	+2·1	+1·8	+0·85	+0·85	+1·5	−0·1	+1·2	+0·9	+1·85	+0·6
90	+2·0	+1·7	−1·9	−1·0	+0·1	+1·75	−0·95	+0·7	−1·6	+2·15	0	+0·6
135	−1·8	−0·1	−2·0	+0·3	−0·75	+0·75	−0·5	+1·05	−1·1	+2·4	−1·6	+0·4
180	−2·0	+0·1	−1·4	−1·4	−1·75	−0·1	−1·5	0	−1·7	±2·1	−1·8	0

										
θ	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}
degrees										
0	+1·4	0	+2·05	0	+1·6	0	+2·0	0	+2·0	0
45	+1·2	+1·6	+1·95	+0·6	+1·5	+1·5	+1·8	+0·1	+1·55	+1·55
90	0	+2·2	+0·5	+0·9	0	+1·9	0	+0·1	0	+2·0

NOTE — In this table, the force coefficient C_f is given in relation to the dimension *b* and not, as in other cases, in relation to effective frontal area A_e.

TABLE 27 FORCE COEFFICIENTS FOR WIRES AND CABLES ($l/D = 100$)

[*Clause* 6.3.3.2(d)]

FLOW REGIME	FORCE COEFFICIENT, C_f FOR			
	Smooth Surface	Moderately Smooth Wire (Galvanized or Painted)	Fine Stranded Cables	Thick Stranded Cables
(1)	(2)	(3)	(4)	(5)
$DV_d < 0{\cdot}6$ m²/s	—	—	1·2	1·3
$DV_d \geqslant 0{\cdot}6$ m²/s	—	—	0·9	1·1
$DV_d < 0{\cdot}6$ m²/s	1·2	1·2	—	—
$DV_d \geqslant 6$ m²/s	0·5	0·7	—	—

6.3.3.3 *Single frames* — Force coefficients for a single frame having either:

a) all flat sided members, or

b) all circular members in which all the members of the frame have either:

i) DV_d less than 6 m²/s, or

ii) DV_d greater than 6 m²/s.

shall be as given in Table 28 according to the type of the member, the diameter (D), the design wind speed (V_d) and the solidity ratio (ϕ).

TABLE 28 FORCE COEFFICIENTS FOR SINGLE FRAMES

SOLIDITY RATIO ϕ	FORCE COEFFICIENTS, C_f, FOR		
	Flat-sided Members	Circular Sections	
		Subcritical flow ($DV_d < 6$ m²/s)	Supercritical flow ($DV_d \geqslant 6$ m²/s)
(1)	(2)	(3)	(4)
0·1	1·9	1·2	0·7
0·2	1·0	1·2	0·8
0·3	1·7	1·2	0·8
0·4	1·7	1·1	0·8
0·5	1·6	1·1	0·8
0·75	1·6	1·5	1·4
1·00	2·0	2·0	2·0

Linear interpolation between the values is permitted.

Force coefficients for a single frame not complying with the above requirements shall be calculated as follows:

$$C_f = \gamma\, C_{f\,super} + (1-\gamma)\frac{A_{circ\,sub}}{A_{sub}}\, C_{f\,sub} + (1-\gamma)\frac{A_{flat}}{A_{sub}}\, C_{f\,flat}$$

where

$C_{f\,super}$ = force coefficient for the supercritical circular members as given in Table 28 or Appendix D,

$C_{f\,sub}$ = force coefficient for subcritical circular members as given in Table 28 or Appendix D,

$C_{f\,flat}$ = force coefficient for the flat sided members as given in Table 28,

$A_{circ\,sub}$ = effective area of subcritical circular members,

A_{flat} = effective area of flat-sided members,

A_{sub} = $A_{circ\,sub} + A_{flat}$, and

$$\gamma = \frac{\left(\text{Area of the frame in a supercritical flow}\right)}{A_e}$$

6.3.3.4 *Multiple frame buildings* — This section applies to structures having two or more parallel frames where the windward frames may have a shielding effect upon the frames to leeward side. The windward frame and any unshield parts of other frames shall be calculated in accordance with **6.3.3.3**, but the wind load on the parts of frames that are sheltered should be multiplied by a shielding factor which is dependent upon the solidity ratio of the windward frame, the types of the members comprising the frame and the spacing ratio of the frames. The values of the shielding factors are given in Table 29.

TABLE 29 SHIELDING FACTOR η FOR MULTIPLE FRAMES

EFFECTIVE SOLIDITY RATIO, β	FRAME SPACING RATIO				
	<0·5	1·0	2·0	4·0	>8·0
(1)	(2)	(3)	(4)	(5)	(6)
0	1·0	1·0	1·0	1·0	1·0
0·1	0·9	1·0	1·0	1·0	1·0
0·2	0·8	0·9	1·0	1·0	1·0
0·3	0·7	0·8	1·0	1·0	1·0
0·4	0·6	0·7	1·0	1·0	1·0
0·5	0·5	0·6	0·9	1·0	1·0
0·7	0·3	0·6	0·8	0·9	1·0
1·0	0·3	0·6	0·6	0·8	1·0

Linear interpolation between values is permitted.

Where there are more than two frames of similar geometry and spacing, the wind load on the third and subsequent frames should be taken as equal to that on the second frame. The loads on the various frames shall be added to obtain total load on the structure.

a) The frame spacing ratio is equal to the distance, centre to centre of the frames, beams or girders divided by the least overall dimension of the frame, beam or girder measured at right angles to the direction of the wind. For triangular framed structures or rectangular framed structures diagonal to the wind, the spacing ratio should be calculated from the mean distance between the frames in the direction of the wind.

b) Effective solidity ratio, β:

β = ϕ for flat-sided members.

β is to be obtained from Fig. 7 for members of circular cross-sections.

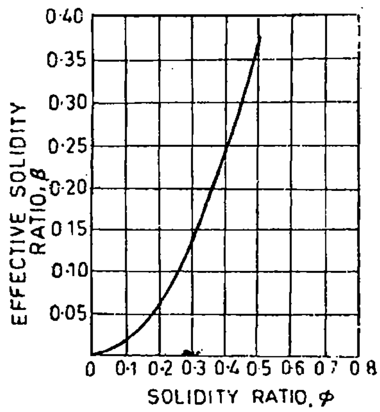


Fig. 7 Effective Solidity Ratio, β for Round Section Members

6.3.3.5 *Lattice towers*

a) Force coefficient for lattice towers of square or equilateral triangle section with flat-sided members for wind blowing against any face shall be as given in Table 30.

TABLE 30 OVERALL FORCE COEFFICIENT FOR TOWERS COMPOSED OF FLAT-SIDED MEMBERS

Solidity Ratio ϕ	Force Coefficient for Square Towers	Force Coefficient for Equilateral Triangular Towers
(1)	(2)	(3)
0·1	3·8	3·1
0·2	3·3	2·7
0·3	2·8	2·3
0·4	2·3	1·9
0·5	2·1	1·5

b) For square lattice towers with flat-sided members the maximum load, which occurs when the wind blows into a corner shall be taken as 1·2 times the load for the wind blowing against a face.

c) For equilateral-triangle lattice towers with flat-sided members, the load may be assumed to be constant for any inclination of wind to a face.

d) Force coefficients for lattice towers of square section with circular members, all in the same flow regime, may be as given in Table 31.

e) Force coefficients for lattice towers of equilateral-triangle section with circular members all in the same flow ragime may be as given in Table 32.

TABLE 31 OVERALL FORCE COEFFICIENT FOR SQUARE TOWERS COMPOSED OF ROUNDED MEMBERS

[*Clause* 6.3.3.5(d)]

Solidity Ratio of Front Face	Force Coefficient for Subcritical Flow ($DV_d < 6\ m^2/s$)		Force Coefficient for Supercritical Flow ($DV_d \geqslant 6\ m^2/s$)	
	Onto face	Onto corner	Onto face	Onto corner
(1)	(2)	(3)	(4)	(5)
0·05	2·4	2·5	1·1	1·2
0·1	2·2	2·3	1·2	1·3
0·2	1·9	2·1	1·3	1·6
0·3	1·7	1·9	1·4	1·6
0·4	1·6	1·9	1·4	1·6
0·5	1·4	1·9	1·4	1·6

TABLE 32 OVERALL FORCE COEFFICIENT FOR EQUILATERAL-TRIANGULAR TOWERS COMPOSED OF ROUNDED MEMBERS

[*Clause* 6.3.3.5(e)]

Solidity Ratio of Front Face ϕ	Force Coefficient for Subcritical Flow ($DV_d < 6\ m^2/s$)	Force Coefficient for Supercritcial Flow ($DV_d \leqslant 6\ m^2/s$)
	All wind directions	All wind directions
(1)	(2)	(3)
0·05	1·8	0·8
0·1	1·7	0·8
0·2	1·6	1·1
0·3	1·5	1·1
0·4	1·5	1·1
0·5	1·4	1·2

6.3.3.6 *Tower appurtenances* — The wind loading on tower appurtenances, such as ladders, conduits, lights, elevators, etc, shall be calculated using appropriate net pressure coefficients for these elements. Allowance may be made for shielding effect from other elements.

7. DYNAMIC EFFECTS

7.1 General — Flexible slender structures and structural elements shall be investigated to ascertain the importance of wind induced oscillations or excitations along and across the direction of wind.

In general, the following guidelines may be used for examining the problems of wind induced oscillations:

a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5·0, and

b) Buildings and closed structures whose natural frequency in the first mode is less than 1·0 Hz.

Any building or structure which does not satisfy either of the above two criteria shall be examined for dynamic effects of wind.

NOTE 1 — The fundamental time period (T) may either be established by experimental observations on similar buildings or calculated by any rational method of analysis. In the absence of such data, T may be determined as follows for multi-storeyed buildings:

a) For moment resisting frames without bracing or shear walls for resisting the lateral loads

$$T = 0{\cdot}1\ n$$

where

n = number of storeys including basement storeys; and

b) For all others

$$T = \frac{0{\cdot}09\ H}{\sqrt{d}}$$

where

H = total height of the main structure of the building in metres, and

d = maximum base dimension of building in metres in a direction parallel to the applied wind force.

NOTE 2 — If preliminary studies indicate that wind-induced oscillations are likely to be significant, investigations should be persuade with the aid of analytical methods or, if necessary, by means of wind tunnel tests on models.

NOTE 3 — Cross-wind motions may by due to lateral gustiness of the wind, unsteady wake flow (for example, vortex shedding), negative aerodynamic damping or to a combination of these effects. These cross-wind motions can become critical in the design of tall buildings/structures.

NOTE 4 — Motions in the direction of wind (known also as buffeting) are caused by fluctuating wind force associated with gusts. The excitations depend on gust energy available at the resonant frequency.

NOTE 5 — The wake shed from an upstream body may intensify motions in the direction of the wind, and may also affect crosswind motions.

NOTE 6 — The designer must be aware of the following three forms of wind induced motion which are characterized by increasing amplitude of oscillation with the increase of wind speed.

a) *Galloping* — Galloping is transverse oscillations of some structures due to the development of aerodynamic forces which are in phase with the motion. It is characterized by the progressively increasing amplitude of transverse vibration with increase of wind speed. The cross-section which are particularly prone to this type of excitation include the following:

i) All structures with non-circular cross-sections, such as triangular, square, polygons, as well as angles, crosses, and T-sections.

ii) Twisted cables and cables with ice encrustations.

b) *Flutter* — Flutter is unstable oscillatory motion of a structure due to coupling between aerodynamic force and elastic deformation of the structure. Perhaps the most common form is oscillatory motion due to combined bending and torsion. Although oscillatory motions in each degree of freedom may be damped, instability can set in due to energy transfer from one mode of oscillation to another, and the structure is seen to execute sustained or divergent oscillations with a type of motion which is a combination of the individual modes of motion. Such energy transfer takes place when the natural frequencies of modes, taken individually, are close to each other (ratio being typically less than 2·0). Flutter can set in at wind speeds much less than those required for exciting the individual modes of motion. Long span suspension bridge decks or any member of a structure with large values of d/t (where d is the depth of a structure or structural member parallel to wind stream and t is the least lateral dimension of a member) are prone to low speed flutter. Wind tunnel testing is required to determine critical flutter speeds and the likely structural response. Other types of flutter are single degree of freedom stall flutter, torsional flutter, etc.

c) *Ovalling* — This walled structures with open ends at one or both ends such as oil storage tanks, and natural draught cooling towers in which the ratio of the diameter of minimum lateral dimension to the wall thickness is of the order of 100 or more, are prone to ovalling oscillations. These oscillations are characterized by periodic radial deformation of the hollow structure.

NOTE 7 — Buildings and structures that may be subjected to serious wind excited oscillations require careful investigation. It is to be noted that wind induced oscillations may occur at wind speeds lower than the static design wind speed for the location.

NOTE 8 — Analytical methods for the response of dynamic structures to wind loading can be found in the following publications:

i) Engineering Science Data, Wind Engineering Sub-Series (4 volumes), London, ESDU International.

ii) 'Wind Engineering in the Eighties', Construction Industry Research and Information Association, 1981, London.

iii) 'Wind Effects on Structures' by E. Simiu and R.H. Scanlan, New York, John Wiley and Sons, 1978.

iv) Supplement to the National Building Code of Canada. 1980. NRCC, No. 17724, Ottawa, National Research Council of Canada, 1980.

v) Wind forces on structures by Peter Sachs. Pergamon press.

vi) Flow induced vibration by Robert D. Clevins, Von Nostrand Reinfold Co.

vii) Appropriate Indian Standards (*see* 1.1.3).

NOTE 9 — In assessing wind loads due to such dynamic phenomenon as galloping, flutter and ovalling, if the required information is not available either in the references of Note 8 or other literature, specialist advise shall be sought, including experiments on models in wind tunnels.

7.2 Motion Due to Vortex Shedding

7.2.1 *Slender Structures* — For a structure, the shedding frequency, η shall be determined by the following formula:

$$\eta = \frac{S V_d}{b}$$

where

S = Strouhal number,

V_d = design wind velocity, and

b = breadth of a structure or structural members in the horizontal plane normal to the wind direction.

a) *Circular Structures* — For structures circular in cross-section:

$S = 0{\cdot}20$ for bV_z not greater than 7, and

$= 0{\cdot}25$ for bV_z greater than 7.

b) *Rectangular Structures* — For structures of rectangular cross-section:

$S = 0{\cdot}15$ for all values of bV_z.

NOTE 1 — Significant cross wind motions may be produced by vortex shedding if the natural frequency of the structure or structural element is equal to the frequency of the vortex shedding within the range of expected wind velocities. In such cases, further analysis should be carried out on the basis of references given in Note 8 of **7.1**.

NOTE 2 — Unlined welded steel chimney stacks and similar structures are prone to excitation by vortex shedding.

NOTE 3 — Intensification of the effects of periodic vortex shedding has been reported in cases where two or more similar structures are located in close proximity, for example, at less than 20 *b* apart, where *b* is the dimension of the structure normal to the wind.

NOTE 4 — The formulae given in **7.2.1**(a) and (b) are valid for infinitely long cylindrical structures. The value of *S* decreases slowly as the ratio of length to maximum transverse width decreases; the reduction being up to about half the value, if the structure is only three times higher than its width. Vortex shedding need not be considered if the ratio of length to maximum transverse width is less than 2·0.

8. GUST FACTOR (*GF*) OR GUST EFFECTIVENESS FACTOR (*GEF*) METHOD

8.1 Application — Only the method of calculating load along wind or drag load by using gust factor method is given in the code since methods for calculating load across-wind or other components are not fully matured for all types of structures. However, it is permissible for a designer to use gust factor method to calculate all components of load on a structure using any available theory. However, such a theory must take into account the random nature of atmospheric wind speed.

NOTE — It may be noted that investigations for various types of wind induced oscillations outlined in **7** are in no way related to the use of gust factor method given in **8** although the study of **7** is needed for using gust factor method.

8.2 Hourly Mean Wind — Use of the existing theories of gust factor method require a knowledge of maximum wind speeds averaged over one hour at a particular location. Hourly mean wind speeds at different heights in different terrains is given in Table 33.

NOTE — It must also be recognized that the ratio of hourly mean wind (HMW) to peak speed given in Table 33 may not be obtainable in India since extreme wind occurs mainly due to cyclones and thunderstorms, unlike in UK and Canada where the mechanism is fully developed pressure system. However Table 33 may be followed at present for the estimation of the hourly mean wind speed till more reliable values become available.

8.2.1 *Variation of Hourly Mean Wind Speed with Height* — The variation of hourly mean wind speed with height shall be calculated as follows:

$$\bar{V}_z = V_b\, k_1\, \bar{k}_2\, k_3$$

where

$\bar{V}_z$ = hourly mean wind speed in m/s, at height z;

V_b = regional basic wind speed in m/s (*see* Fig. 1);

k_1 = probability factor (*see* **5.3.1**);

$\bar{k}_2$ = terrain and height factor (*see* Table 33); and

k_3 = topography factor (*see* **5.3.3**).

TABLE 33 HOURLY MEAN WIND SPEED FACTOR $\bar{k}_2$ IN DIFFERENT TERRAINS FOR DIFFERENT HEIGHTS

(*Clauses* 8.2 *and* 8.2.1)

HEIGHT m	TERRAIN			
	Category 1	Category 2	Category 3	Category 4
(1)	(2)	(3)	(4)	(5)
Up to 10	0·78	0·67	0·50	0·24
15	0·82	0·72	0·55	0·24
20	0·85	0·75	0·59	0·24
30	0·88	0·79	0·64	0·34
50	0·93	0·85	0·70	0·45
100	0·99	0·92	0·79	0·57
150	1·03	0·96	0·84	0·64
200	1·06	1·00	0·88	0·68
250	1·08	1·02	0·91	0·72
300	1·09	1·04	0·93	0·74
350	1·11	1·06	0·95	0·77
400	1·12	1·07	0·97	0·79
450	1·13	1·08	0·98	0·81
500	1·14	1·09	0·99	0·82

8.3 Along Wind Load — Along wind load on a structure on a strip area (A_e) at any height (z) is given by:

$$F_z = C_f\, A_e\, \bar{p}_z\, G$$

where

F_z = along wind load on the structure at any height z corresponding to strip area A_e,

C_f = force coefficient for the building,

A_e = effective frontal area considered for the structure at height z,

$\bar{p}_z$ = design pressure at height z due to hourly mean wind obtained as $0{\cdot}6\,\bar{V}_z^2$ (N/m²),

G = gust factor $\left(= \dfrac{\text{peak load}}{\text{mean load}}\right)$, and is given by:

$$G = 1 + g_f\, r \sqrt{\left[B\,(1+\phi)^2 + \frac{SE}{\beta}\right]}$$

where

g_f = peak factor defined as the ratio of the expected peak value to the root mean value of a fluctuating load, and

r = roughness factor which is dependent on the size of the structure in relation to the ground roughness.

The value of '$g_f r$' is given in Fig. 8,

B = background factor indicating a measure of slowly varying component of fluctuating wind load and is obtained from Fig. 9,

$\frac{SE}{\beta}$ = measure of the resonant component of the fluctuating wind load,

S = size reduction factor (*see* Fig. 10),

E = measure of available energy in the wind stream at the natural frequency of the structure (*see* Fig. 11),

β = damping coefficient (as a fraction of critical damping) of the structure (*see* Table 34), and

$\phi = \frac{g_f r \sqrt{B}}{4}$ and is to be accounted only for buildings less than 75 m high in terrain Category 4 and for buildings less than 25 m high in terrain Category 3, and is to be taken as zero in all other cases.

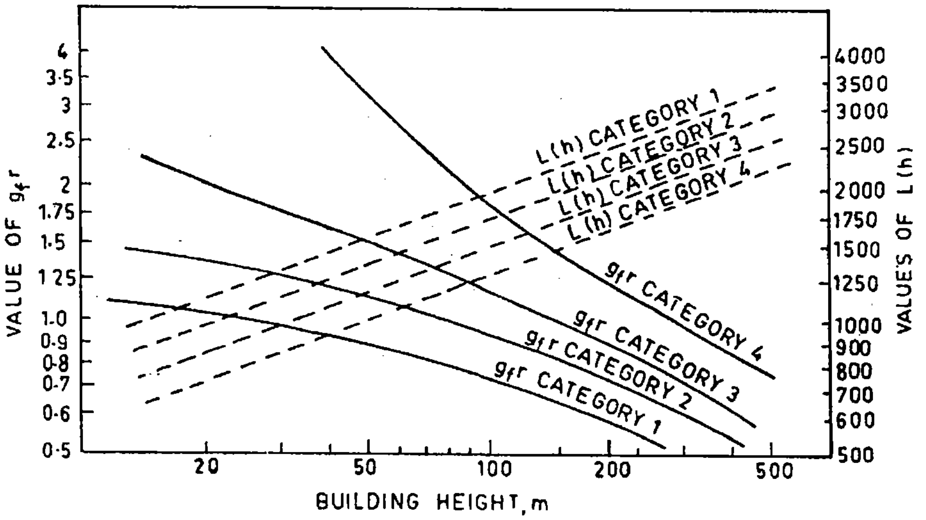


FIG. 8 VALUES OF $g_f r$ AND $L(h)$

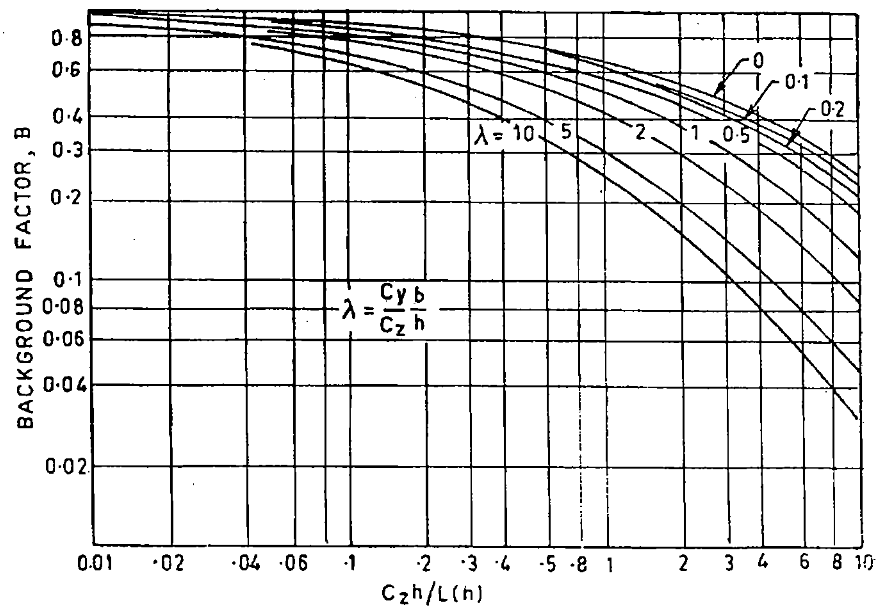


FIG. 9 BACKGROUND FACTOR B

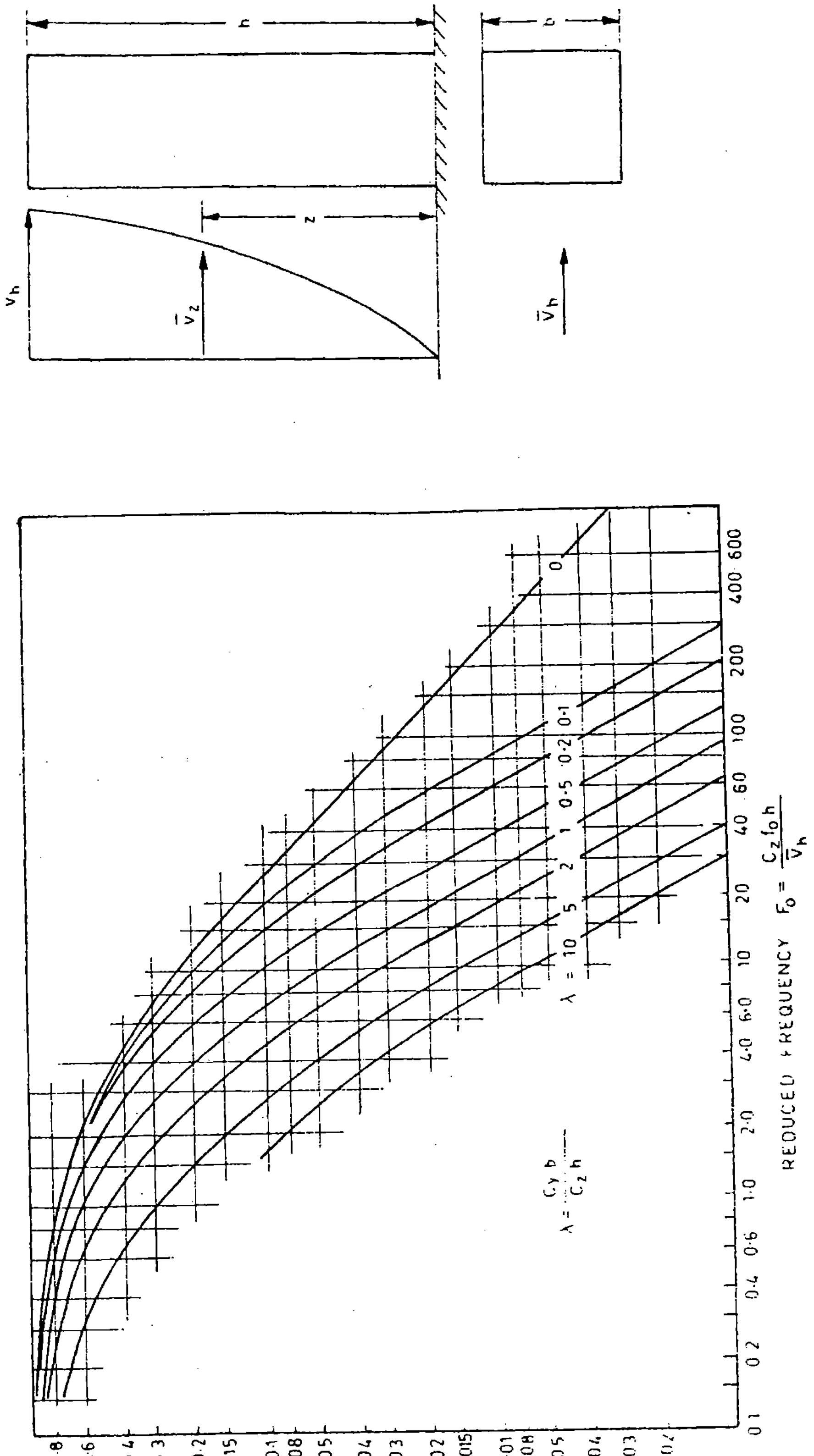


FIG. 10 SIZE REDUCTION FACTOR, *S*

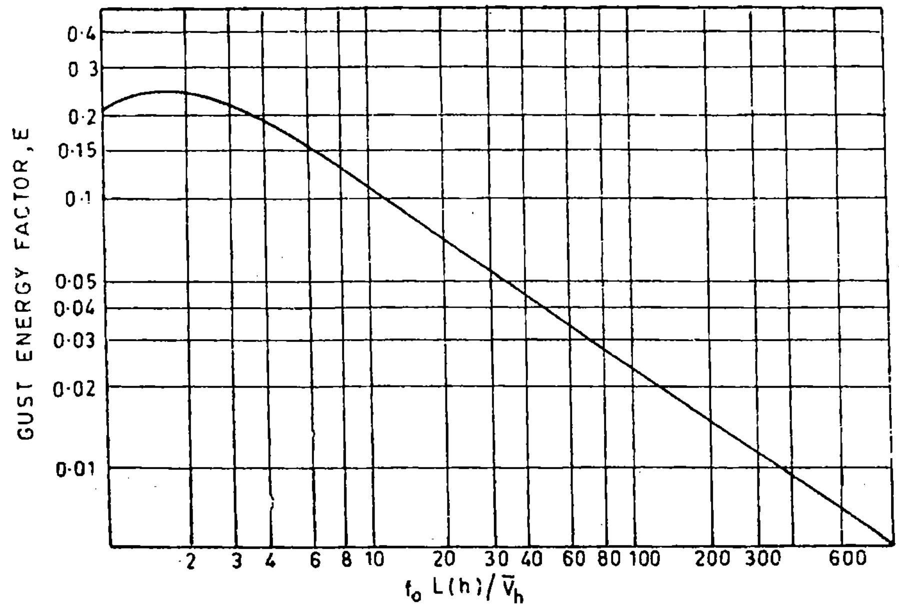


FIG. 11 GUST ENERGY FACTOR, *E*

In figures 8 to 11,

$$\lambda = \frac{C_y\, b}{C_z\, h} \text{ and } F_0 = \frac{C_z f_0\, h}{\bar{V}_h}$$

where

C_y = lateral correlation constant which may be taken as 10 in the absence of more precise load data,

C_z = longitudinal correlation constant which may be taken as 12 in the absence of more precise load data,

b = breadth of a structure normal to the wind stream,

h = height of a structure,

$\bar{V}_h = \bar{V}_z$ = hourly mean wind speed at height z,

f_0 = natural frequency of the structure, and

$L_{(h)}$ = a measure of turbulence length scale (*see* Fig. 9).

TABLE 34 SUGGESTED VALUES OF DAMPING COEFFICIENT

(*Clause* 8.3)

NATURE OF STRUCTURE	DAMPING COEFFICIENT, β
(1)	(2)
Welded steel structures	0·010
Bolted steel structures	0·020
Reinforced concrete structures	0·016

8.3.1 The peak acceleration along the wind direction at the top of the structure is given by the following formula:

$$a = (2\pi f_0)^2\, \bar{x}\, g_f r \sqrt{\frac{SE}{\beta}}$$

where

$\bar{x}$ = mean deflection at the position where the acceleration is required. Other notations are same as given in **8.3**.

APPENDIX A

(*Clause* 5.2)

BASIC WIND SPEED AT 10 m HEIGHT FOR SOME IMPORTANT CITIES/TOWNS

City/Town	*Basic Wind Speed* (m/s)
Agra	47
Ahmadabad	39
Ajmer	47
Almora	47
Amritsar	47
Asansol	47
Aurangabad	39
Bahraich	47
Bangalore	33
Barauni	47
Bareilly	47
Bhatinda	47
Bhilai	39
Bhopal	39
Bhubaneshwar	50
Bhuj	50
Bikaner	47
Bokaro	47
Bombay	44
Calcutta	50
Calicut	39
Chandigarh	47
Coimbatore	39
Cuttack	50
Darbhanga	55
Darjeeling	47
Dehra Dun	47
Delhi	47
Durgapur	47
Gangtok	47
Gauhati	50
Gaya	39
Gorakhpur	47
Hyderabad	44
Imphal	47
Jabalpur	47
Jaipur	47
Jamshedpur	47
Jhansi	47
Jodhpur	47
Kanpur	47
Kohima	44
Kurnool	39
Lakshadweep	39
Lucknow	47
Ludhiana	47
Madras	50
Madurai	39
Mandi	39
Mangalore	39
Moradabad	47
Mysore	33
Nagpur	44
Nainital	47
Nasik	39
Nellore	50
Panjim	39
Patiala	47
Patna	47
Pondicherry	50
Port Blair	44
Pune	39
Raipur	39
Rajkot	39
Ranchi	39
Roorkee	39
Rourkela	39
Simla	39
Srinagar	39
Surat	44
Tiruchchirrappalli	47
Trivandrum	39
Udaipur	47
Vadodara	44
Varanasi	47
Vijaywada	50
Visakhapatnam	50

APPENDIX B

[*Clause* 5.3.2.4(b)(ii)]

CHANGES IN TERRAIN CATEGORIES

B-1. LOW TO HIGH NUMBER

B-1.1 In cases of transition from a low category number (corresponding to a low terrain roughness) to a higher category number (corresponding to a rougher terrain), the velocity profile over the rougher terrain shall be determined as follows:

a) Below height h_x, the velocities shall be determined in relation to the rougher terrain; and

b) Above height h_x, the velocities shall be determined in relation to the less rough (more distant) terrain.

B-2. HIGH TO LOW NUMBER

B-2.1 In cases of transition from a more rough to a less rough terrain, the velocity profile shall be determined as follows:

a) Above height h_x, the velocities shall be determined in accordance with the rougher (more distant) terrain; and

b) Below height h_x, the velocity shall be taken as the lesser of the following:

i) that determined in accordance with the less rough terrain, and

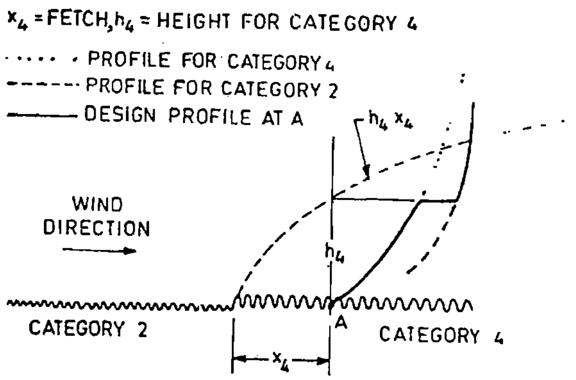
ii) the velocity at height h_x as determined in relation to the rougher terrain.

NOTE — Examples of determination of velocity profiles in the vicinity of a change in terrain category are shown in Fig. 12A and 12B.

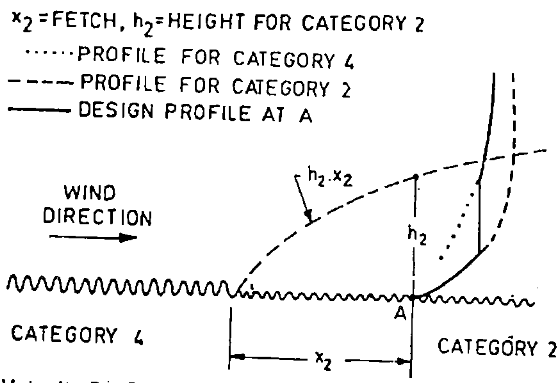
B-3. MORE THAN ONE CATEGORY

B-3.1 Terrain changes involving more than one category shall be treated in similar fashion to that described in **B-1** and **B-2**.

NOTE — Examples involving three terrain categories are shown in Fig. 12C.

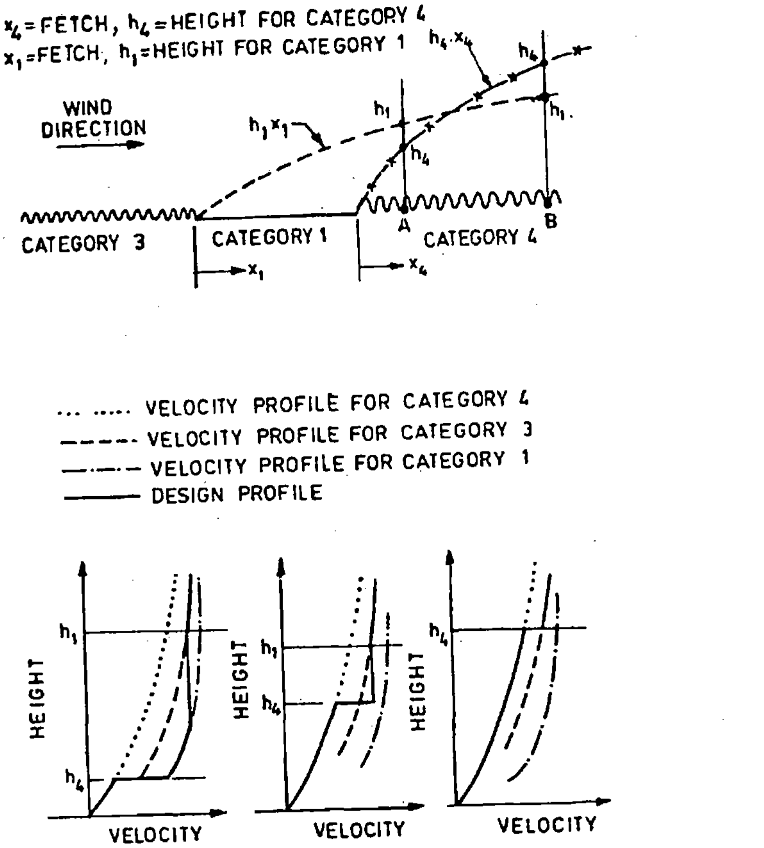


12A Determination of Velocity Profile Near a Change in Terrain Category (less rough to more rough)



12B Determination of Velocity Profile Near a Change in Terrain Category (more rough to less rough)

FIG. 12 VELOCITY PROFILE IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY — *Contd*



12C Determination of Design Profile Involving More Than One Change in Terrain Category

FIG. 12 VELOCITY PROFILE IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY

APPENDIX C

(*Clause* 5.3.3.1)

EFFECT OF A CLIFF OR ESCARPMENT ON EQUIVALENT HEIGHT ABOVE GROUND (k_3 FACTOR)

C-1. The influence of the topographic feature is considered to extend 1·5 L_e upwind add 2·5 L_e downwind of the summit of crest of the feature where L_e is the effective horizontal length of the hill depending on slope as indicated below (*see* Fig. 13):

Slope	L_e
$3° < \theta \leqslant 17°$	L
$> 17°$	$\frac{Z}{0{\cdot}3}$

where

L = actual length of the upwind slope in the wind direction,

Z = effective height of the feature, and

θ = upwind slope in the wind direction.

If the zone downwind from the crest of the feature is relatively flat ($\theta < 3°$) for a distance exceeding L_e, then the feature should be treated as an escarpment. If not, then the feature should be treated as a hill or ridge. Examples of typical features are given in Fig. 13.

NOTE 1 — No difference is made, in evaluating k_3 between a three dimensional hill and two dimensional ridge.

NOTE 2 — In undulating terrain, it is often not possible to decide whether the local topography to the site is significant in terms of wind flow. In such cases, the average value of the terrain upwind of the site for a distance of 5 km should be taken as the base level from wind to assess the height, z, and the upwind slope θ, of the feature.

C-2. TOPOGRAPHY FACTOR, k_3

The topography factor k_3 is given by the following:

$$k_3 = 1 + C s$$

where C has the following values:

Slope	*C*
$3° < \theta \leqslant 17°$	$1{\cdot}2 \left(\frac{z}{L} \right)$
$> 17°$	0·36

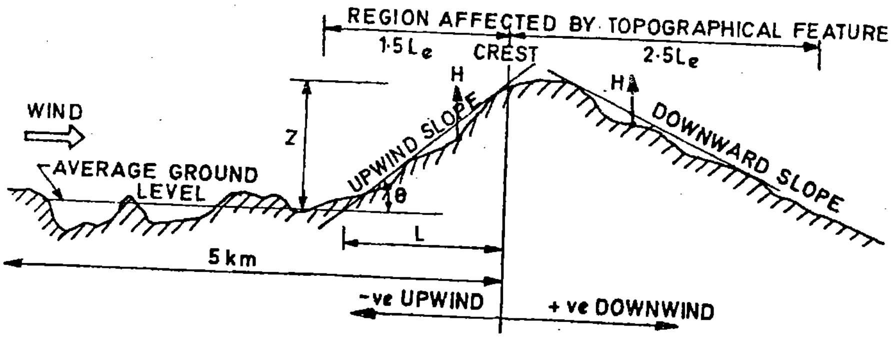
and s is a factor derived in accordance with **C-2.1** appropriate to the height, H above mean ground level and the distance, X, from the summit or crest relative to the effective length, L_e.

C-2.1 The factor, s, should be determined from:

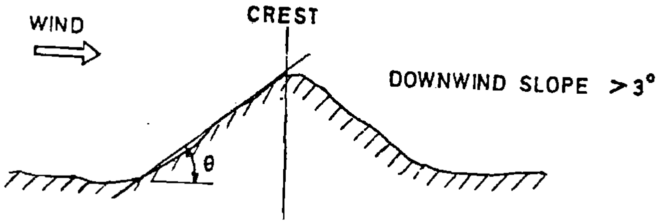
a) Figure 14 for cliffs and escarpments, and

b) Figure 15 for hills and ridges.

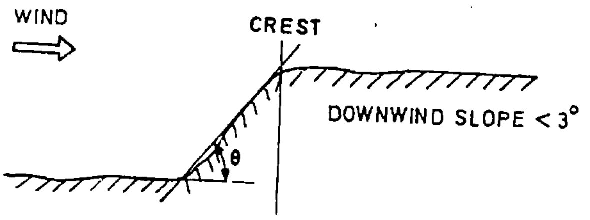
NOTE — Where the downwind slope of a hill or ridge is greater than 3°, there will be large regions of reduced accelerations or even shelter and it is not possible to give general design rules to cater for these circumstances. Values of s from Fig. 15 may be used as upper bound values.



13A General Notations



13B Cliff and Escarpment



13C Hill and Ridge

FIG. 13 TOPOGRAPHICAL DIMENSIONS

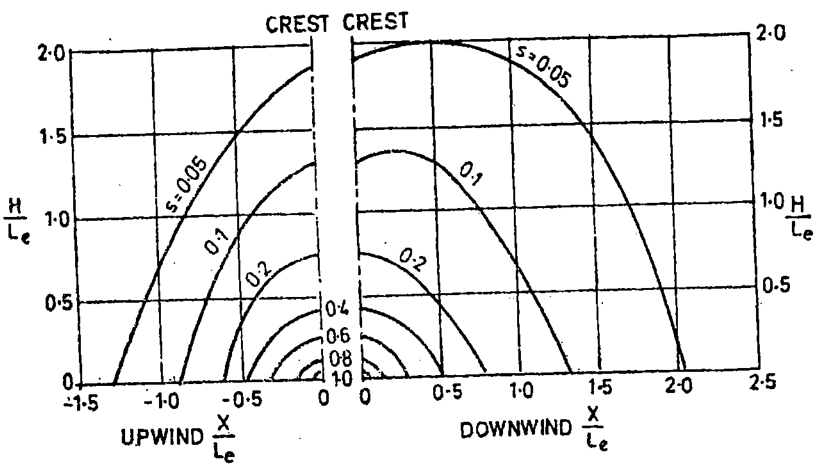


FIG. 14 FACTOR *s* FOR CLIFF AND ESCARPMENT

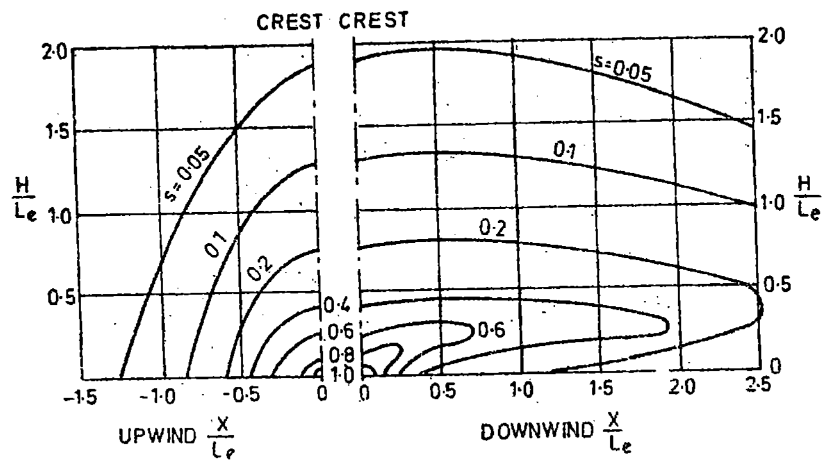


FIG. 15 FACTOR *s* FOR RIDGE AND HILL

APPENDIX D

[*Clauses* 6.3.2.2, 6.3.3.2(c) *and* 6.3.3 3(b)]

WIND FORCE ON CIRCULAR SECTIONS

D-1. The wind force on any object is given by:

$$F = C_f \, A_e \, p_d$$

where

C_f = force coefficient,

A_e = effective area of the object normal to the wind direction, and

p_d = design pressure of the wind.

For most shapes, the force coefficient remains approximately constant over the whole range of wind speeds likely to be encountered. However, for objects of circular cross-section, it varies considerably.

For a circular section, the force coefficient depends upon the way in which the wind flows around it and is dependent upon the velocity and kinematic viscosity of the wind and diameter of the section. The force coefficient is usually quoted against a non-dimensional parameter, called the Reynolds number, which takes account of the velocity and viscosity of the flowing medium (in this case the wind), and the member diameter.

$$\text{Reynolds number, } R_e = \frac{DV_d}{\gamma}$$

where

D = diameter of the member,

V_d = design wind speed, and

γ = kinematic viscosity of the air which is 1.46×10^{-5} m²s at 15°C and standard atmospheric pressure.

Since in most natural environments likely to be found in India, the kinematic viscosity of the air is fairly constant, it is convenient to use DV_d as the parameter instead of Reynolds numbers and this has been done in this code.

The dependence of a circular section's force coefficient or Reynolds number is due to the change in the wake developed behind the body.

At a low Reynolds number, the wake is as shown in Fig. 16 and the force coefficient is typically 1·2. As Reynolds number is increased, the wake gradually changes to that shown in Fig. 17, that is, the wake width d_w decreases and the separation point, S, moves from front to the back of the body.

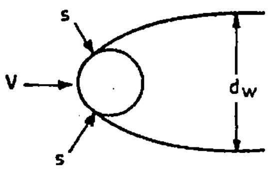


FIG. 16 WAKE IN SUBCRITICAL FLOW

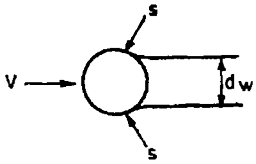


FIG. 17 WAKE IN SURERCRITICAL FLOW

As a result, the force coefficient shows a rapid drop at a critical value of Reynolds number, followed by a gradual rise as Reynolds number is increased still further.

The variation of C_f with parameter DV_d is shown in Fig. 5 for infinitely long circular cylinders having various values of relative surface roughness (ε/D) when subjected to wind having an intensity and scale of turbulence typical of built-up urban areas. The curve for a smooth cylinder (ε/D) = 1×10^{-5} in a steady air-stream, as found in a low-turbulence wind tunnel, is shown for comparison.

It can be seen that the main effect of free-stream turbulence is to decrease the critical value of the parameter DV_d. For subcritical flows, turbulence can produce a considerable reduction in C_f below the steady air-stream values. For supercritical flows, this effect becomes significantly smaller.

If the surface of the cylinder is deliberately roughened such as by incorporating flutes, rivetted construction, etc, then the data given in Fig. 5 for appropriate value of $\varepsilon/D > 0$ shall be used.

NOTE — In case of uncertainty regarding the value of ε to be used for small roughnesses, ε/D shall be taken as 0·001.

velocity and viscosity of the flowing medium (in this case the wind), and the member diameter.

$$\text{Reynolds number, } R_e = \frac{D V_d}{\gamma}$$

where

D = diameter of the member,

V_d = design wind speed, and

γ = kinematic viscosity of the air which is $1{\cdot}46 \times 10^{-5}$ m²s at 15°C and standard atmospheric pressure.

Since in most natural environments likely to be found in India, the kinematic viscosity of the air is fairly constant, it is convenient to use $D V_d$ as the parameter instead of Reynolds numbers and this has been done in this code.

The dependence of a circular section's force coefficient or Reynolds number is due to the change in the wake developed behind the body.

At a low Reynolds number, the wake is as shown in Fig. 16 and the force coefficient is typically 1·2. As Reynolds number is increased, the wake gradually changes to that shown in Fig. 17, that is, the wake width d_w decreases and the separation point, S, moves from front to the back of the body.

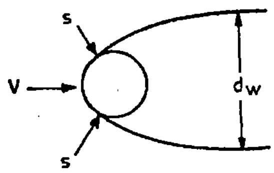


FIG. 16 WAKE IN SUBCRITICAL FLOW

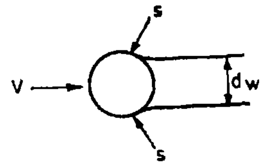


FIG. 17 WAKE IN SURERCRITICAL FLOW

As a result, the force coefficient shows a rapid drop at a critical value of Reynolds number, followed by a gradual rise as Reynolds number is increased still further.

The variation of C_f with parameter $D V_d$ is shown in Fig. 5 for infinitely long circular cylinders having various values of relative surface roughness (ε/D) when subjected to wind having an intensity and scale of turbulence typical of built-up urban areas. The curve for a smooth cylinder (ε/D) = 1×10^{-5} in a steady air-stream, as found in a low-turbulence wind tunnel, is shown for comparison.

It can be seen that the main effect of free-stream turbulence is to decrease the critical value of the parameter $D V_d$. For subcritical flows, turbulence can produce a considerable reduction in C_f below the steady air-stream values. For supercritical flows, this effect becomes significantly smaller.

If the surface of the cylinder is deliberately roughened such as by incorporating flutes, rivetted construction, etc, then the data given in Fig. 5 for appropriate value of $\varepsilon/D > 0$ shall be used.

NOTE — In case of uncertainty regarding the value of ε to be used for small roughnesses, ε/D shall be taken as 0·001.

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Amendments Issued Since Publication

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IS 875 (Part 4) : 1987
(Reaffirmed 2003)

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 4 SNOW LOADS

(Second Revision)

Ninth Reprint DECEMBER 2010

UDC 624.042.42 : 006.7

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

October 1988 **Price Group 4**

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 4 SNOW LOADS

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 4) (Second Revision) was adopted by the Bureau of Indian Standards on 9 November 1987, after the draft finalized by the Structural Safety Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy. structural safety, fire safety; and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in this Code by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, wind loads, snow loads and other external loads, the structure would be required to bear. Strict conformity to loading standards recommended in this Code, it is hoped, will not only ensure the structural safety of the buildings which are being designed and constructed in the country and thereby reduce the hazards to life and property caused by unsafe structures, but also eliminate the wastage caused by assuming unnecessarily heavy loadings. Notwithstanding what is stated regarding the structural safety of buildings, the application of the provisions should be carried out by competent and responsible structural designer who would satisfy himself that the structure designed in accordance with this code meets the desired performance requirements when the same is carried out according to specifications.

0.3 This Code was first published in 1957 for the guidance of civil engineers, designers and architects associated with the planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effects on structures undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs, both curved and sloping, were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

0.3.1 With the increased adoption of the Code, a number of comments were received on the provisions on live load values adopted for different occupancies. Simultaneously live loads surveys have been carried out in America, Canada and other countries to arrive at realistic live loads based on actual determination of loading (movable and immovable) in different occupancies. Keeping this in view and other developments in the field of wind engineering, the Sectional Committee responsible for the preparation of this standard has decided to prepare the second revision in the following five parts:

- Part 1 Dead Loads
- Part 2 Imposed Loads
- Part 3 Wind Loads
- Part 4 Snow Loads
- Part 5 Special Loads and Load Combinations

Earthquake load is covered in IS : 1893-1984* which should be considered along with the above loads.

0.3.2 This part (Part 4) deals with snow loads on roofs of buildings.

The committee responsible for the preparation of the code while reviewing the available snow-fall data, felt the paucity of data on which to make specific recommendations on the depth of ground snow load for different regions effected by snow-fall. In due course the characteristic

*Criteria for earthquake resistant designing of structures (*fourth revision*).

snow load on ground for different regions will be included based on studies.

0.4 This part is based on ISO 4355-1981 (E) 'Basis for design of structures — Determination of snow loads on roofs', issued by the International Organization for Standardization.

1. SCOPE

1.1 This standard (Part 4) deals with snow loads on roofs of buildings. Roofs should be designed for the actual load due to snow or for the imposed loads specified in Part 2 Imposed loads, whichever is more severe.

NOTE — Mountainous regions in northern parts of India are subjected to snow-fall.

In India, parts of Jammu and Kashmir (Baramulah District, Srinagar District, Anantnag District and Ladakh District); Punjab, Himachal Pradesh (Chamba, Kulu, Kinnaur District, Mahasu District, Mandi District, Sirmur District and Simla District); and Uttar Pradesh (Dehra Dun District, Tehri Garhwal District, Almora District and Nainital District) experience snow-fall of varying depths two to three times in a year.

2. NOTATIONS

μ (Dimensionless) — Nominal values of the shape coefficients, taking into account snow drifts, sliding snow, etc, with subscripts, if necessary.

l_i (in metres) — Horizontal dimensions with numerical subscripts, if necessary.

h_i (in metres) — Vertical dimensions with numerical subscripts, if necessary.

β_i (in degrees) — Roof slope.

s_0 (in pascals) — Snow load on ground.

s_1 (in pascals) — Snow load on roofs.

3. SNOW LOAD IN ROOF (S)

3.1 The minimum design snow load on a roof area or any other area above ground which is subjected to snow accumulation is obtained by multiplying the snow load on ground, s_0 by the shape coefficient μ, as applicable to the particular roof area considered.

$$s = \mu \, s_0$$

where

s = design snow load in Pa on plan area of roof,

μ = shape coefficient (*see* 4), and

s_0 = ground snow load in Pa (1 Pa = 1N/m^2).

NOTE — Ground snow load at any place depends on the critical combination of the maximum depth of undisturbed aggregate cumulative snow-fall and its average density. In due course the characteristic snow load on ground for different regions will be included based on studies. Till such time the users of this standard are advised to contanct either Snow and Avalanches Study Establishment (Defence Research and Development Organization) Manali (HP) or Indian Meteorological Department (IMD), Pune in the absence of any specific information for any location.

4. SHAPE COEFFICIENTS

4.1 General Principles

In perfectly calm weather, falling snow would cover roofs and the ground with a uniform blanket of snow and the design snow load could be considerd as a uniformly distributed load. Truly uniform loading conditions, however, are rare and have usually only been observed in areas that are sheltered on all sides by high trees, buildings, etc. In such a case, the shape coefficient would be equal to untiy.

In most regions, snow falls are accompanied or followed by winds. The winds will redistribute the snow and on some roofs, especially multi-level roofs, the accumulated drift load may reach a multiple of the ground load. Roofs which are sheltered by other buildings, vegetation, etc, may collect more snow load than the ground level. The phenomenon is of the same nature as that illustrated for multilevel roofs in **4.2.4**.

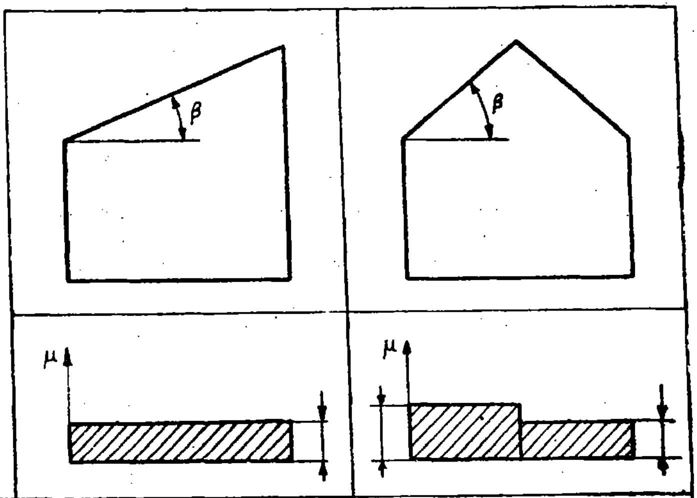
So far sufficient data are not available to determine the shape coefficient in a statistical basis. Therefore, a nominal value is given. A representative sample of roof is shown in **4.2**. However, in special cases such as strip loading, cleaning of the roof periodically by deliberate heating of the roof, etc, have to be treated separately.

The distribution of snow in the direction parallel to the eaves is assumed to be uniform.

4.2 Shape Coefficients for Selected Types of Roofs

4.2.1

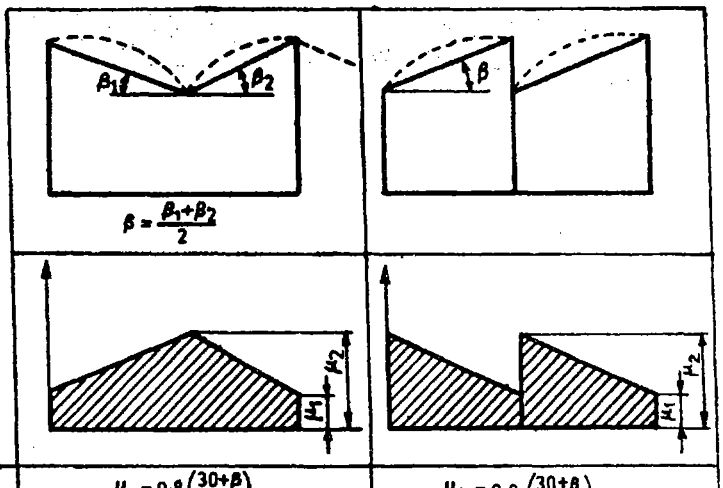
	Simple Flat and Monopitch Roofs	Simple Pitched Roofs (Positive Roof Slope)*



	Simple Flat and Monopitch Roofs	Simple Pitched Roofs (Positive Roof Slope)*
$0° < \beta \leq 30°$	$\mu_1 = 0{\cdot}8$	$\mu_2 = \mu_1 = 0{\cdot}8$
$15° < \beta \leq 30°$		$\mu_2 = 0.8 + 0{\cdot}4\left(\frac{\beta - 15}{15}\right)$ $\mu_1 = 0{\cdot}8$
$30° < \beta < 60°$	$\mu_1 = 0{\cdot}8\left(\frac{60 - \beta}{30}\right)$	$\mu_2 = 1{\cdot}2\left(\frac{60 - \beta}{30}\right)$ $\mu_1 = 0{\cdot}8\left(\frac{60 - \beta}{30}\right)$
$\beta > 60°$	$\mu_1 = 0$	$\mu_2 = \mu_1 = 0$

4.2.2

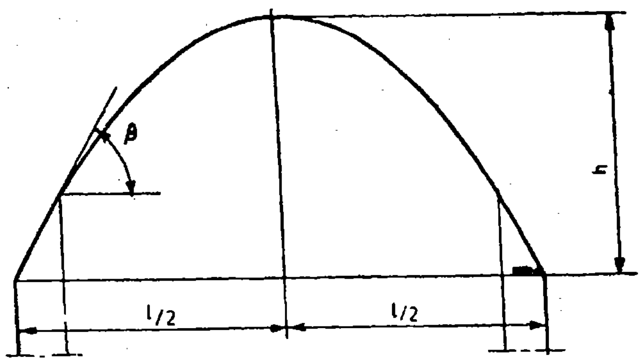
	Simple or Multiple Pitched Roofs (Negative Roof Slope)	Two-Span or Multispan Roofs



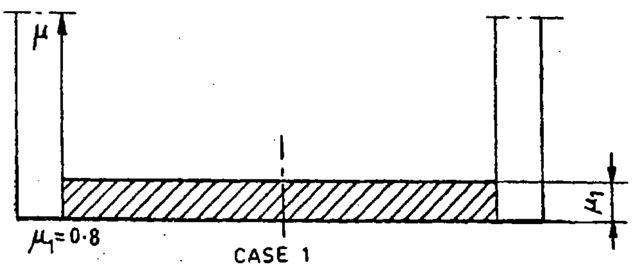
	Simple or Multiple Pitched Roofs (Negative Roof Slope)	Two-Span or Multispan Roofs
$0° < \beta < 30°$	$\mu_2 = 0{\cdot}8\left(\frac{30 + \beta}{30}\right)$ $\mu_1 = 0{\cdot}8$	$\mu_2 = 0{\cdot}8\left(\frac{30 + \beta}{30}\right)$ $\mu_1 = 0{\cdot}8$
$30° < \beta < 60°$	$\mu_2 = 1{\cdot}6$ $\mu_1 = 0{\cdot}8\left(\frac{60 - \beta}{30}\right)$	$\mu_2 = 1{\cdot}6$ $\mu_1 = 0{\cdot}8\left(\frac{60 - \beta}{30}\right)$
$\beta > 60°$	$\mu_2 = 1{\cdot}6$ $\mu_1 = 0$	$\mu_2 = 1{\cdot}6$ $\mu_1 = 0$

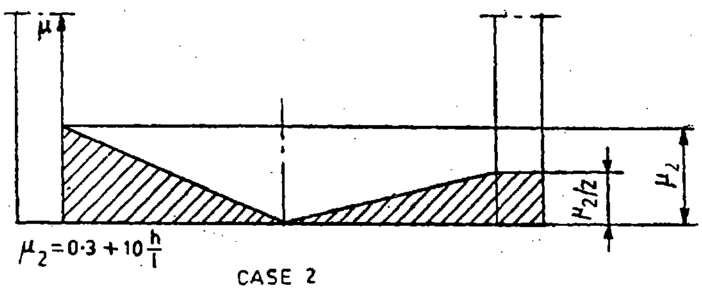
*For asymmetrical simple pitched roofs, each side of the roof shall be treated as one half of corresponding symmetrical roofs.

4.2.3 Simple Curved Roofs



The following cases 1 and 2 must be examined:



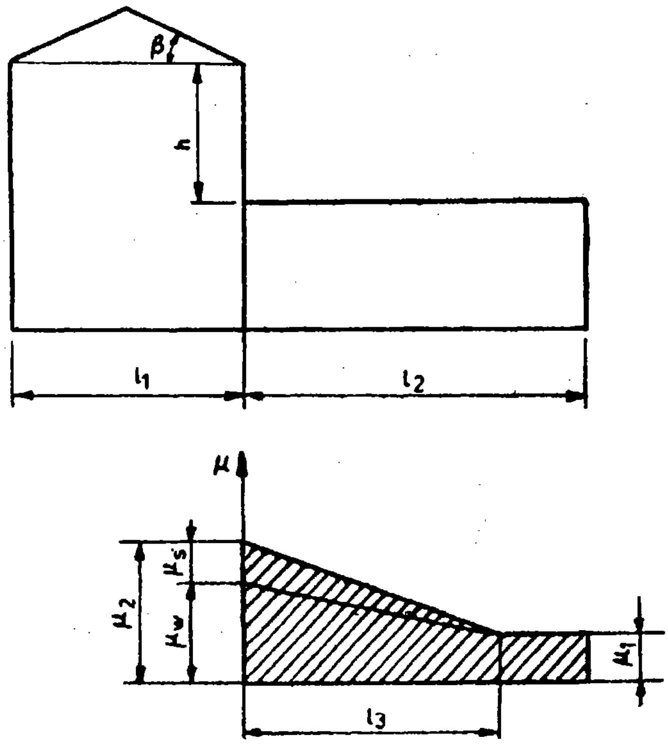


Restriction:

$\mu_s \leqslant 2{\cdot}3$

$\mu = 0$ if $\beta > 60°$

4.2.4 Multilevel Roofs*



$\mu_1 = 0{\cdot}8$

$\mu_2 = \mu_s + \mu_w$

where

μ_s = due to sliding

μ_w = due to wind

$l_3 = 2h$† but is restricted as follows:

$5 \text{ m} \leqslant l_3 \leqslant 15 \text{ m}$

$$\mu_w = \frac{l_1 + l_2}{2h} < \frac{kh}{s_0}$$

with the restriction $0{\cdot}8 < \mu_w < 4{\cdot}0$

where

h is in metres

s_0 is in kilopascals (kilonewtons per square metre)

$k = 2 \text{ kN/m}^3$

$\beta > 15°$: μ_s is determined from an additional load amounting to 50 percent of the maximum total load on the adjacent slope of the upper roof‡, and is distributed linearly as shown on the figure.

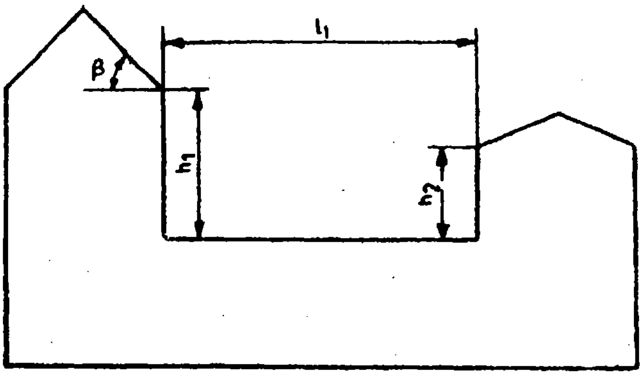
$\beta \leqslant 15°$: $\mu_s = 0$

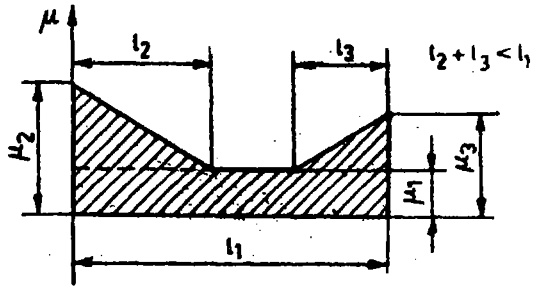
*A more extensive formula for μ_w is described in Appendix A.

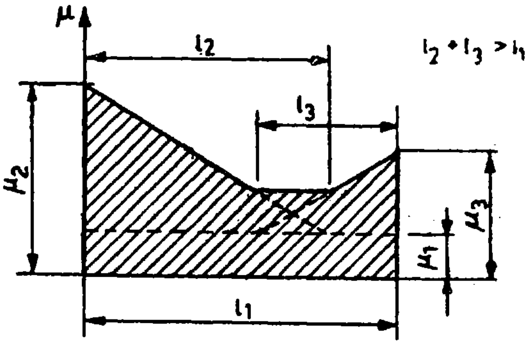
†If $l_2 < l_3$, the coefficient μ is determined by interpolation between μ_1 and μ_2.

‡The load on the upper roof is calculated according to **4.2.1** or **4.2.2**.

4.2.5 Complex Multilevel Roofs







$l_2 = 2h_1$; $l_3 = 2h_2$; $\mu_1 = 0{\cdot}8$

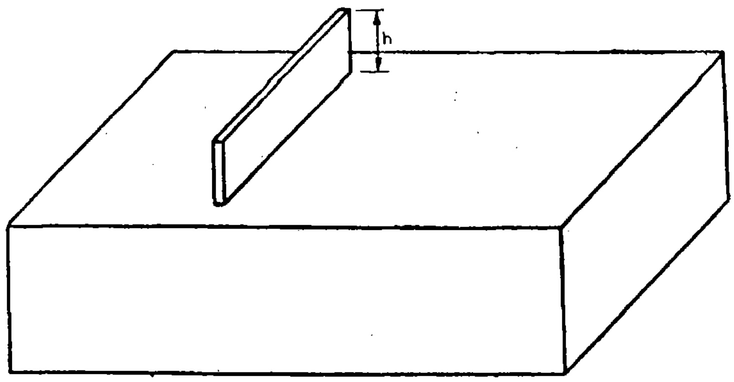
Restriction:

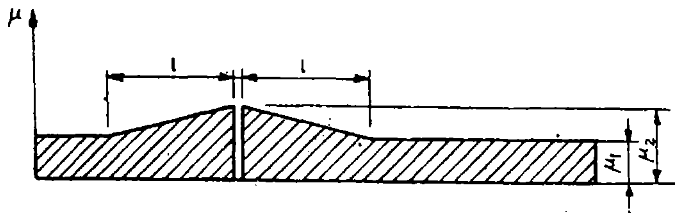
5 m < l_2 < 15 m;

5 m < l_3 < 15 m;

μ_2 and μ_3. ($\mu_3 + \mu_W$), are calculated according to 4.2.1, 4.2.2 and 4.2.4.

4.2.6 Roofs with Local Projections and Obstructions





$$\mu_2 = \frac{kh}{s_0}$$

where

h is in metres

s_0 is in kilopascals (kilonewtons per square metre)

k = 2 kN/m³

$\mu_1 = 0.8$

$l = 2h$

Restrictions:

$0.8 \leqslant \mu_2 < 2.0$

$5 \text{ m} < l \leqslant 15 \text{ m}$

4.3 Shape Coefficients in Areas Exposed to Wind

The shape coefficients given in **4.2** and Appendix A may be reduced by 25 percent provided the designer has demonstrated that the following conditions are fulfilled:

a) The building is located in an exposed location such as open level terrain with only scattered buildings, trees or other obstructions so that the roof is exposed to the winds on all sides and is not likely to become shielded in the future by obstructions higher than the roof within a distance from the building equal to ten times the height of the obstruction above the roof level;

b) The roof does not have any significant projections such as parapet walls which may prevent snow from being blown off the roof.

NOTE — In some areas, winter climate may not be of such a nature as to produce a significant reduction of roof loads from the snow load on the ground. These areas are:

a) Winter calm valleys in the mountains where sometimes layer after layer of snow accumulates on roofs without any appreciable removal of snow by wind; and

b) Areas (that is, high temperature) where the maximum snow load may be the result of single snowstorm, occasionally without appreciable wind removal.

In such areas, the determination of the shape coefficients shall be based on local experience with due regard to the likelihood of wind drifting and sliding.

5. ICE LOAD ON WIRES

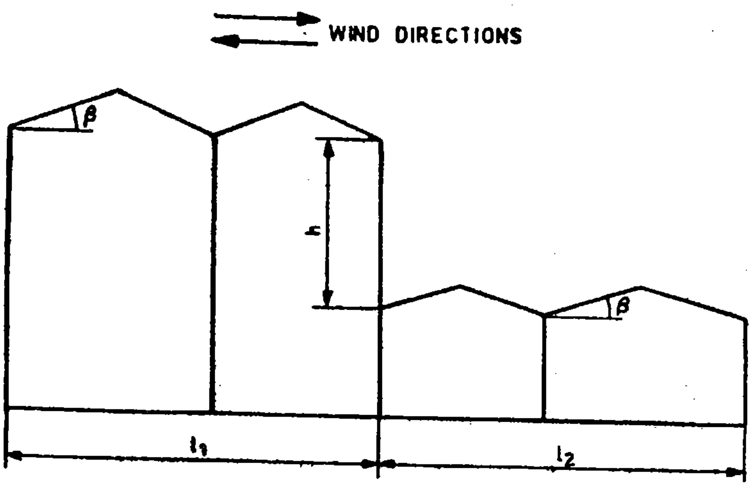
5.1 Ice loads are required to be taken into account in the design of overhead electrical-transmission and communication lines, over-head contact lines for electric traction, aerial masts and similar structures in zones subjected to ice formation. The thickness of ice deposit alround may be taken to be between 3 and 10 mm depending upon the location of the structure. The mass density of ice may be assumed to be equal to 0·9 g/cm³. While considering the wind force on wires and cables, the increase in diameter due to ice formation shall be taken into consideration.

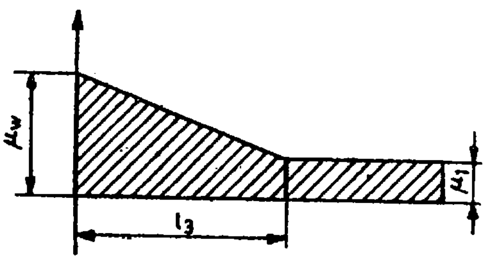
APPENDIX A

(*Clauses* **4.2.4** *and* **4.3**)

SHAPE COEFFICIENTS FOR MULTILEVEL ROOFS

A more comprehensive formula for the shape coefficient for multilevel roofs than that given in **4.2.4** is as follows:





$$\mu_w = 1 + \frac{1}{h} (m_1 l_1 + m_2 l_2)(l_3 - 2 h)$$

$\mu_1 = 0{\cdot}8$

$l_3 = 2\,h$

(h and l being in metres)

Restriction :

$$\mu_w < \frac{kh}{s_0}$$

where

s_0 is in kilopascals (kilonewtons per square metre)

k is in newtons per cubic metre

$l_3 < 15\ m$

Values of m_1 (m_2) for the higher (lower) roof depend on its profile and are taken as equal to:

0·5 for plane roofs with slopes $\beta < 20°$ and vaulted roofs with $\frac{f}{l} < \frac{1}{8}$

0·3 for plane roofs with slopes $\beta > 20°$ and vaulted roofs with $\frac{f}{l} > \frac{1}{8}$

The coefficients m_1 and m_2 may be adjusted to take into account conditions for transfer of snow on the roof surface (that is, wind, temperature, etc.).

NOTE — The other condition of loading also shall be tried.

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(Reaffirmed 2008)

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 5 SPECIAL LOADS AND LOAD COMBINATIONS

(Second Revision)

Seventh Reprint JANUARY 2011
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UDC 624.042 : 006.76

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

Gr 5 *July* 1988

AMENDMENT NO. 1 DECEMBER 2006
TO
IS 875 (PART 5) : 1987 CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 5 SPECIAL LOADS AND LOAD COMBINATIONS

(Second Revision)

(*Page* 9, *clause* **4.1**, *first para, last sentence*) — Substitute the following for the existing:

'The cracks usually propagate if the loading is cyclic and repetitive.'

(*Page* 9, *clause* **4.1**, *second para, line* 1) — Substitute 'cyclic and repetitive loading' *for* 'loading cycles'.

(*Page* 17, *Note* 4) — Insert the following matter at the end:

'In case of high water table, the effects of buoyancy have to be suitably taken into consideration.'

(*Page* 17, *Note* 5) — Insert the following new note and renumber the subsequent notes:

'NOTE 5 — In case of high water table, the factor of safety of 1.2 against uplift alone shall be provided.'

(CED 37)

1—403 BIS/ND/2010

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 5 SPECIAL LOADS AND LOAD COMBINATIONS

(Second Revision)

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(*Continued on page* 18)

Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 5 SPECIAL LOADS AND LOAD COMBINATIONS

(Second Revision)

0. FOREWORD

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0.3 This standard code of practice was first published in 1957 for the guidance of civil engineers, designers and architects associated with planning and design of buildings. It included the provisions for basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effects on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs both curved and sloping were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

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Part 1 Dead loads

Part 2 Imposed loads

Part 3 Wind loads

Part 4 Snow loads

Part 5 Special loads and load combinations.

Earthquake load is covered in a separate standard, namely IS : 1893-1984* which should be considered along with the above loads.

0.3.2 This code (Part 5) deals with loads and load effects (other than those covered in Parts 1 to 4, and seismic loads) due to temperature changes, internally generating stresses (due to creep, shrinkage, differential settlement, etc) in the building and its components, soil and hydrostatic pressure, accidental loads, etc. This part also includes guidance on load combinations.

0.4 The code has taken into account the prevailing practices in regard to loading standards followed in this country by the various municipal authorities and has also taken note of the developments in a number of countries abroad. In the preparation of this code, the following national standards have been examined:

a) National Building Code of Canada (1977) Supplement No. 4. Canadian Structural Design Manual.

*Criteria for earthquake resistant design of structures (*third revision*).

b) DS 410-1983 Code of practice for loads for the design of structures. Danish Standards Institution.

c) NZS 4203-1976 New Zealand Standard General structural design and design loading for building. Standards Association of New Zealand.

d) ANSI A 58.1-1982 American Standard Building code requirements for minimum design loads in buildings and other structures.

1. SCOPE

1.1 This code (Part 5) deals with loads and load effects due to temperature changes, soil and hydrostatic pressures, internally generating stresses, (due to creep, shrinkage, differential settlement, etc), accidental loads etc, to be considered in the design of buildings as appropriate. This part also includes guidance on load combinations. The nature of loads to be considered for a particular situation is to be based on engineering judgement.

2. TEMPERATURE EFFECTS

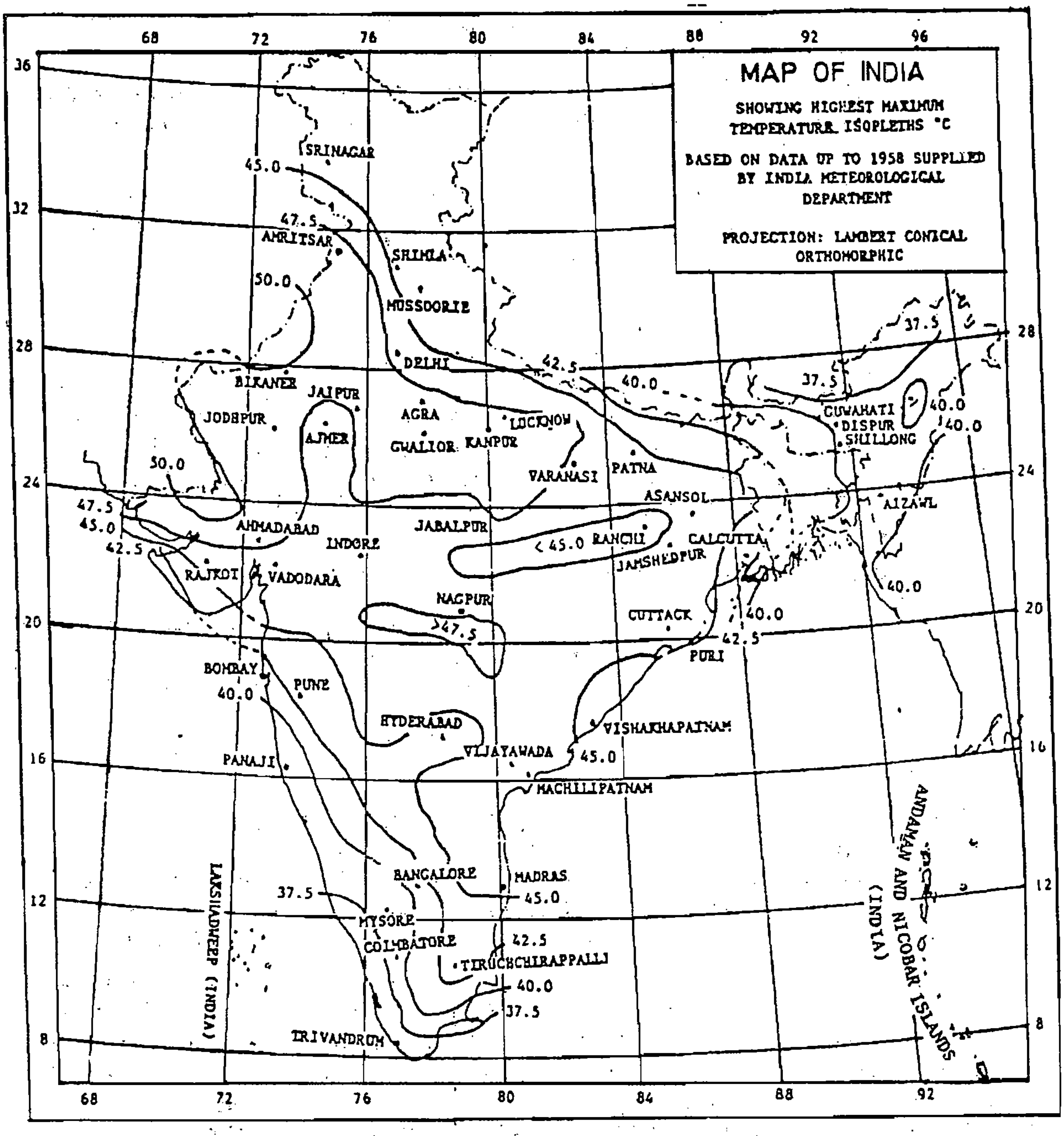
2.1 Expansion and contraction due to changes in temperature of the materials of a structure shall be considered in design. Provision shall be made either to relieve the stress by provision of expansion/contraction joints in accordance with IS : 3414-1968* or design the structure to carry additional stresses due to temperature effects as appropriate to the problem.

2.1.1 The temperature range varies for different regions and under different diurnal and seasonal conditions. The absolute maximum and minimum temperature which may be expected in different localities in the country are indicated in Fig. 1 and 2 respectively. These figures may be used for guidance in assessing the maximum variations of temperature.

2.1.2 The temperatures indicated in Fig. 1 and 2 are the air temperatures in the shade. The range of variation in temperature of the building materials may be appreciably greater or less than the variation of air temperature and is influenced by the condition of exposure and the rate at which the materials composing the structure absorb or radiate heat. This difference in temperature variations of the material and air should be given due consideration.

2.1.3 The structural analysis must take into account: (a) changes of the mean (through the section) temperature in relation to the initial temperature (st), and (b) the temperature gradient through the section.

*Code of practice for design and installation of joints in buildings.



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

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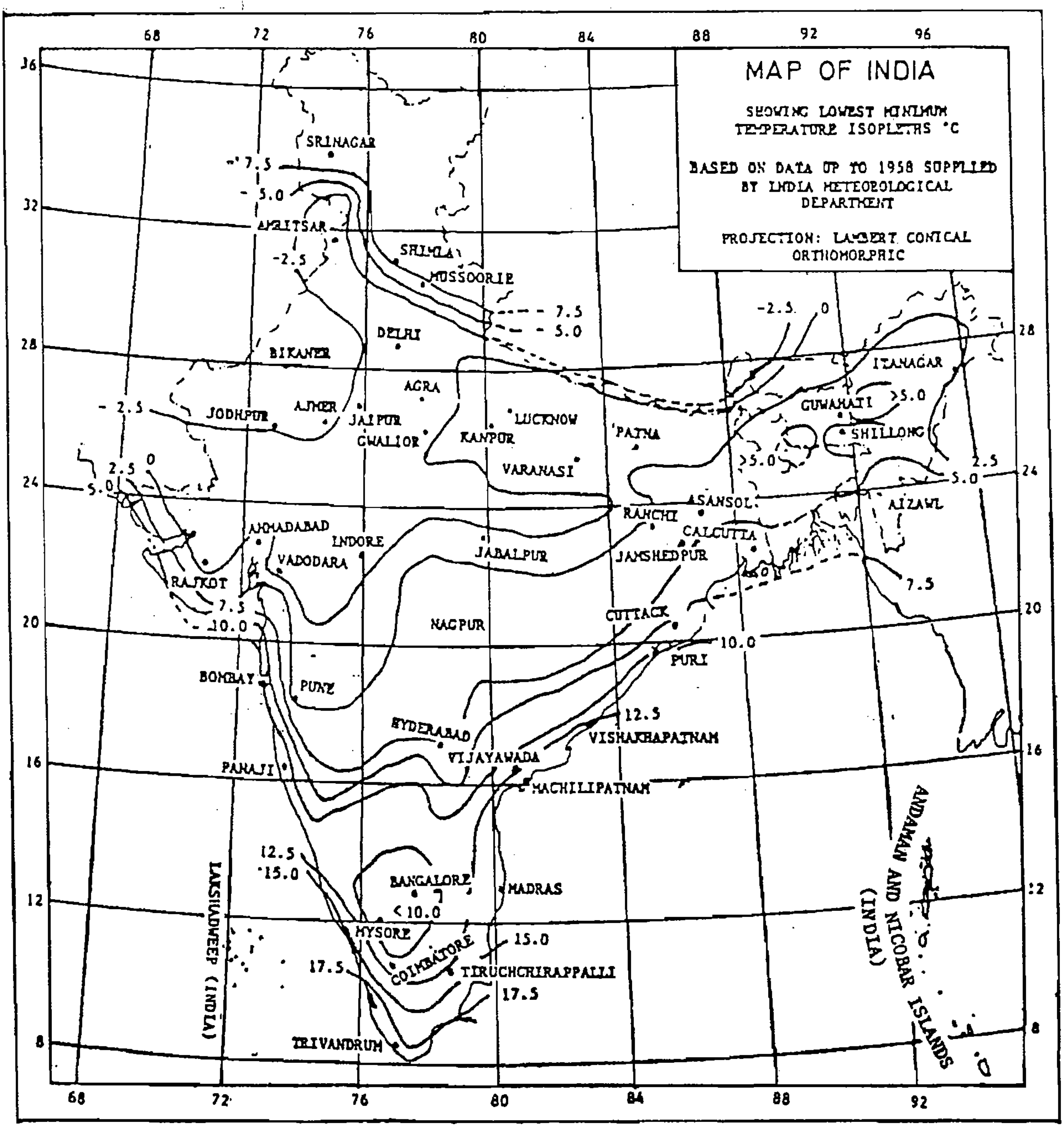
FIG. 1 CHART SHOWING HIGHEST MAXIMUM TEMPERATURE



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

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FIG. 2 CHART SHOWING LOWEST MINIMUM TEMPERATURE

2.1.3.1 It should be borne in mind that the changes of mean temperature in relation to the initial are liable to differ as between one structural element and another in buildings or structures, as for example, between the external walls and the internal elements of a building. The distribution of temperature through section of single-leaf structural elements may be assumed linear for the purpose of analysis.

2.1.3.2 The effect of mean temperature changes t_1, and t_2, and the temperature gradients v_1 and v_2 in the hot and cold seasons for single-leaf structural elements shall be evaluated on the basis of analytical principles.

NOTE 1 — For portions of the structure below ground level, the variation of temperature is generally insignificant. However, during the period of construction when the portions of the structure are exposed to weather elements, adequate provision should be made to encounter adverse effects, if any.

NOTE 2 — If it can be shown by engineering principles, or if it is known from experience, that neglect of some or all the effects of temperature do not affect the structural safety and serviceability, they need not be considered in design.

3. HYDROSTATIC AND SOIL PRESSURE

3.1 In the design of structures or parts of structures below ground level, such as retaining walls and other walls in basement floors. the pressure exerted by soil or water or both shall be duly accounted for on the basis of established theories. Due allowance shall be made for possible surcharge from stationary or moving loads. When a portion or whole of the soil is below the free water surface, the lateral earth pressure shall be evaluated for weight of soil diminished by buoyancy and the full hydrostatic pressure.

3.1.1 All foundation slabs and other footings subjected to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure. Checking of overturning of foundation under submerged condition shall be done considering buoyant weight of foundation.

3.2 While determining the lateral soil pressure on column like structural members, such as pillars which rest in sloping soils, the width of the member shall be taken as follows (*see* Fig. 3):

Actual Width of Member	*Ratio of Effective Width to Actual Width*
Less than 0·5 m	3·0
Beyond 0·5 m and up to 1 m	3·0 to 2·0
Beyond 1 m	2·0

The relieving pressure of soil in front of the structural member concerned may generally not be taken into account.

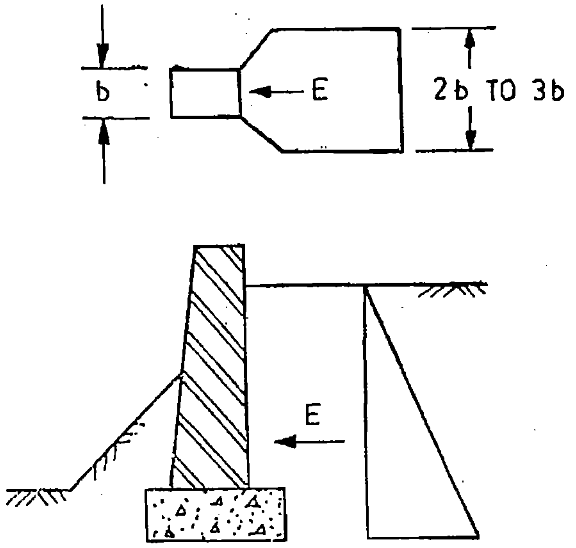

FIG. 3 SKETCH SHOWING EFFECTIVE WIDTH OF PILLAR FOR CALCULATING SOIL PRESSURE

3.3 Safe guarding of structures and structural members against over-turning and horizontal sliding shall be verified. Imposed loads having favourable effect shall be disregarded for the purpose. Due consideration shall be given to the possibility of soil being permanently or temporarily removed.

4. FATIGUE

4.1 General — Fatigue cracks are usually initiated at points of high stress concentration. These stress concentrations may be caused by or associated with holes (such as bolt or rivet holes in steel structures), welds including stray or fusions in steel structures, defects in materials, and local and general changes in geometry of members. The cracks usually propogate if loading is continuous.

Where there is such loading cycles, sudden changes of shape of a member or part of a member, specially in regions of tensile stress and/or local secondary bending, shall be avoided. Suitable steps shall be taken to avoid critical vibrations due to wind and other causes.

4.2 Where necessary, permissible stresses shall be reduced to allow for the effects of fatigue. Allowance for fatigue shall be made for combinations of stresses due to dead load and imposed load. Stresses due to wind and earthquakes may be ignored when fatigue is being considered unless otherwise specified in the relevant codes of practice.

Each element of the structure shall be designed for the number of stress cycles of each magnitude to which it is estimated that the element is liable to be subjected during the expected life of the structure. The number of cycles of each magnitude shall be estimated in the light of available data regarding the probable frequency of occurrence of each type of loading.

NOTE — Apart from the general observations made herein the code is unable to provide any precise guidance in estimating the probablistic behaviour and response of structures of various types arising out of repetitive loading approaching fatigue conditions in structural members, joints, materials, etc.

5. STRUCTURAL SAFETY DURING CONSTRUCTION

5.1 All loads required to be carried by the structures or any part of it due to storage or positioning of construction materials and erection equipment including all loads due to operation of such equipment, shall be considered as erection loads. Proper provision shall be made, including temporary bracings to take care of all stresses due to erection loads. The structure as a whole and all parts of structure in conjunction with the temporary bracings shall be capable of sustaining these erection loads without exceeding the permissible stresses specified in respective codes of practice. Dead load, wind load and such parts of imposed load as would be imposed on the structure during the period of erection shall be taken as acting together with erection loads.

6. ACCIDENTAL LOADS

6.0 General — The occurrence of accidental loads with a significant value, is unlikely on a given structure over the period of time under consideration, and also in most cases is of short duration. The occurrence of an accidental load could in many cases be expected to cause severe consequences unless special measures are taken:

The accidental loads arising out of human action include the following:

a) Impacts and collisions,

b) Explosions, and

c) Fire.

Characteristic of the above stated loads are that they are not a consequence of normal use and that they are undesired, and that extensive efforts are made to avoid them. As a result, the probability of occurrence of an accidental load is small whereas the consequences may be severe.

The causes of accidental loads may be:

a) inadequate safety of equipment (due to poor design or poor maintenance); and

b) wrong operation (due to insufficient teaching or training, indisposition, negligence or unfavourable external circumstances).

In most cases, accidental loads only develop under a combination of several unfavourable occurrence. In practical applications, it may be necessary to neglect the most unlikely loads. The probability of occurrence of accidental loads which are neglected may differ for different consequences of a possible failure. A data base for a detailed calculation of the probability will seldom be available.

NOTE — *Determination of Accidental Loads* — Types and magnitude of accidental loads should preferably be based on a risk analysis. The analysis should consider all factors influencing the magnitude of the action, including preventive measures for accidental situations. Generally, only the principal load bearing system need be designed for relevant ultimate limit states.

6.1 Impacts and Collisions

6.1.1 *General* — During an impact, the kinetic impact energy has to be absorbed by the vehicle hitting the structure and by the structure itself. In an accurate analysis, the probability of occurrence of an impact with a certain energy and the deformation characteristics of the object hitting the structure and the structure itself at the actual place must be considered. Impact energies for dropped objects should be based on the actual loading capacity and lifting height.

Common sources of impact are:

a) vehicles;

b) dropped objects from cranes, fork lifts, etc;

c) cranes out of control, crane failures; and

d) flying fragments.

The codal requirements regarding impact from vehicles and cranes are given in **6.1.2** and **6.1.3**.

6.1.2 *Collisions Between Vehicles and Structural Elements* — In road traffic, the requirement that a structure shall be able to resist collision may be assumed to be fulfilled if it is demonstrated that the structural element is able to stop a fictitious vehicle, as described in the following. It is assumed that the vehicle strikes the structural element at height of 1·2 m in any possible direction and at a speed of 10 m/s (36 km/h).

The fictitious vehicle shall be considered to consist of two masses m_1 and m_2 which during compression of the vehicle produce an impact force increasing uniformly from zero, corresponding to the rigidities C_1 and C_2. It is assumed that the mass m_1 is breaked completely before the braking of mass m_2 begins.

The following numerical values should be used:

m_1 = 400 kg, C_1 = 10 000 kN per m the vehicle is compressed.

m_2 = 12 000 kg, C_2 = 300 kN per m the vehicle is compressed.

NOTE — The described fictitious collision corresponds in the case of a non-elastic structural element to a maximum static force of 630 kN for the mass m_1 and 600 kN for the mass m_2 irrespective of the elasticity. It will, therefore, be on the safe side to assume the static force to be 630 kN.

In addition, braking of the mass m_1 will result in an impact wave, the effect of which will depend to a great extent on the kind of structural element concerned. Consequently, it will not always be sufficient to design for the static force.

6.1.3 *Safety Railings* — With regard to safety railings put up to protect structures against collision due to road traffic, it should be shown that the railings are able to resist on impact as described in **6.1.2.**

NOTE — When a vehicle collides with safety railings, the kinetic energy of the vehicle will be absorbed in part by the deformation of the railings and, in part by the deformation of the vehicle. The part of the kinetic energy which the railings should be able to absorb without breaking down may be determined on the basis of the assumed rigidity of the vehicle during the compression.

6.1.4 *Crane Impact Load on Buffer Stop* — The basic horizontal load P_y (tonnes), acting along the crane track produced by impact of the crane on the buffer stop, is calculated by the following formula:

$$P_y = M\, V^2/F$$

where

V = speed at which the crane is travelling at the moment of impact (assumed equal to half the nominal value) (m/s);

F = maximum shortening of the bufter, assumed equal to 0·1 m for light duty, medium-duty and heavy-duty cranes with flexible load suspension and loading capacity not exceeding 50 t, and 0·2 m in every other cranes; and

M = the reduced crane mass (t.s²/m); and is obtained by the formula:

$$M = \frac{1}{g}\left[\frac{P_h}{2} + (P_t + kQ)\,\frac{L_k - l}{L_k}\right]$$

where

g = acceleration due to gravity (9·81 m/s^2);

P_h = crane bridge weight (t);

P_t = crab weight (t);

k = a coefficient, assumed equal to zero for cranes with flexible load suspension and equal to one for cranes with rigid suspension;

Q = crane loading capacity (t);

L_k = crane span (m); and

l = nearness of crab (m).

6.2 Explosions

6.2.1 *General* — Explosions may cause impulsive loading on a structure. The following types of explosions are particularly relevant:

a) Internal gas explosions which may be caused by leakage of gas piping (including piping outside the room), evaporation from volatile liquids or unintentional evaporation from surface material (for example, fire);

b) Internal dust explosions;

c) Boiler failure;

d) External gas cloud explosions; and

e) External explosions of high-explosives (TNT, dynamite).

The codal requirement regarding internal gas explosions is given in **6.2.2**.

6.2.2 *Explosion Effect in Closed Rooms* — Gas explosion may be caused, for example, by leaks in gas pipes (inclusive of pipes outside the room), evaporation from volatile liquids or unintentional evaporation of gas from wall sheathings (for example, caused by fire).

NOTE 1 — The effect of explosions depends on the exploding medium, the concentration of the explosion, the shape of the room, possibilities of ventilation of the explosion, and the ductility and dynamic properties of the structure. In rooms with little possibility for relief of the pressure from the explosion, very large pressures may occur.

Internal overpressure from an internal gas explosion in rooms of sizes comparable to residential rooms and with ventilation areas consisting of window glass breaking at a pressure of 4 kN/m^2 (3-4 mm machine made glass) may be calculated from the following method:

a) The overpressure is assumed to depend on a factor A/V, where A is the total window area in m^2, V is the volume in m^3 of the room considered.

b) The internal pressure is assumed to act simultaneously upon all walls and floors in one closed room.

c) The action q_o may be taken as static action.

If account is taken of the time curve of action, the following (Fig. 4) schematic correspondence between pressure and time is assumed, where t_1 is the time from the start of combustion until maximum pressure is reached, and t_2 is the time from maximum pressure to the end of combustion. For t_1 and t_2, the most unfavourable values should be chosen in relation to the dynamic properties of the structures. However, the values should be chosen within the intervals as given in Fig. 5.

NOTE 2 — Figure 4 is based on tests with gas explosions in room corresponding to ordinary residential flats and should, therefore, not be applied to considerably different conditions. The figure corresponds to an explosion caused by town gas and it might therefore, be somewhat on the safe side in rooms where there is only the possibility of gases with a lower rate of combustion.

The pressure may be applied solely in one room or in more rooms at the same time. In the latter case, all rooms are incorporated in the volume V. Only windows or other similarly weak and light weight structural elements may be taken to be ventilation areas even through certain limited structural parts break at pressures less than q_o.

Figure 4 is given purely as guide and probability of occurrence of an explosion should be checked in each case using appropriate values.

6.3 Vertical Load on Air Raid Shelters

6.3.1 *Characteristic Values* — As regards buildings in which the individual floors are acted upon by a total characteristic imposed action of up to 5·0 kN/m^2, vertical actions on air raid shelters generally located below ground level, for example, basement, etc, should be considered to have the following characteristic values:

a) Buildings with up to 2 storeys	28 kN/m^2
b) Buildings with 3 to 4 storeys	34 kN/m^2
c) Buildings with more than 4 storeys	41 kN/m^2
d) Buildings of particularly stable construction irrespective of the number of storeys	28 kN/m^2

In the case of buildings with floors that are acted upon by a characteristic imposed action larger than 5·0 kN/m^2, the above values should be increased by the difference between the average imposed action on all storeys above the one concerned and 5·0 kN/m^2.

NOTE 1 — By storeys it is understood, every utilizable storey above the shelter.

NOTE 2 — By buildings of a particular stable construction it is understood, buildings in which the load-bearing structures are made from reinforced *in-situ* concrete.

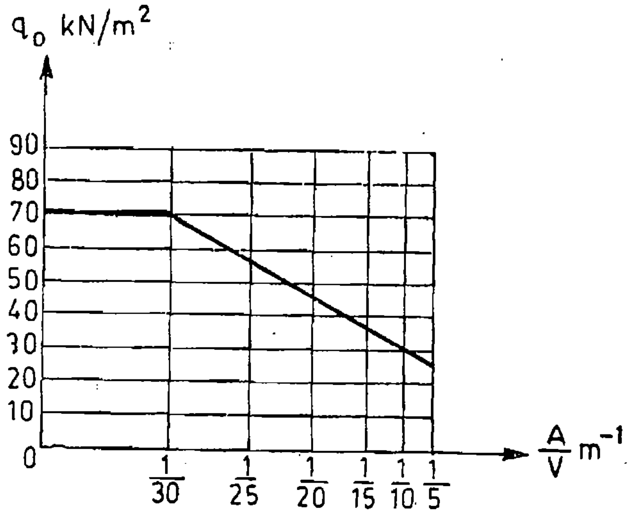

FIG. 4 SKETCH SHOWING RELATION BETWEEN PRESSURE AND TIME

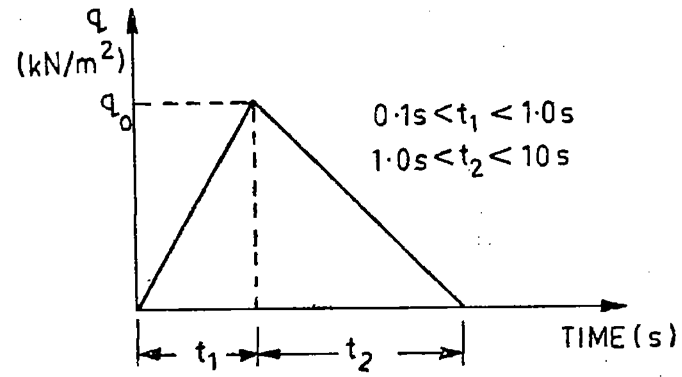

FIG. 5 SKETCH SHOWING TIME INTERVAL AND PRESSURE

6.4 Fire

6.4.1 *General* — Possible extraordinary loads during a fire may be considered as accidental actions. Examples are loads from people along escape routes and loads on another structure from structure failing because of a fire.

6.4.2 *Thermal Effect During Fire* — The thermal effect during fire may be determined from one of the following methods:

a) Time-temperature curve and the required fire resistance (minutes), or

b) Energy balance method.

If the thermal effect during fire is determined from energy balance method, the fire load is taken to be:

$$q = 12\ t_b$$

where

q = fire action (KJ per m² floor), and

t_b = required fire resistance (minutes) (*see* IS : 1642-1960*).

NOTE — The fire action is defined as the total quantity of heat produced by complete combustion of all combustible material in the fire compartment, inclusive of stored goods and equipment together with building structures and building materials.

7. OTHER LOADS

7.1 Other loads not included in the present code such as special loads due to technical process, moisture and shrinkage effects, etc, should be taken into account where stipulated by building design codes or established in accordance with the performance requirement of the structure.

8. LOAD COMBINATIONS

8.0 General — A judicious combination of the loads (specified in Parts 1 to 4 of this standard and earthquake), keeping in view the probability of:

a) their acting together, and

b) their disposition in relation to other loads and severity of stresses or deformations caused by combinations of the various loads is necessary to ensure the required safety and economy in the design of a structure.

8.1 Load Combinations — Keeping the aspect specified in **8.0**, the various loads should, therefore, be combined in accordance with the stipulations in the relevant design codes. In the absence of such recommendations, the following loading combinations, whichever combination produces the most unfavourable effect in the building, foundation or structural member concerned may be adopted (as a general guidance). It should also be recognized in load combinations that the simultaneous occurrence of maximum values of wind, earthquake, imposed and snow loads is not likely.

a) DL

b) $DL+IL$

c) $DL+WL$

d) $DL+EL$

e) $DL+TL$

f) $DL+IL+WL$

g) $DL+IL+EL$

*Code of practice for safety of buildings (general) : Materials and details of construction.

h) $DL+IL+TL$

j) $DL+WL+TL$

k) $DL+EL+TL$

m) $DL+IL+WL+TL$

n) $DL+IL+EL+TL$

(DL = dead load, IL = imposed load, WL = wind load, EL = earthquake load, TL = temperature load).

NOTE 1 — When snow load is present on roofs, replace imposed load by snow load for the purpose of above load combinations.

NOTE 2 — The relevant design codes shall be followed for permissible stresses when the structure is designed by working stress method and for partial safety factors when the structure is designed by limit state design method for each of the above load combinations.

NOTE 3 — Whenever imposed load (*IL*) is combined with earthquake load (*EL*), the appropriate part of imposed load as specified in IS : 1893-1984* should be used both for evaluating earthquake effect and for combined load effects used in such combination.

NOTE 4 — For the purpose of stability of the structure as a whole against overturning, the restoring moment shall be not less than 1·2 times the maximum overturning moment due to dead load plus 1·4 times the maximum overturning moment due to imposed loads. In cases where dead load provides the restoring moment, only 0·9 times the dead load shall be considered. The restoring moments due to imposed loads shall be ignored.

NOTE 5 — The structure shall have a factor against sliding of not less than 1·4 under the most adverse combination of the applied loads/forces. In this case, only 0·9 times the dead load shall be taken into account.

NOTE 6 — Where the bearing pressure on soil due to wind alone is less than 25 percent of that due to dead load and imposed load, it may be neglected in design. Where this exceeds 25 percent foundation may be so proportioned that the pressure due to combined effect of dead load, imposed load and wind load does not exceed the allowable bearing pressure by more than 25 percent. When earthquake effect is included, the permissible increase is allowable bearing pressure in the soil shall be in accordance with IS : 1893-1984*.

Reduced imposed load (*IL*) specified in Part 2 of this standard for the design of supporting structures should not be applied in combination with earthquake forces.

NOTE 7 — Other loads and accidental load combinations not included should be dealt with appropriately.

NOTE 8 — Crane load combinations are covered under/Part 2 of this standard (*see* **6.4** of Part 2 of this standard).

*Criteria for earthquake resistant design of structures (*fourth revision*).

(*Continued from page* 2)

Panel on Loads (Other than Wind Loads), BDC 37 : P3

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IS 875 (Part 3) : 2015

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भाग 3 हवा भार

(तीसरा पुनरीक्षण)

Design Loads (Other than Earthquake) for Buildings and Structures — Code of Practice

Part 3 Wind Loads

(Third Revision)

ICS 91.100.10

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Structural Safety Sectional Committee, CED 37

FOREWORD

This Indian Standard (Part 3) (Third Revision) was adopted by the Bureau of Indian Standards after the draft finalized by the Structural Safety Sectional Committee had been approved by the Civil Engineering Division Council.

A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each one of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in loading codes by way of laying down minimum design loads, which have to be assumed for dead loads, imposed loads, wind loads and other external loads, the structure would be required to bear. Strict conformity to loading standards, it is hoped, will not only ensures the structural safety of the buildings and structures which are being designed and constructed in the country and thereby reduce loss of life and property caused by unsafe structures, but also eliminates the wastage caused by assuming unnecessarily heavy loadings without proper assessment.

This standard was first published in 1957 for the guidance of civil engineers, designers and architects associated with the planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of the buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effect on structures, undertaken by the special Committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs, both covered and sloping were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

With the increased adoption of this standard, a number of comments were received on provision of live loads adopted for different occupancies. Subsequently the Committee recommended the formulation of this standard in the following five parts, during the second revision of IS 875 in 1987:

Part 1	Dead loads
Part 2	Imposed loads
Part 3	Wind loads
Part 4	Snow loads
Part 5	Special loads and load combinations

This standard (Part 3) deals with wind loads to be considered when designing buildings, structures and components thereof.

In this current revision, the Committee recommends the following modifications/inclusions by taking into account the recent improvements that have been made in the wind engineering descriptive, through R & D efforts nationally and internationally:

a) Aerodynamic roughness heights for individual terrain categories have been explicitly included, and are used to derive turbulence intensity and mean hourly wind speed profiles.
b) The previous classification of structures into B and C classes has been deleted and accordingly the modification factor, k_2 is renamed as terrain roughness and height factor.
c) The values of k_2 factor corresponding to previous class A type structure only, are retained in this standard.
d) An additional modification factor, termed as importance factor has been included for cyclonic regions.
e) Simple empirical expressions have been suggested for height variations of hourly mean wind speed and also turbulence intensity in different terrains.

(*Continued on third cover*)

Indian Standard

DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES — CODE OF PRACTICE

PART 3 WIND LOADS

(Third Revision)

1 SCOPE

1.1 This standard (Part 3) specifies wind forces and their effects (static and dynamic) that should be taken into account when designing buildings, structures and components thereof.

1.2 Wind speeds vary randomly both in time and space and hence assessment of wind loads and response predictions are very important in the design of several buildings and structures. A large majority of structures met with in practice do not however, suffer wind induced oscillations and generally do not require to be examined for the dynamic effects of wind. For such normal, short and heavy structures, estimation of loads using static wind analysis has proved to be satisfactory. The details of this method involving important wind characteristics such as the basic wind speeds, terrain categories, modification factors, wind pressure and force coefficients, etc, are given in **6** and **7**.

1.3 Nevertheless, there are various types of structures or their components such as some tall buildings, chimneys, latticed towers, cooling towers, transmission towers, guyed masts, communication towers, long span bridges, partially or completely solid faced antenna dish, etc, which require investigation of wind induced oscillations. The influence of dynamic velocity fluctuations on the along wind loads (drag loads) for these structures shall be determined using Gust Factor Method, included in **10**. A method for calculation of across wind response of tall buildings and towers is included in **10.3**.

1.4 This standard also applies to buildings or other structures during erection/construction and the same shall be considered carefully during various stages of erection/construction. In locations where the strongest winds and icing may occur simultaneously, loads on structural members, cables and ropes shall be calculated by assuming an ice covering based on climatic and local experience.

1.5 In the design of special structures, such as chimneys, overhead transmission line towers, etc, specific requirements as specified in the respective Codes shall be adopted in conjunction with the provisions of this Code as far as they are applicable. Some of the Indian Standards available for the design of special structures are:

IS No.	*Title*
4998 : 2015	Criteria for design of reinforced concrete chimneys : Part 1 Assessment of loads (*third revision*) (*under print*)
6533	Code of practice for design and construction of steel chimneys
(Part 1) : 1989	Mechanical aspects
(Part 2) : 1989	Structural aspects
5613 (Part 2/ Sec 1) :1985	Code of practice for design, installation and maintenance of overhead power lines : Part 2 Lines above 11 kV, and up to and including 220 kV, Section 1 Design
802 (Part 1/ Sec 1) : 201*	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 (*fourth revision*) (*under print*)
11504 : 1985	Criteria for structural design of reinforced concrete natural draught cooling towers
14732 : 2000	Guidelines for the evaluation of the response of occupants of fixed structures, especially buildings and off-shore structures, to low-frequency horizontal motion (0.063 to 1 Hz)

NOTES

1 This standard does not apply to buildings or structures with unconventional shapes, unusual locations, and abnormal environmental conditions that have not been covered in this Code. Special investigations are necessary in such cases to establish wind loads and their effects. Wind tunnel studies may also be required in such situations.

2 In the case of tall structures with unsymmetrical geometry, the designs may have to be checked for torsional effects due to wind pressure.

2 REFERENCES

The following standard contains provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was 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 edition of the standard indicated.

IS No.	*Title*
15498 : 2004	Guidelines for improving the cyclonic resistance of low rise houses and other buildings/structures

3 NOTATIONS

3.1 The following notations shall be followed unless otherwise specified in relevant clauses. Notations have been defined in the text at their first appearance. A few of the notations have more than one definition, having been used for denoting different variables:

A = surface area of a structure or part of a structure;

A_e = effective frontal area;

A_z = the effective frontal area of the building at height z;

b = breadth of a structure or structural member normal to the wind stream in the horizontal plane;

B_s = background factor;

C_d = drag coefficient;

$C_{fd'}$ = force coefficient;

C_{fn} = normal force coefficient;

C_{ft} = transverse force coefficient;

C_f' = frictional drag coefficient;

C_p = pressure coefficient;

C_{pe} = external pressure coefficient;

C_{pi} = internal pressure coefficient;

C_{fs} = cross-wind force spectrum coefficient;

$C_{f,z}$ = drag force coefficient of the building corresponding to the area A_z;

C = coefficient, which depends on θ_s, used in the evaluation of k_3 factor;

d = depth of a structure or structural member parallel to wind stream in the horizontal plane;

d_w = wake width;

D = diameter of cylinder or sphere;

E = wind energy factor;

F_z = along wind load on the building/structure at any height z;

F = force normal to the surface;

f_a = first mode natural frequency of the building/structure in along wind direction in Hz;

f_c = first mode natural frequency of the building/structure in across wind direction in Hz;

f_s = vortex shedding frequency;

F_n = normal force;

F_t = transverse force;

F' = frictional force;

G = gust factor;

g_R = peak factor for resonant response;

g_v = peak factor for upwind velocity fluctuations;

h = height of structure above mean ground level;

h_x = height of development of a velocity profile at a distance x down wind from a change in terrain category;

H_s = height factor for resonant response;

H = height above mean ground level on the topography feature;

I = turbulence intensity;

$I_{h,i}$ = turbulence intensity at height h in terrain category i;

$I_{z,i}$ = turbulence intensity at height z in terrain category i;

IF = interference factor;

k = mode shape power exponent;

k_1, k_2, k_3, k_4 = wind speed modification factors;

$\bar{k}_{2,i}$ = hourly mean wind speed factor;

K = force coefficient multiplication factor for individual members of finite length;

K_a = area averaging factor;

K_c = combination factor;

K_d = wind directionality factor;

l = length of the member or larger horizontal dimension of a building;

L = actual length of upwind slope;

L_e = effective length of upwind slope;

L_h = integral turbulence length scale at the height h;

m_0 = average mass per unit height of the structure;

M_a = design peak along wind base bending moment;

M_c = design peak across wind base bending moment;

N = effective reduced frequency;

p_d = design wind pressure;

p_z = design wind pressure at height z;

$\overline{p}_d$ = design hourly mean wind pressure corresponding to $\overline{V}_{z,d}$;

p_e = external pressure;

p_i = internal pressure;

r = roughness factor which is twice the longitudinal turbulence intensity at height h;

R_e = Reynolds number;

s = level on a building/structure for the evaluation of along wind load effects;

s_0 = factor, which depends on H and X, used for the evaluation of k_3 factor;

S_t = strouhal number;

S = size reduction factor;

V_b = regional basic wind speed;

V_z = design wind speed at height z;

$\overline{V}_d$ = design hourly mean wind speed;

$\overline{V}_{d,z}$ = design hourly mean wind speed at height z;

$\overline{V}_{z,H}$ = hourly mean wind speed at height z;

w = lesser horizontal dimension of a building or a structural member;

w' = bay width in multi-bay building;

$\hat{\ddot{x}}$ = peak acceleration at the top of the building/structure in along wind direction, in m/s^2;

x = distance down wind from a change in terrain category;

X = distance from the summit or crest of topography feature relative to the effective length, L_e;

$\hat{\ddot{y}}$ = peak acceleration at the top of the building/structure in across wind direction;

z = a height or distance above the ground;

$z_{0,i}$ = aerodynamic roughness height for ith terrain;

Z = effective height of the topography feature;

α = inclination of the roof to the horizontal;

β = damping coefficient of the building/structure;

η = shielding factor;

ϕ = factor to account for the second order turbulence intensity;

Φ = solidity ratio;

Φ_e = effective solidity ratio;

ε = average height of the surface roughness;

θ_s = upwind slope of the topography feature in the wind direction; and

θ = wind angle from a given axis.

4 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

4.1 Angle of Attack — An angle between the direction of wind and a reference axis of the structure.

4.2 Breadth — It means horizontal dimension of the building measured normal to the direction of wind.

NOTE — Breadth and depth are dimensions measured in relation to the direction of wind, whereas length and width are dimensions related to the plan.

4.3 Depth — It means the horizontal dimension of the building measured in the direction of the wind.

4.4 Developed Height — It is the height of upward penetration of the velocity profile in a new terrain. At large fetch lengths, such penetration reaches the gradient height, above which the wind speed may be taken to be constant. At lesser fetch lengths, a velocity profile of a smaller height but similar to that of the fully developed profile of that terrain category has to be taken, with the additional provision that the velocity at the top of this shorter profile equal to that of the un-penetrated earlier velocity profile at that height.

4.5 Effective Frontal Area — The projected area of the structure normal to the direction of wind.

4.6 Element of Surface Area — The area of surface over which the pressure coefficient is taken to be constant.

4.7 Force Coefficient — A non-dimensional coefficient such that the total wind force on a body is the product of the force coefficient, the dynamic pressure of the incident design wind speed and the reference area over which the force is required.

NOTE — When the force is in the direction of the incident wind, the non-dimensional coefficient will be called as 'drag coefficient'. When the force is perpendicular to the direction of incident wind, the non-dimensional coefficient will be called as 'lift coefficient'.

4.8 Ground Roughness — The nature of the earth's surface as influenced by small scale obstructions such as trees and buildings (as distinct from topography) is called ground roughness.

4.9 Gust — A positive or negative departure of wind speed from its mean value, lasting for not more than, say, 2 min over a specified interval of time.

4.10 Peak Gust — A peak gust or peak gust speed is the wind speed associated with the maximum amplitude.

4.11 Fetch Length — It is the distance measured along the wind from a boundary at which a change in the type of terrain occurs. When the changes in terrain types are encountered (such as, the boundary of a town or city, forest, etc), the wind profile changes in character but such changes are gradual and start at ground level, spreading or penetrating upwards with increasing fetch length.

4.12 Gradient Height — It is the height above the mean ground level at which the gradient wind blows as a result of balance among pressure gradient force, coriolis force and centrifugal force. For the purpose of this Code, the gradient height is taken as the height above the mean ground level, above which the variation of wind speed with height need not be considered.

4.13 High Rise Building (Tall Building) — A building with a height more than or equal to 50 m or having a height to smaller dimension more than 6.

4.14 Low Rise Building — A building having its height less than 20 m.

4.15 Mean Ground Level — The mean ground level is the average horizontal plane of the area enclosed by the boundaries of the structure.

4.16 Pressure Coefficient — It is the ratio of the difference between the pressure acting at a point on the surface and the static pressure of the incident wind to the design wind pressure, where the static and design wind pressures are determined at the height of the point considered after taking into account the geographical location, terrain conditions and shielding effect. The pressure coefficient is also equal to $[1-(V_p/V_z)^2]$, where V_p is the actual wind speed at any point on the structure at a height corresponding to that of V_z.

NOTE — Positive sign of the pressure coefficient indicates pressure acting towards the surface and negative sign indicates pressure acting away from the surface.

4.17 Return Period — It is the number of years, reciprocal of which gives the probability of extreme wind exceeding a given wind speed in anyone year.

4.18 Shielding Effect — Shielding effect or shielding refers to the condition where wind has to pass along some structure(s) or structural element(s) located on the upstream wind side, before meeting the structure or structural element under consideration. A factor called 'shielding factor' is used to account for such effects in estimating the force on the shielded structures.

4.19 Suction — It means pressure less than the atmospheric (static) pressure and is taken to act away from the surface.

4.20 Solidity Ratio — It 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 boundary of the frame normal to the wind direction.

NOTE — Solidity ratio is to be calculated for individual frames.

4.21 Terrain Category — It means the characteristics of the surface irregularities of an area which arise from natural or constructed features. The categories are numbered in increasing order of roughness.

4.22 Topography — The nature of the earth's surface as influenced by the hill and valley configurations.

4.23 Velocity Profile — The variation of the horizontal component of the atmospheric wind speed at different heights above the mean ground level is termed as velocity profile.

5 GENERAL

5.1 Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind; vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 m above ground.

5.2 Very strong winds (more than 80 kmph) are generally associated with cyclonic storms, thunderstorms, dust storms or vigorous monsoons. A feature of the cyclonic storms over the Indian area is that they rapidly weaken after crossing the coasts and move as depressions/lows inland. The influence of a severe storm after striking the coast does not; in general exceed about 60 km, though sometimes, it may extend even up to 120 km. Very short duration hurricanes of very high wind speeds called Kal Baisaki or Norwesters occur fairly frequently during summer months over North East India.

5.3 The wind speeds recorded at any locality are extremely variable and in addition to steady wind at any time, there are effects of gusts which may last for a few seconds. These gusts cause increase in air pressure but their effect on stability of the building may not be so important; often, gusts affect only part of the building and the increased local pressures may be more than balanced by a momentary reduction in the pressure elsewhere. Because of the inertia of the building, short period gusts may not cause any appreciable increase in stress in main components of the building although the walls, roof sheeting and individual cladding units (glass panels) and their supporting members such as purlins, sheeting rails and glazing bars may be more seriously affected. Gusts can also be extremely important for design of structures with high slenderness ratios.

5.4 The liability of a building to high wind pressures depends not only upon the geographical location and proximity of other obstructions to air flow but also upon the characteristics of the structure itself.

5.5 The effect of wind on the structure as a whole is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply.

5.6 The stability calculations as a whole shall be done considering the combined effect, as well as separate effects of imposed loads and wind loads on vertical surfaces, roofs and other part of the building above general roof level.

5.7 Buildings shall also be designed with due attention to the effects of wind on the comfort of people inside and outside the buildings.

6 WIND SPEED

6.1 Nature of Wind in Atmosphere

In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to maximum at a height called the gradient height. There is usually a slight change in direction (Ekman effect) but this is ignored in this standard. The variation with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this average value. The average value depends on the average time employed in analyzing the meteorological data and this averaging time varies from few seconds to several minutes. The magnitude of fluctuating component of the wind speed which is called gust, depends on the averaging time. In general, smaller the averaging interval, more is the magnitude of the gust speed.

6.2 BASIC WIND SPEED

Figure 1 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 s and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 1 have been worked out for a 50 year return period. Basic wind speed for some important cities/towns is also given in Annex A.

6.3 Design Wind Speed (V_z)

The basic wind speed (V_b) for any site shall be obtained from Fig. 1 and shall be modified to include the following effects to get design wind speed, V_z at any height z, for the chosen structure:

a) Risk level,
b) Terrain roughness and height of structure,
c) Local topography, and
d) Importance factor for the cyclonic region.

It can be mathematically expressed as follows:

$$V_z = V_b k_1 k_2 k_3 k_4$$

where

V_z = design wind speed at height z, in m/s;

k_1 = probability factor (risk coefficient) (*see* **6.3.1**);

k_2 = terrain roughness and height factor (*see* **6.3.2**);

k_3 = topography factor (*see* **6.3.3**); and

k_4 = importance factor for the cyclonic region (*see* **6.3.4**).

NOTE — Wind speed may be taken as constant up to a height of 10 m. However, pressures for buildings less than 10 m high may be reduced by 20 percent for evaluating stability and design of the framing.

6.3.1 *Risk Coefficient (k_1 Factor)* — Figure 1 gives basic wind speeds for terrain Category 2 as applicable at 10 m above ground level based on 50 years mean return period. The suggested life period to be assumed in design and the corresponding k_1 factors for different class of structures for the purpose of design are given in Table 1. In the design of buildings and structures, a regional basic wind speed having a mean return period of 50 years shall be used except as specified in the note of Table 1.

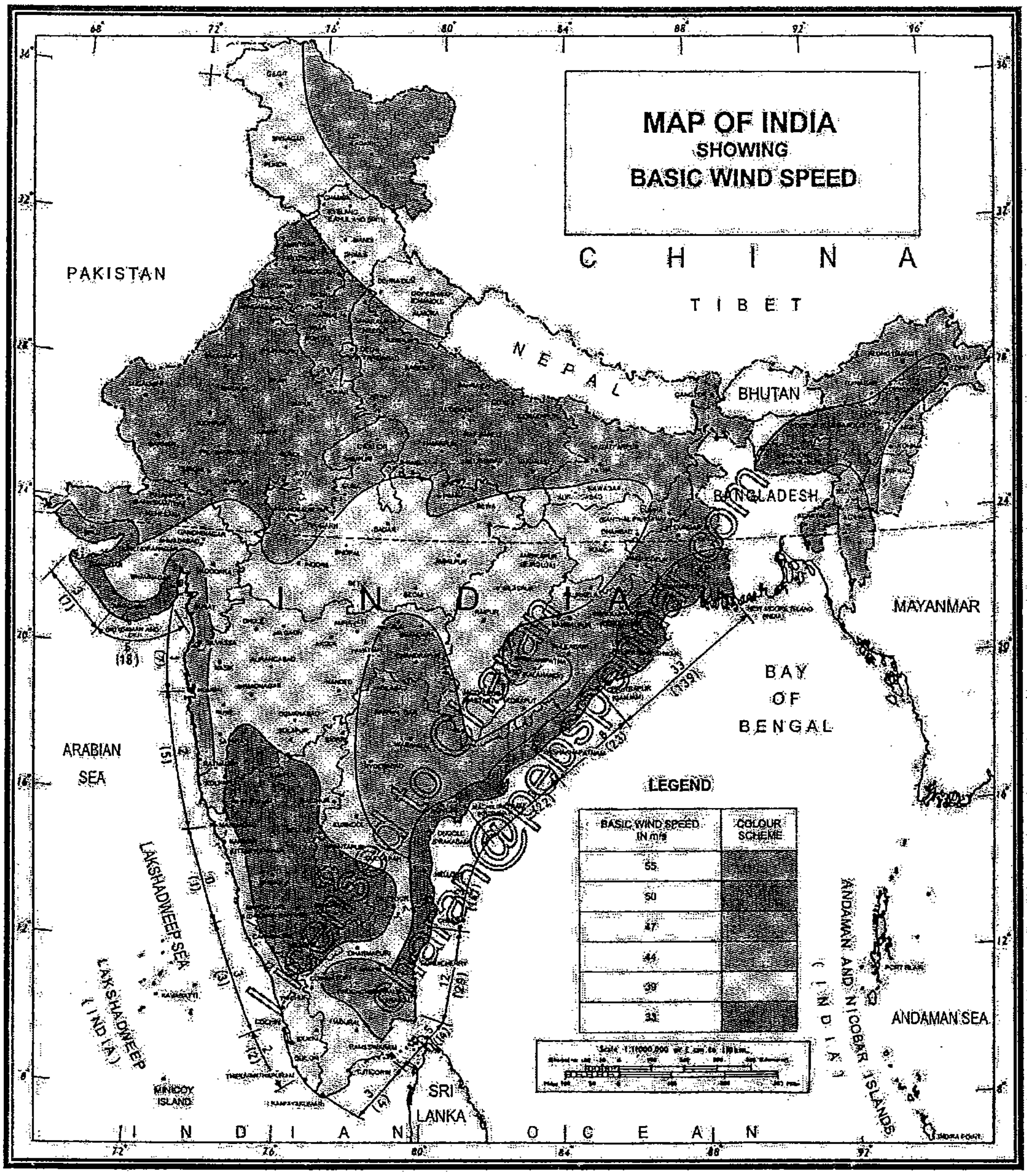
6.3.2 *Terrain, Height Factor (k_2 Factor)*

6.3.2.1 *Terrain*

Selection of terrain categories shall be made with due regard to the effect of obstructions which constitute the ground surface roughness. The terrain category used in the design of a structure may vary depending on the direction of wind under consideration. Wherever sufficient meteorological information is available about the nature of wind direction, the orientation of any building or structure may be suitably planned.

Terrain in which a specific structure stands shall be assessed as being one of the following terrain categories:

a) *Category 1* — Exposed open terrain with few or no obstructions and in which the average



Based upon Survey of India Outline Map printed in 1993.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

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

height of any object surrounding the structure is less than 1.5 m. The equivalent aerodynamic roughness height, ($z_{0,1}$) for this terrain is 0.002 m. Typically this category represents open sea-coasts and flat plains without trees.

b) *Category 2* — Open terrain with well scattered obstructions having heights generally between 1.5 m and 10 m. The equivalent aerodynamic roughness height, ($z_{0,2}$) for this terrain is 0.02 m.

This is the criterion for measurement of regional basic wind speeds and represents airfields, open park lands and undeveloped sparsely built-up outskirts of towns and suburbs. Open land adjacent to sea coast may also be classified as Category 2 due to roughness of large sea waves at high winds.

c) *Category 3* — Terrain with numerous closely spaced obstructions having the size of buildings/structures up to 10 m in height with or without a few isolated tall structures. The equivalent aerodynamic roughness height, ($z_{0,3}$) for this terrain is 0.2 m.

This category represents well wooded areas, and shrubs, towns and industrial areas full or partially developed.

It is likely that the, next higher category than this will not exist in most design situations

Table 1 Risk Coefficients for Different Classes of Structures in Different Wind Speed Zones
(*Clause* 6.3.1)

Sl No.	Class of Structure	Mean Probable Design Life of Structure in Years	k_1 Factor for Basic Wind Speed m/s					
			33	39	44	47	50	55
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	All general buildings and structures	50	1.0	1.0	1.0	1.0	1.0	1.0
ii)	Temporary sheds, structures such as those used during construction operations (for example, formwork and false work), structures during construction stages and boundary walls	5	0.82	0.76	0.73	0.71	0.70	0.67
iii)	Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings	25	0.94	0.92	0.91	0.90	0.90	0.89
iv)	Important buildings and structures such as hospitals communication buildings/towers, power plant structures	100	1.05	1.06	1.07	1.07	1.08	1.08

NOTE — The factor k_1 is based on statistical concepts which take into account the degree of reliability required and period of time in years during which these will be exposed to wind, that is, life of the structure. Whatever wind speed is adopted for design purposes, there is always a probability (however small) that it may exceed in a storm of exceptional violence; more the period of years over which there is exposure to the wind, more is the probability. Larger return periods ranging from 100 to 1 000 years (implying lower risk level) in association with larger periods of exposure may have to be selected for exceptionally important structures, such as, nuclear power reactors and satellite communication towers. Equation given below may be used in such cases to estimate k_1 factors for different periods of exposure and chosen probability of exceedance (risk level). The probability level of 0.63 is normally considered sufficient for design of buildings and structures against wind effects and the values of k_1 corresponding to this risk level are given above.

$$k_1 = \frac{X_{N,P}}{X_{50,0.63}} = \frac{A - B\left[\ln\left\{-\frac{1}{N}\ln(1-P_N)\right\}\right]}{A+4B}$$

where

N = mean probable design life of structure in years;

P_N = risk level in N consecutive years (probability that the design wind speed is exceeded at least once in N successive years), nominal value = 0.63;

$X_{N,P}$ = extreme wind speed for given values of N and P_N; and

$X_{50,0.63}$ = extreme wind speed for N = 50 years and P_N = 0.63

A and B have the following values for different basic wind speed zones:

Zone m/s	A* m/s	B* m/s
33	23.1 (83.2)	2.6 (9.2)
39	23.3 (84.0)	3.9 (14.0)
44	24.4 (88.0)	5.0 (18.0)
47	24.4 (88.0)	5.7 (20.5)
50	24.7 (88.8)	6.3 (22.8)
55	25.2 (90.8)	7.6 (27.3)

* Values of A and B, in kmph, are given in bracket.

and that selection of a more severe category will be deliberate.

d) *Category 4* — Terrain with numerous large high closely spaced obstructions. The equivalent aerodynamic roughness height, ($z_{0,4}$) for this terrain is 2.0 m.

This category represents large city centers, generally with obstructions above 25 m and well developed industrial complexes.

6.3.2.2 *Variation of wind speed with height in different terrains (k_2 factor)*

Table 2 gives multiplying factors (k_2) by which the basic wind speed given in Fig. 1 shall be multiplied to obtain the wind speed at different heights, in each terrain category.

Table 2 Factors to Obtain Design Wind Speed Variation with Height in Different Terrains

(*Clause* 6.3.2.2)

Sl No.	Height z m	Terrain and Height Multiplier (k_2)			
		Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	10	1.05	1.00	0.91	0.80
ii)	15	1.09	1.05	0.97	0.80
iii)	20	1.12	1.07	1.01	0.80
iv)	30	1.15	1.12	1.06	0.97
v)	50	1.20	1.17	1.12	1.10
vi)	100	1.26	1.24	1.20	1.20
vii)	150	1.30	1.28	1.24	1.24
viii)	200	1.32	1.30	1.27	1.27
ix)	250	1.34	1.32	1.29	1.28
x)	300	1.35	1.34	1.31	1.30
xi)	350	1.35	1.35	1.32	1.31
xii)	400	1.35	1.35	1.34	1.32
xiii)	450	1.35	1.35	1.35	1.33
xiv)	500	1.35	1.35	1.35	1.34

NOTE — For intermediate values of height z in a given terrain category, use linear interpolation.

6.3.2.3 *Terrain categories in relation to the direction of wind*

The terrain category used in the design of a structure may vary depending on the direction of wind under consideration. Where sufficient meteorological information is available, the basic wind speed may be varied for specific wind direction.

6.3.2.4 *Changes in terrain categories*

The velocity profile for a given terrain category does not develop to full height immediately with the commencement of that terrain category but develop gradually to height (h_x) which increases with the fetch or upwind distance (x).

a) Fetch and developed height relationship — The relation between the developed height (h_x) and the fetch (x) for wind-flow over each of the four terrain categories may be taken as given in Table 3.

b) For structures of heights more than the developed height (h_x) in Table 3, the velocity profile may be determined in accordance with the following:
   1) The less or least rough terrain, or
   2) The method described in Annex B.

Table 3 Fetch and Developed Height Relationship

(*Clause* 6.3.2.4)

Sl No.	Fetch (x) km	Developed Height, h_x m			
		Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	0.2	12	20	35	60
ii)	0.5	20	30	35	95
iii)	1	25	45	80	130
iv)	2	35	65	110	190
v)	5	60	100	170	300
vi)	10	80	140	250	450
vii)	20	120	200	350	500
viii)	50	180	300	400	500

6.3.3 *Topography (k_3 Factor)*

The basic wind speed V_b given in Fig. 1 takes into account the general level of site above sea level. This does not allow for local topographic features such as hills, valleys, cliffs, escarpments, or ridges which can significantly affect wind speed in their vicinity. The effect of topography is to accelerate wind near the summits of hills or crests of cliffs, escarpments or ridges and decelerate the wind in valleys or near the foot of cliffs, steep escarpments, or ridges.

6.3.3.1 The effect of topography shall be significant at a site when the upwind slope (θ) is more than about 3°, and below that, the value of k_3 may be taken to be equal to 1.0. The value of k_3 is confined in the range of 1.0 to 1.36 for slopes more than 3°. A method of evaluating the value of k_3 for values more than 1.0 is given in Annex C. It may be noted that the value of k_3 varies with height above ground level, at a maximum near the ground, and reducing to 1.0 at higher levels.

6.3.4 *Importance Factor for Cyclonic Region (k_4)*

The east coast of India is relatively more vulnerable for occurrences of severe cyclones. On the west coast, Gujarat is vulnerable for severe cyclones. Studies of wind speed and damage to buildings and structures point to the fact that the speeds given in the basic wind speed map are often exceeded during the cyclones. The effect of cyclonic storms is largely felt in a belt of approximately 60 km width at the coast. In order to ensure better safety of structures in this region (60 km wide on the east coast as well as on the Gujarat Coast), the following values of k_4 (as recommended in IS 15498) are stipulated as applicable according to the importance of the structure:

	k_4
Structures of post-cyclone importance for emergency services (such as cyclone shelters, hospitals, schools, communication towers, etc)	1.30
Industrial structures	1.15
All other structures	1.00

6.4 Hourly Mean Wind Speed

The hourly mean wind speed at height z, for different terrains can be obtained as

$$\overline{V}_{z,H} = \overline{k}_{2,i} V_b$$

where

$\overline{k}_{2,i}$ = hourly mean wind speed factor for terrain category 1

$$= 0.1423 \left[\ln\left(\frac{z}{z_{0,i}}\right) \right] (z_{0,i})^{0.0706}$$

The design hourly mean wind speed at height z can be obtained as:

$$\overline{V}_{z,d} = \overline{V}_{z,H} k_1 k_3 k_4$$

$$= \overline{V}_b k_1 \overline{k}_{2,i} k_3 k_4$$

6.5 Turbulence Intensity

The turbulence intensity variations with height for different terrains can be obtained using the relations given below:

a) *Terrain category 1*

$$I_{z,1} = 0.3507 - 0.0535 \log_{10}\left(\frac{z}{z_{0,1}}\right)$$

b) *Terrain category 2*

$$I_{z,2} = I_{z,1} + \frac{1}{7}\left(I_{z,4} - I_{z,1}\right)$$

c) *Terrain category 3*

$$I_{z,3} = I_{z,1} + \frac{3}{7}\left(I_{z,4} - I_{z,1}\right)$$

d) *Terrain category 4*

$$I_{z,4} = 0.466 - 0.135\,8 \log_{10}\left(\frac{z}{z_{0,4}}\right)$$

6.6 Off Shore Wind Velocity

Cyclonic storms form far away from the sea coast and gradually reduce in speed as they approach the sea coast. Cyclonic storms generally extend up to about 60 km inland after striking the coast. Their effect on land is already reflected in basic wind speeds specified in Fig. 1. The influence of wind speed off the coast up to a distance of about 200 km may be taken as 1.15 times the value on the nearest coast in the absence of any definite wind data. The factor 1.15 shall be used in addition to k_4.

7 WIND PRESSURES AND FORCES ON BUILDINGS/STRUCTURES

7.1 General

The wind load on a building shall be calculated for:

a) Building as a whole,

b) Individual structural elements as roofs and walls, and

c) Individual cladding units including glazing and their fixings.

7.2 Design Wind Pressure

The wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind speed:

$$p_z = 0.6\, V_z^2$$

where

p_z = wind pressure at height z, in N/m^2; and

V_z = design wind speed at height z, in m/s.

The design wind pressure p_d can be obtained as,

$$p_d = K_d\, K_a\, K_c\, p_z$$

where

K_d = wind directionality factor,

K_a = area averaging factor, and

K_c = combination factor (*see* **7.3.3.13**).

The value of p_d, however shall not be taken as less than 0.70 p_z.

NOTES

1 The coefficient 0.6 (in SI units) in the above formula depends on a number of factors and mainly on the atmospheric pressure and air temperature. The value chosen corresponds to the average Indian atmospheric conditions.

2 K_d should be taken as 1.0 when considering local pressure coefficients.

7.2.1 *Wind Directionality Factor, K_d*

Considering the randomness in the directionality of wind and recognizing the fact that pressure or force coefficients are determined for specific wind directions, it is specified that for buildings, solid signs, open signs, lattice frameworks, and trussed towers (triangular, square, rectangular) a factor of 0.90 may be used on the design wind pressure. For circular or near-circular forms this factor may be taken as 1.0.

For the cyclone affected regions also the factor K_d shall be taken as 1.0.

7.2.2 *Area Averaging Factor, K_a*

Pressure coefficients given in **7.3** are a result of averaging the measured pressure values over a given area. As the area becomes larger, the correlation of measured values decrease and *vice-versa*. The decrease in pressures due to larger areas may be taken into account as given in Table 4.

Table 4 Area Averaging Factor (K_a)
(*Clause* 7.2.2)

Sl No.	Tributary Area (A) m^2	Area Averaging Factor (Ka)*
(1)	(2)	(3)
i)	≤10	1.0
ii)	25	0.9
iii)	≥100	0.8

* Linear interpolation for intermediate values of a is permitted.

7.2.2.1 *Tributary area*

a) *Overall structure* — For evaluating loads on frames the tributary area shall be taken as the centre to centre distances between frames multiplied by the individual panel dimension in the other direction together with overall pressure coefficients.

b) *Individual elements* — For beam type elements, purlins, etc, the tributary area shall be taken as effective span multiplied by spacing. The effective span is the actual span for mid span and cantilever load effects; and half the sum of adjacent spans for support moments and reactions.

For plate type elements, the area of individual plates between supports is taken as the tributary area.

For glass cladding, individual pane area of glass is the tributary area.

7.3 Pressure Coefficients

The pressure coefficients are always given for a particular surface or part of the surface of a building. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (C_p) and the design wind pressure at the height of the surface from the ground. The average values of these pressure coefficients for some building shapes are given in **7.3.2** and **7.3.3**.

Average values of pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building, the total load should be calculated for each of the critical directions shown from all quadrants. Where considerable variation of pressure occurs over a surface, it has been sub-divided and mean pressure coefficients given for each of its several parts.

In addition, areas of high local suction (negative pressure concentration) frequently occurring near the edges of walls and roofs are separately shown. Coefficients for the local effects should only be used for calculation of forces on these local areas affecting roof sheeting, glass panels, and individual cladding units including their fixtures. They should not be used for calculating force on entire structural elements such as roof, walls or structure as a whole.

NOTES

1 The pressure coefficients given in different tables have been obtained mainly from measurements on models in wind tunnels, and the great majority of data available has been obtained in conditions of relatively smooth flow. Where sufficient field data exist as in the case of rectangular buildings, values have been obtained to allow for turbulent flow.

2 In recent years, wall glazing and cladding design has been a source of major concern. Although of less consequence than the collapse of main structures, damage to glass can be hazardous and cause considerable financial losses.

3 For pressure coefficients for structures not covered here, reference may be made to specialist literature on the subject or advice may be sought from specialists in the subject.

7.3.1 *Wind Load on Individual Members*

When calculating the wind load on individual structural elements such as roofs and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite faces of such elements or units. For clad structures, it is, therefore, necessary to know the internal pressure as well as the external pressure. Then the wind load, F, acting in a direction normal to the individual structural element or cladding unit is:

$$F = (C_{pe} - C_{pi})\, A\, p_d$$

where

C_{pe} = external pressure coefficient,

C_{pi} = internal pressure coefficient,

A = surface area of structural element or cladding unit, and

p_d = design wind pressure.

NOTES

1 If the surface design pressure varies with height, the surface areas of the structural element may be sub-divided so that the specified pressures are taken over appropriate areas.

2 Positive wind load indicates the force acting towards the structural element and negative away from it.

7.3.2 *Internal Pressure Coefficients*

Internal air pressure in a building depends upon the degree of permeability of cladding to the flow of air. The internal air pressure may be positive or negative depending on the direction of flow of air in relation to openings in the buildings.

7.3.2.1 In the case of buildings where the claddings permit the flow of air with openings not more than about 5 percent of the wall area but where there are no large openings, it is necessary to consider the possibility of the internal pressure being positive or negative. Two design conditions shall be examined, one with an internal pressure coefficient of +0.2 and another with an internal pressure coefficient of –0.2.

The internal pressure coefficient is algebraically added to the external pressure coefficient and the analysis which indicates greater distress of the member shall be adopted. In most situations a simple inspection of the sign of external pressure will at once indicate the proper sign of the internal pressure coefficient to be taken for design.

NOTE — The term normal permeability relates to the flow of air commonly afforded by claddings not only through open windows and doors, but also through the slits round the closed windows and doors and through chimneys, ventilators and through the joints between roof coverings, the total open area being less than 5 percent of area of the walls having the openings.

7.3.2.2 *Buildings with medium and large openings*

Buildings with medium and large openings may also exhibit either positive or negative internal pressure depending upon the direction of wind. Buildings with medium openings between about 5 and 20 percent of wall area shall be examined for an internal pressure coefficient of +0.5 and later with an internal pressure coefficient of –0.5, and the analysis which produces greater distress of the member shall be adopted. Buildings with large openings, that is, openings larger than 20 percent of the wall area shall be examined once with an internal pressure coefficient of +0.7 and again with an internal pressure coefficient of –0.7, and the analysis which produces greater distress of the member shall be adopted.

Buildings with one open side or opening exceeding 20 percent of wall area may be assumed to be subjected to internal positive pressure or suction similar to those of buildings with large openings. A few examples of buildings with one side openings are shown in Fig. 2 indicating values of internal pressure coefficients with respect to the direction of wind.

7.3.3 *External Pressure Coefficients*

7.3.3.1 *Walls*

The average external pressure coefficient for the walls of clad buildings of rectangular plan shall be as given in Table 5. In addition, local pressure concentration coefficients are also given.

7.3.3.2 *Pitched, hipped and mono slope roofs of clad buildings*

The average external pressure coefficients and pressure concentration coefficients for pitched roofs of rectangular clad building shall be as given in Table 6. Where no pressure concentration coefficients are given, the average coefficients shall apply. The pressure coefficients on the under-side of any overhanging roof shall be taken in accordance with **7.3.3.5**.

For mono slope roofs of rectangular clad buildings, the average pressure coefficient and pressure concentration coefficient for mono slope (lean-to) roofs of rectangular clad buildings shall be as given in Table 7.

NOTES

1 The pressure concentration shall be assumed to act outward (suction pressure) at the ridges, eaves, cornices and 90° corners of roofs.

2 The pressure concentration shall not be included with the net external pressure when computing overall load.

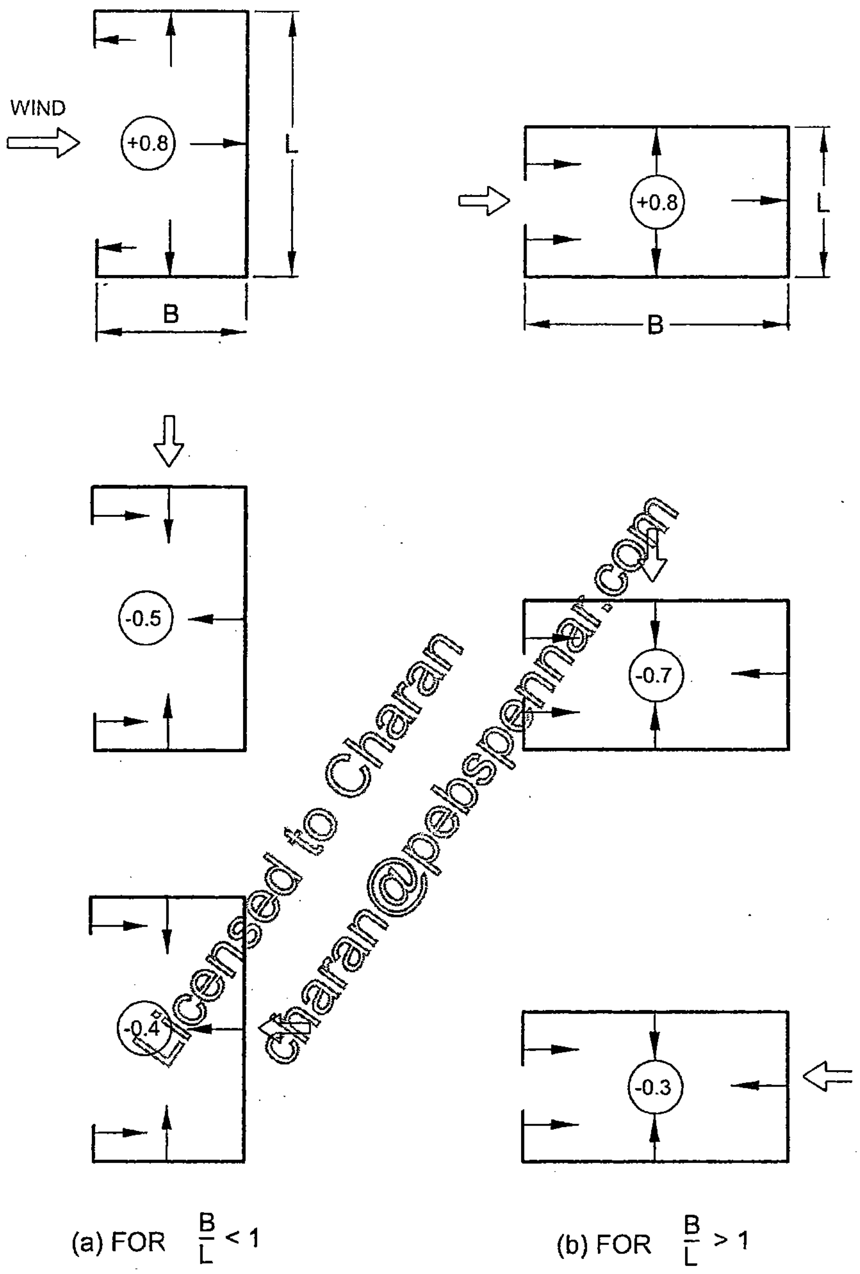
3 For hipped roofs, pressure coefficients (including local values) may be taken on all the four slopes, as appropriate from Table 6, and be reduced by 20 percent for the hip slope.

7.3.3.3 *Canopy roofs with* ($1/4 < h/w < 1$ *and* $1 < L/w < 3$)

The pressure coefficients are given in Tables 8 and 9 separately for mono-pitch and double pitch canopy roofs such as open-air parking garages, shelter areas, outdoor areas, railway platforms, stadia and theatres. The coefficients take into account of the combined effect of the wind exerted on and under the roof for all wind directions; the resultant is to be taken normal to the canopy. Where the local coefficients overlap, the greater of the two given values should be taken. However, the effect of partial closures of one side and or both sides, such as those due to trains, buses and stored materials shall be foreseen and taken into account.

The solidity ratio f is equal to the area of obstructions under the canopy divided by the gross area under the canopy, both areas normal to the wind direction. f = 0 represents a canopy with no obstructions underneath. f = 1 represents the canopy fully blocked with contents to the downwind eaves. Values of C_p for intermediate solidities may be linearly interpolated between these two extremes, and apply upwind of the position of maximum blockage only. For downwind of the position of maximum blockage, the coefficients for f = 0 may be used.

In addition to the forces due to the pressures normal to the canopy, there will be horizontal loads on the canopy



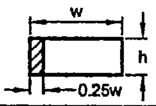
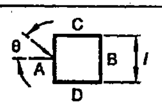
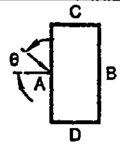
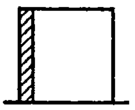
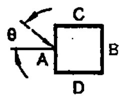
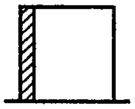
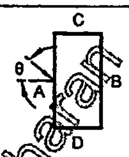
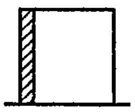
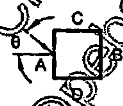
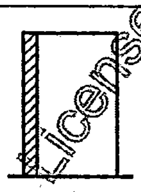
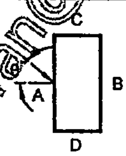
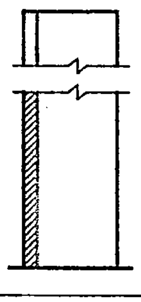
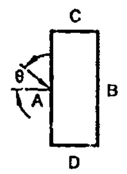
(c) FOR $\frac{B}{L}$ = 1, USE AVERAGE VALUES

(ARROWS INDICATE DIRECTION OF WIND FLOW)

FIG. 2 BUILDINGS WITH ONE SIDE OPENINGS

Table 5 External Pressure Coefficients (C_{pe}) for Walls of Rectangular Clad Buildings

(*Clause* 7.3.3.1)

BUILDING HEIGHT RATIO	BUILDING PLAN RATIO	ELEVATION	PLAN	WIND ANGLE θ	C_{pe} FOR SURFACE A	C_{pe} FOR SURFACE B	C_{pe} FOR SURFACE C	C_{pe} FOR SURFACE D	LOCAL C_{pe}
				Degrees					
$\frac{h}{w} \le \frac{1}{2}$	$1 < \frac{l}{w} \le \frac{3}{2}$			0 90	+0.7 -0.5	-0.2 -0.5	-0.5 +0.7	-0.5 -0.2	-0.8
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+0.7 -0.5	-0.25 -0.5	-0.6 +0.7	-0.6 -0.1	-1.0
$\frac{1}{2} < \frac{h}{w} \le \frac{3}{2}$	$1 \le \frac{l}{w} \le \frac{3}{2}$			0 90	+0.7 -0.6	-0.25 -0.6	-0.6 +0.7	-0.6 -0.25	-1.1
	$\frac{3}{2} \le \frac{l}{w} < 4$			0 90	+0.7 -0.5	-0.3 -0.5	-0.7 +0.7	-0.7 -0.1	-1.1
$\frac{3}{2} < \frac{h}{w} < 6$	$1 < \frac{l}{w} \le \frac{3}{2}$			0 90	+0.8 -0.8	-0.25 -0.8	-0.8 +0.8	-0.8 -0.25	-1.2
	$\frac{3}{2} \le \frac{l}{w} < 4$			0 90	+0.7 -0.5	-0.4 -0.5	-0.7 +0.8	-0.7 -0.1	-1.2
$\frac{h}{w} \ge 6$	$\frac{l}{w} = \frac{3}{2}$			0 90	+0.95 -0.8	-1.85 -0.8	-0.9 +0.9	-0.9 -0.85	1.25
	$\frac{l}{w} = 1.0$			0 90	+0.95 -0.7	-1.25 -0.7	-0.7 +0.95	-0.7 -1.25	1.25
	$\frac{l}{w} = 2$			0 90	+0.85 -0.75	-0.75 -0.75	-0.75 +0.85	-0.75 -0.75	1.25

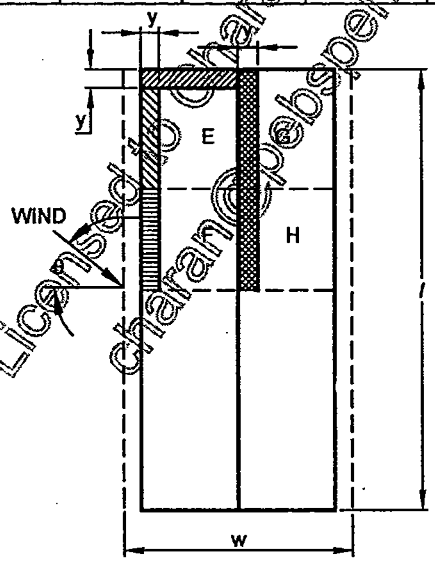
NOTE

h is the height to eaves or parapet, *l* is the greater horizontal dimensions of a building and *w* is the lesser horizontal dimensions of a building.

Table 6 External Pressure Coefficients (Cpe) for Pitched Roofs of Rectangular Clad Buildings

(*Clause* 7.3.3.2)

BUILDING HEIGHT RATIO	ROOF ANGLE α (Degrees)	WIND ANGLE θ 0° EF	WIND ANGLE θ 0° GH	WIND ANGLE θ 90° EG	WIND ANGLE θ 90° FH	LOCAL COEFFICIENTS (1)	LOCAL COEFFICIENTS (2)	LOCAL COEFFICIENTS (3)	LOCAL COEFFICIENTS (4)
$\frac{h}{w} \le \frac{1}{2}$	0	-0.8	-0.4	-0.8	-0.4	-2.0	-2.0	-2.0	—
	5	-0.9	-0.4	-0.8	-0.4	-1.4	-1.2	-1.2	-1.0
	10	-1.2	-0.4	-0.8	-0.6	-1.4	-1.4		-1.2
	20	-0.4	-0.4	-0.7	-0.6	-1.0			-1.2
	30	0	-0.4	-0.7	-0.6	-0.8			-1.1
	45	+0.3	-0.5	-0.7	-0.6				-1.1
	60	+0.7	-0.6	-0.7	-0.6				-1.1
$\frac{1}{2} \le \frac{h}{w} \le \frac{3}{2}$	0	-0.8	-0.6	-1.0	-0.6	-2.0	-2.0	-2.0	—
	5	-0.9	-0.6	-0.9	-0.6	-2.0	-2.0	-1.5	-1.0
	10	-1.1	-0.6	-0.8	-0.6	-2.0	-2.0	-1.5	-1.2
	20	-0.7	-0.5	-0.8	-0.6	-1.5	-1.5	-1.5	-1.0
	30	-0.2	-0.5	-0.8	-0.8	-1.0			-1.0
	45	+0.2	-0.5	-0.8	-0.8				
	60	+0.6	-0.5	-0.8	-0.8				
$\frac{3}{2} < \frac{h}{w} < 6$	0	-0.7	-0.6	-0.9	-0.7	-2.0	-2.0	-2.0	—
	5	-0.7	-0.6	-0.8	-0.8	-2.0	-2.0	-1.5	-1.0
	10	-0.7	-0.6	-0.8	-0.8	-2.0	-2.0	-1.5	-1.2
	20	-0.8	-0.6	-0.8	-0.8	-1.5	-1.5	-1.5	-1.2
	30	-1.0	-0.5	-0.8	-0.7	-1.5			
	40	-0.2	-0.5	-0.8	-0.7	-1.0			
	50	+0.2	-0.5	-0.8	-0.7				
	60	+0.5	-0.5	-0.8	-0.7				



KEY PLAN

$y = h$ or $0.15\ w$

Whichever is the lesser.

NOTE

1 h is the height to eaves or parapet and w is the lesser horizontal dimension of a building.

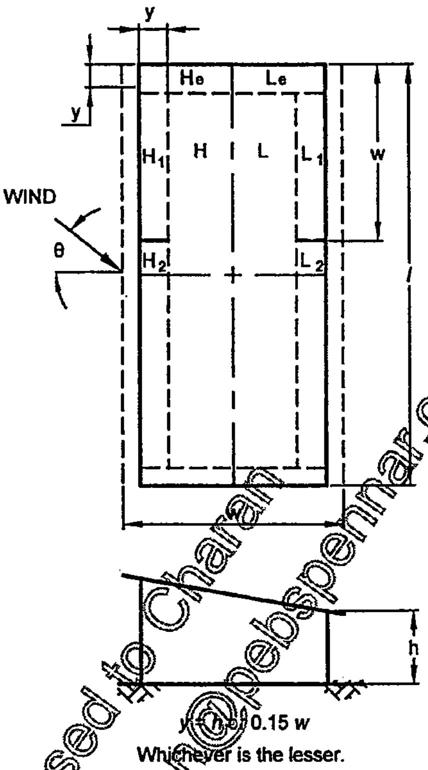
2 Where no local coefficients are given, the overall coefficient apply.

3 For hipped roofs the local coefficient for the hip ridge may be conservatively taken as the the appropriate ridge value.

4 w and l are dimensions between the walls excluding overhangs.

Table 7 External Pressure Coefficients (Cpe) for Monoslope Roofs of Rectangular Clad Buildings $\frac{h}{w} < 2$

(*Clause* 7.3.3.2)



NOTE :- Area *H* and area *L* refer to the whole quadrant.

ROOF ANGLE α	WIND ANGLE θ										LOCAL COEFFICIENTS (C_{pe})					
	0°		45°		90°		135°		180°							
	H	*L*	*H*	*L*	*H* & *L* *	*H* & *L* **	*H*	*L*	*H*	*L*	H_1	H_2	L_1	L_2	H_e	L_e
Degrees																
5	-1.0	-0.5	-1.0	-0.9	-1.0	-0.5	-0.9	-1.0	-0.5	-1.0	-2.0	-1.5	-2.0	-1.5	-2.0	-2.0
10	-1.0	-0.5	-1.0	-0.8	-1.0	-0.5	-0.8	-1.0	-0.4	-1.0	-2.0	-1.5	-2.0	-1.5	-2.0	-2.0
15	-0.9	-0.5	-1.0	-0.7	-1.0	-0.5	-0.6	-1.0	-0.3	-1.0	-1.8	-0.9	-1.8	-1.4	-2.0	-2.0
20	-0.8	-0.5	-1.0	-0.6	-0.9	-0.5	-0.5	-1.0	-0.2	-1.0	-1.8	-0.8	-1.8	-1.4	-2.0	-2.0
25	-0.7	-0.5	-1.0	-0.6	-0.8	-0.5	-0.3	-0.9	-0.1	-0.9	-1.8	-0.7	-0.9	-0.9	-2.0	-2.0
30	-0.5	-0.5	-1.0	-0.6	-0.8	-0.5	-0.1	-0.6	0	-0.6	-1.8	-0.5	-0.5	-0.5	-2.0	-2.0

* Applied to length *w*/2 from wind-ward end. ** Applies to remainder

NOTE

1 *h* is the height of eaves at lower side, is the greater horizontal dimensions of a building and *w* is the lesser horizontal dimension of a building.

2 *l* and *w* are overall length and width including overhangs.

due to the wind pressure on any fascia and to friction over the surface of the canopy. For any wind direction, only the greater of these two forces need to be taken into account. Fascia loads should be calculated on the area of the surface facing the wind, using a force coefficient of 1.3. Frictional drag should be calculated using the coefficients given in **7.4.1**.

NOTE — Tables 10 to 15 may be used to get internal and external pressure coefficients for pitches and troughed free roofs for some specific cases for which aspect ratios and roof slopes have been specified. However, while using Tables 10 to 15 any significant departure from it should be investigated carefully. No increase shall be made for local effects except as indicated.

7.3.3.4 *Pitched and saw-tooth roofs multi-span buildings*

For pitched and saw-tooth roofs of multi-span buildings, the external average pressure coefficients shall be as given in Tables 16 and 17 respectively provided that all the spans shall be equal and the height to the eaves shall not exceed the span.

7.3.3.5 *Pressure coefficients on overhangs from roofs*

The pressure coefficients on the top over-hanging portion of the roofs shall be taken to be the same as that of the nearest top portion of the non-overhanging portion of the roofs. The pressure coefficients for the underside surface of the over-hanging portions shall be taken as follows and shall be taken as positive if the overhanging portion is on the windward side:

a) 1.25, if the overhanging slopes downwards;
b) 1.00, if the overhanging is horizontal; and
c) 0.75, if the overhanging slopes upwards.

For overhanging portions on sides other than windward side, the average pressure coefficients on adjoining walls may be used.

7.3.3.6 *Curved roofs*

For curved roofs the external pressure coefficients shall be as given in Table 18. Allowance for local effects shall be made in accordance with Table 6. Two values of C_2 have been given for elevated curved roofs. Both the load cases have to be analyzed, and critical load effects are to be considered in design.

7.3.3.7 *Cylindrical structures*

For the purpose of calculating the wind pressure distribution around a cylindrical structure of circular cross-section, the value of external pressure coefficients given in Table 19 may be used, provided that the Reynolds number is more than 10 000. They may be used for wind blowing normal to the axis of cylinders having axis normal to the ground plane (that is, chimneys and silos) and cylinders having their axis parallel to the ground plane (that is, horizontal tanks), provided that the clearance between the tank and the ground is not less than the diameter of the cylinder. h is height of a vertical cylinder or length of a horizontal cylinder. Where there is a free flow of air around both ends, h is to be taken as half the length when calculating h/D ratio.

In the calculation of resultant load on the periphery of the cylinder, the value of C_{pi} shall be taken into account. For open ended cylinders, C_{pi} shall be taken as follows:

a) − 0.8, where h/D is more than or equal to 0.3; and
b) − 0.5, where h/D is less than 0.3.

7.3.3.8 *Roofs and bottoms of cylindrical elevated structures*

The external pressure coefficients for roofs and bottoms of cylindrical elevated structures shall be as given in Table 20.

Alternately, the pressure distribution given in Fig. 3 can be used together with the force coefficients given in Table 25 for the cylindrical portion.

7.3.3.9 *Combined roofs*

The average external pressure coefficients for combined roofs are shown in Table 21.

7.3.3.10 *Roofs with skylight*

The average external pressure coefficients for roofs with skylight are shown in Table 22.

7.3.3.11 *Grandstands*

The pressure coefficients on the roof (top and bottom) and rear wall of a typical grandstand roof which is open on three sides are given in Table 23. The pressure coefficients are valid for a particular ratio of dimensions as specified in Table 21 but may be used for deviations up to 20 percent. In general, the maximum wind load occurs when the wind is blowing into the open front of the stand, causing positive pressure under the roof and negative pressure on the roof.

7.3.3.12 *Spheres*

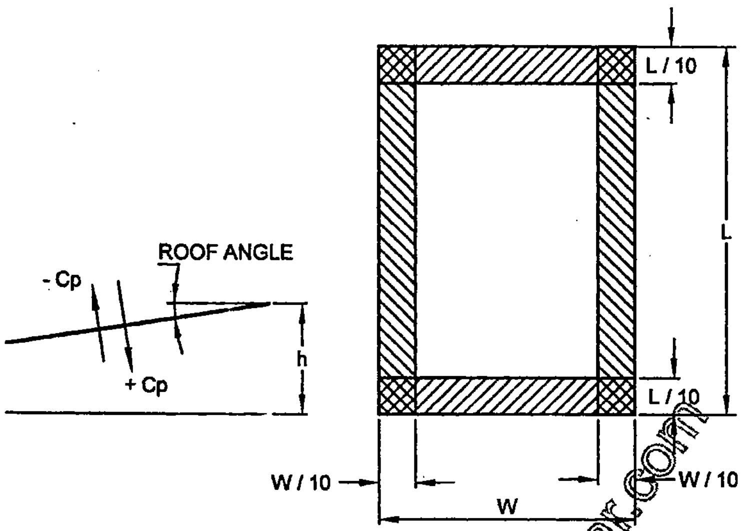
The external pressure coefficients for spheres shall be as given in Table 24.

7.3.3.13 *Frames*

When taking wind loads on frames of clad buildings it is reasonable to assume that the pressures or suctions inside and outside the structure shall not be fully correlated. Therefore when taking the combined effect of wind loads on the frame, a reduction factor of $K_c = 0.90$ may be used over the building envelope when roof is subjected to pressure and internal pressure is suction, or *vice-versa*.

Table 8 Pressure Coefficients for Monoslope Free Roofs

(*Clause* 7.3.3.3)



ROOF ANGLE (Degree) α	SOLIDITY RATIO Φ	MAXIMUM (LARGEST + ve) AND MINIMUM (LARGEST - ve) PRESSURE COEFFICIENTS			
		OVERALL COEFFICIENTS	LOCAL COEFFICIENTS		
0	All values of Φ	+ 0.2	+ 0.5	+ 1.8	+ 1.1
5		+ 0.4	+ 0.8	+ 2.1	+ 1.3
10		+ 0.5	+ 1.2	+ 2.4	+ 1.6
15		+ 0.7	+ 1.4	+ 2.7	+ 1.8
20		+ 0.8	+ 1.7	+ 2.9	+ 2.1
25		+ 1.0	+ 2.0	+ 3.1	+ 2.3
30		+ 1.2	+ 2.2	+ 3.2	+ 2.4
0	Φ = 0	- 0.5	- 0.6	- 1.3	- 1.4
	Φ = 1	- 1.0	- 1.2	- 1.8	- 1.9
5	Φ = 0	- 0.7	- 1.1	- 1.7	- 1.8
	Φ = 1	- 1.1	- 1.6	- 2.2	- 2.3
10	Φ = 0	- 0.9	- 1.5	- 2.0	- 2.1
	Φ = 1	- 1.3	- 2.1	- 2.6	- 2.7
15	Φ = 0	- 1.1	- 1.8	- 2.4	- 2.5
	Φ = 1	- 1.4	- 2.3	- 2.9	- 3.0
20	Φ = 0	- 1.3	- 2.2	- 2.8	- 2.9
	Φ = 1	- 1.5	- 2.6	- 3.1	- 3.2
25	Φ = 0	- 1.6	- 2.6	- 3.2	- 3.2
	Φ = 1	- 1.7	- 2.8	- 3.5	- 3.5
30	Φ = 0	- 1.8	- 3.0	- 3.8	- 3.6
	Φ = 1	- 1.8	- 3.0	- 3.8	- 3.6

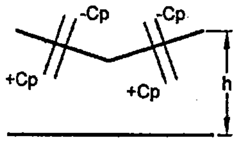
NOTES

1 For monopitch canopies the centre of pressure should be taken to act at 0.3 w from the windward edge.

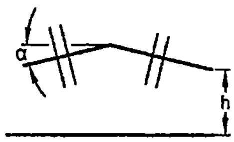
2 W and L are overall width and length including overhangs.

Table 9 Pressure Coefficients for Free Standing Double Sloped Roofs

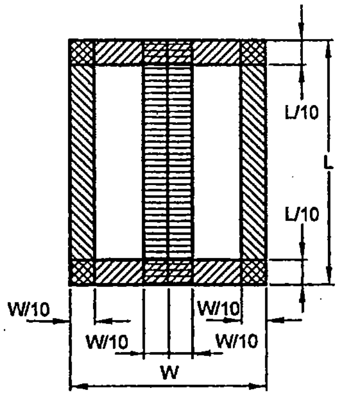
(*Clause* 7.3.3.3)



- ve ROOF ANGLE



+ ve ROOF ANGLE



KEY PLAN

ROOF ANGLE (Degrees) α	SOLIDITY RATIO Φ	MAXIMUM (LARGEST + ve) AND MINIMUM (LARGEST - ve) PRESSURE COEFFICIENTS				
		OVERALL COEFFICIENTS	LOCAL COEFFICIENTS			
-20	All values of Φ	+0.7	+0.8	+1.6	+0.6	+1.7
-15		+0.5	+0.6	+1.5	+0.7	+1.4
-10		+0.4	+0.6	+1.4	+0.8	+1.1
-5		+0.3	+0.5	+1.5	+0.8	+0.8
+5		+0.3	+0.6	+1.8	+1.3	+0.4
+10		+0.4	+0.7	+1.8	+1.4	+0.4
+15		+0.4	+0.9	+1.9	+1.4	+0.4
+20		+0.6	+1.1	+1.9	+1.5	+0.4
+25		+0.7	+1.2	+1.9	+1.6	+0.5
+30		+0.9	+1.3	+1.9	+1.6	+0.7
-20	Φ = 0	-0.7	-0.9	-1.3	-1.6	-0.6
	Φ = 1	-0.9	-1.2	-1.7	-1.9	-1.2
-15	Φ = 0	-0.6	-0.8	-1.3	-1.6	-0.6
	Φ = 1	-0.8	-1.1	-1.7	-1.9	-1.2
-10	Φ = 0	-0.6	-0.8	-1.3	-1.5	-0.6
	Φ = 1	-0.8	-1.1	-1.7	-1.9	-1.3
-5	Φ = 0	-0.5	-0.7	-1.3	-1.6	-0.6
	Φ = 1	-0.8	-1.5	-1.7	-1.9	-1.4
+5	Φ = 0	-0.6	-0.6	-1.4	-1.4	-1.1
	Φ = 1	-0.9	-1.3	-1.8	-1.8	-2.1
+10	Φ = 0	-0.7	-0.7	-1.5	-1.4	-1.4
	Φ = 1	-1.1	-1.4	-2.0	-1.8	-2.4
+15	Φ = 0	-0.8	-0.9	-1.7	-1.4	-1.8
	Φ = 1	-1.2	-1.5	-2.2	-1.9	-2.8
+20	Φ = 0	-0.9	-1.2	-1.8	-1.4	-2.0
	Φ = 1	-1.3	-1.7	-2.3	-1.9	-3.0
+25	Φ = 0	-1.0	-1.4	-1.9	-1.4	-2.0
	Φ = 1	-1.4	-1.9	-2.4	-2.1	-3.0
+30	Φ = 0	-1.0	-1.4	-1.9	-1.4	-2.0
	Φ = 1	-1.4	-2.1	-2.6	-2.2	-3.0

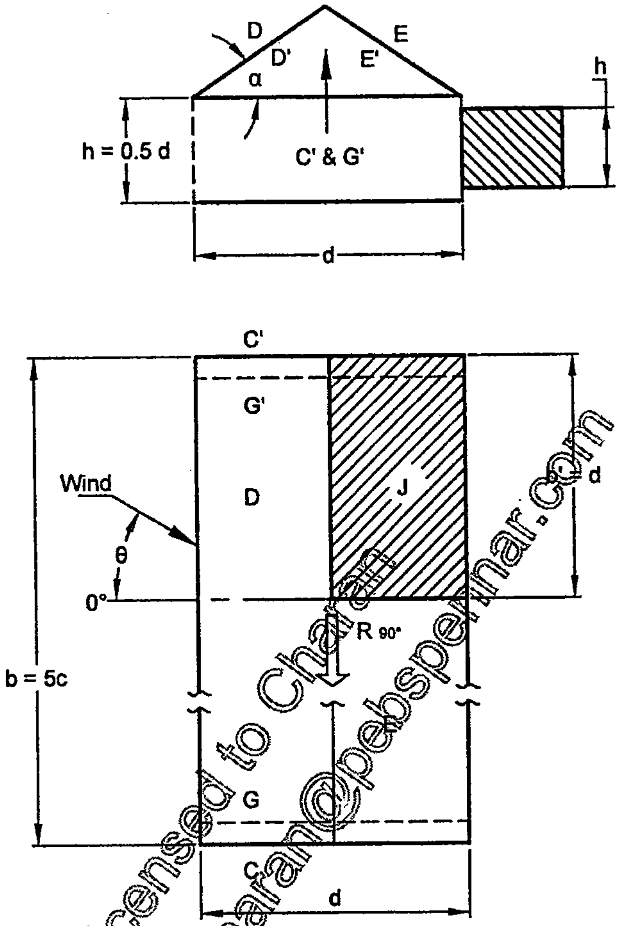
NOTES

1 Each slope of a duopitch canopy should be able to withstand forces using both the maximum and the minimum coefficients, and the whole canopy should be able to support forces using one slope at the maximum coefficient with the other slope at the minimum coefficient. For duoptich canopies the centre of pressure should be taken to act at the centre of each slope.

2 *W* and *L* are overall width and length including overhangs

Table 10 Pressure Coefficients (Top and Bottom) for Pitched Roofs, Roof Slope α = 30°

(*Clause* 7.3.3.3)



Roof slope α = 30°

θ = 0°- 45°, *D, D', E, E'* full length.

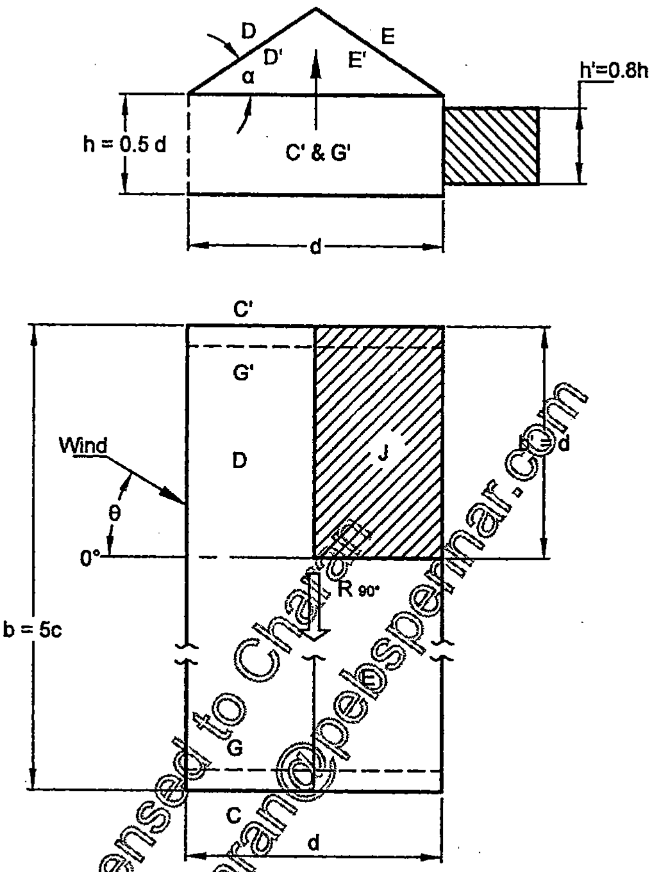
θ = 90°, *D, D', E, E'* part length.

b', thereafter $C_p = 0$

θ	PRESSURE COEFFICIENTS, C_p							
	D	*D'*	*E*	*E'*	END SURFACES			
					C	*C'*	*G*	*G'*
0° 45° 90°	+ 0.6 + 0.1 - 0.3	- 1.0 - 0.3 - 0.4	- 0.5 - 0.6 - 0.3	- 0.9 - 0.3 - 0.4	- 0.3	- 0.8	- 0.3	- 0.4
For all value of θ	For J : C_p Top = 1.0, C_p bottom = - 0.2 Tangentially acting friction : $R_{90°} = 0.05\, p_d\, bd$							

Table 11 Pressure Coefficients (Top and Bottom) for Pitched Roofs, Roof α = 30° with effects of Train or Stored Material

(*Clause* 7.3.3.3)

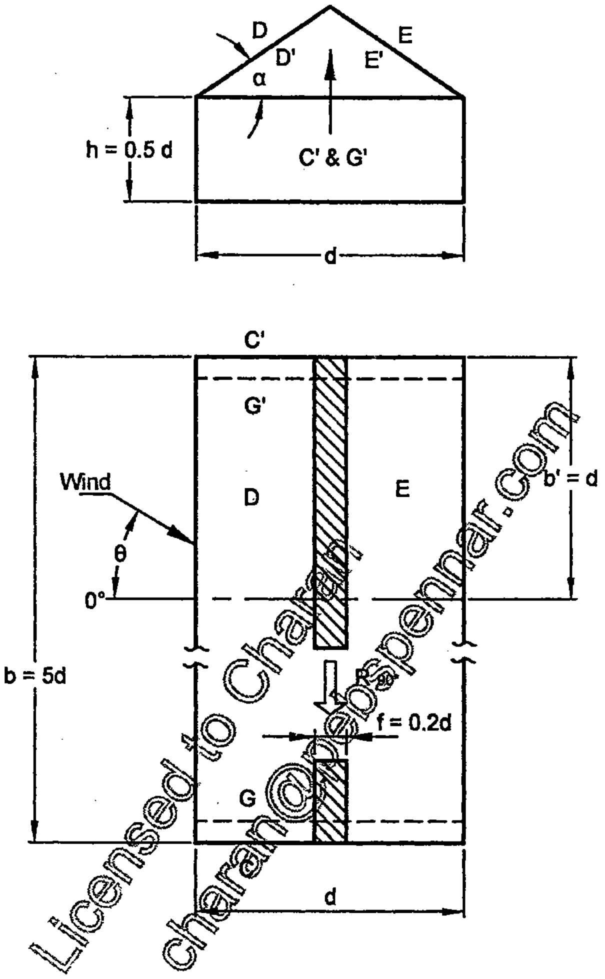


Roof slope α = 30°
Effects of trains or stored materials.
θ = 0°- 45°, or 135° - 180°, *D, D', E, E'* full length.
θ = 90°, *D, D', E, E'* part length.
b', thereafter C_p = 0

<table>
<tr><th rowspan="3">θ</th><th colspan="8">PRESSURE COEFFICIENTS, C_p</th></tr>
<tr><th rowspan="2">D</th><th rowspan="2">D'</th><th rowspan="2">E</th><th rowspan="2">E'</th><th colspan="4">END SURFACES</th></tr>
<tr><th>C</th><th>C'</th><th>G</th><th>G'</th></tr>
<tr><td>0°</td><td>+ 0.1</td><td>+ 0.8</td><td>- 0.7</td><td>+ 0.9</td><td rowspan="4">- 0.3</td><td rowspan="4">+ 0.8</td><td rowspan="4">+ 0.3</td><td rowspan="4">- 0.4</td></tr>
<tr><td>45°</td><td>- 0.1</td><td>+ 0.5</td><td>- 0.8</td><td>+ 0.5</td></tr>
<tr><td>90°</td><td>- 0.4</td><td>- 0.5</td><td>- 0.4</td><td>- 0.5</td></tr>
<tr><td>180°</td><td>- 0.3</td><td>- 0.6</td><td>+ 0.4</td><td>- 0.6</td></tr>
<tr><td>For all value of θ</td><td colspan="8">For J : C_p Top = -1.5, C_p bottom = 0.5
Tangentially acting friction : $R_{90°} = 0.05\, p_d\, bd$</td></tr>
</table>

Table 12 Pressure Coefficients (Top and Bottom) for Pitched Roofs, α = 10°

(*Clause* 7.3.3.3)



Roof slope α = 10°

θ = 0°- 45°, *D, D', E, E'* full length.

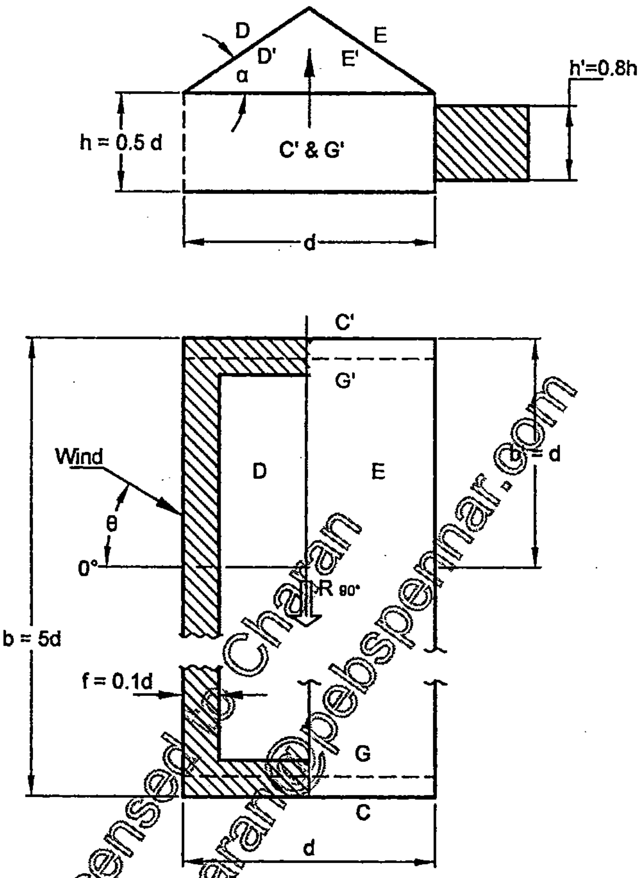
θ = 90°, *D, D', E, E'* part length.

b', thereafter C_p= 0

θ	PRESSURE COEFFICIENTS, C_p							
	D	*D'*	*E*	*E'*	END SURFACES			
					C	*C'*	*G*	*G'*
0° 45° 90°	- 1.0 - 0.3 - 0.3	+ 0.3 + 0.1 0	- 0.5 - 0.3 - 0.3	+ 0.2 + 0.1 0	- 0.4	+ 0.8	+ 0.3	- 0.6
For all value of θ	For *f* : C_p Top = - 1.0, C_p bottom = 0.4 Tangentially acting friction : $R_{90°} = 0.1\, p_d\, bd$							

Table 13 Pressure Coefficients (Top and Bottom) for Pitched Free Roofs, α = 10° with effects of Train or Stored Materials

(*Clause* 7.3.3.3)

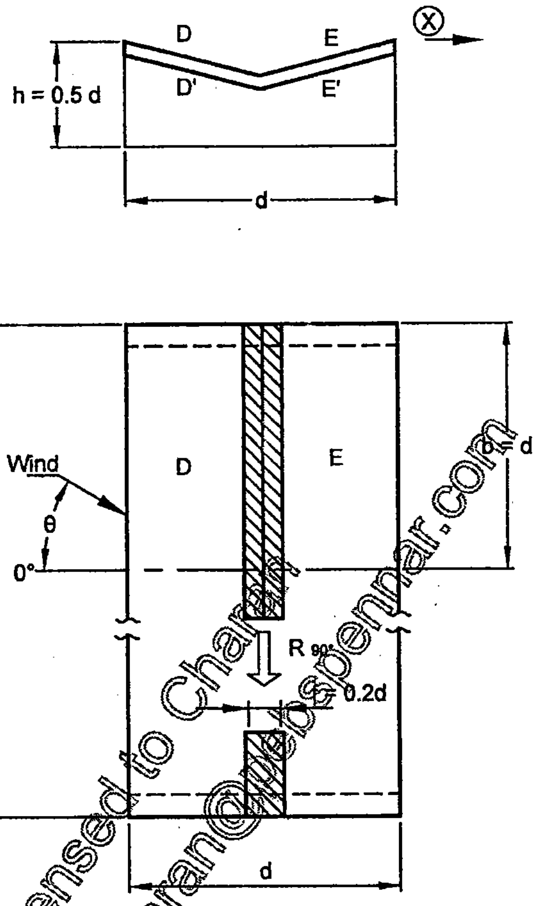


Roof slope α = 10°
Effects of trains or stored materials.
θ = 0°- 45°, or 135° - 180°, *D, D', E, E'* full length.
θ = 90°, *D, D', E, E'* part length.
b', thereafter C_p= 0

θ	PRESSURE COEFFICIENTS, C_p							
	D	*D'*	*E*	*E'*	END SURFACES			
					C	*C'*	*G*	*G'*
0° 45° 90° 180°	- 1.3 - 0.5 - 0.3 - 0.4	+ 0.8 + 0.4 0 - 0.3	- 0.6 - 0.3 - 0.3 - 0.6	0.7 + 0.3 0 - 0.3	- 0.4	+ 0.8	+ 0.3	- 0.6
For all value of θ	For *f* : C_p Top = -1.6, C_p bottom = - 0.9 Tangentially acting friction : $R_{90°} = 0.1 p_d bd$							

Table 14 Pressure Coefficients for Troughed Free Roofs, $\alpha = 10°$

(*Clause* 7.3.3.3)



Roof slope $\alpha = 10°$

$\theta = 0°- 45°$, *D, D', E, E'* full length.

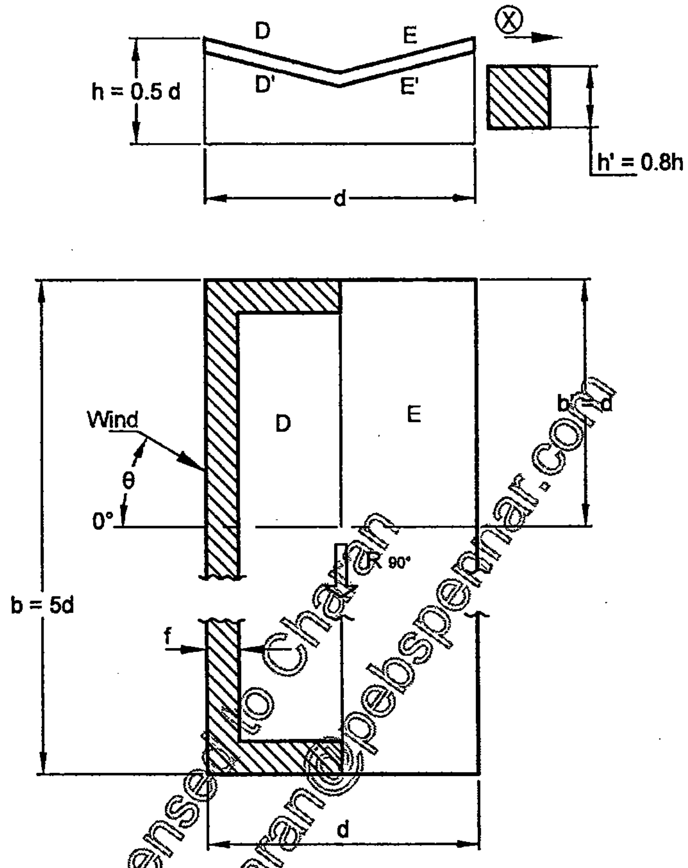
$\theta = 90°$, *D, D', E, E'* part length.

b', thereafter $C_p = 0$

θ	PRESSURE COEFFICIENTS, C_p			
	D	*D'*	*E*	*E'*
0°	+ 0.3	- 0.7	+ 0.2	- 0.9
45°	0	- 0.2	+ 0.1	- 0.3
90°	- 0.1	0.1	- 0.1	+ 0.1
For all value of θ	For *f* : C_p Top = 0.4, C_p bottom = - 1.5 Tangentially acting friction : $R_{90°} = 0.1 p_d\, bd$			

Table 15 Pressure Coefficients (Top and Bottom) for Troughed Free Roofs, α = 10° with Effects of Train or Stored Materials

(*Clause* 7.3.3.3)

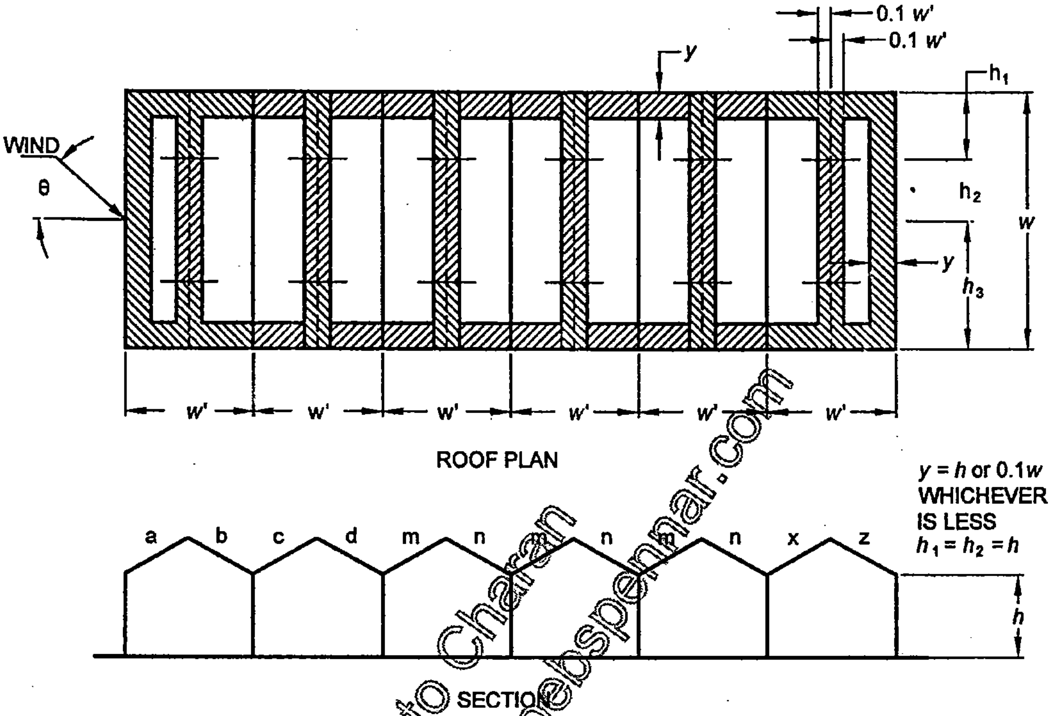


Roof slope α = 10°
Effects of trains or stored materials.
θ = 0°- 45°, or 135° - 180°, *D, D', E, E'* full length.
θ = 90°, *D, D', E, E'* part length.
b', thereafter C_p = 0

θ	PRESSURE COEFFICIENTS, C_p			
	D	*D'*	*E*	*E'*
0°	- 0.7	+ 0.8	- 0.6	+ 0.6
45°	- 0.4	+ 0.3	- 0.2	+ 0.2
90°	- 0.1	+ 0.1	- 0.1	+ 0.1
180°	- 0.4	- 0.2	- 0.6	- 0.3
For all value of θ	For *f* : C_p Top = -1.1, C_p bottom = 0.9 Tangentially acting friction : $R_{90°} = 0.1\, p_d\, bd$			

Table 16 External Pressure Coefficients (C_{pe}) for Pitched Roofs of Multispan Buildings (All Spans Equal) with $h < w'$

(*Clause* 7.3.3.4)



ROOF ANGLE α Degrees	WIND ANGLE θ Degrees	FIRST SPAN a		FIRST INTERME-DIATE SPAN c	d	OTHER INTERME-DIATE SPANS m	n	END SPAN x	z	LOCAL COEFFICIENT (▧)	LOCAL COEFFICIENT (▨)
5	0	-0.9	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3		
10		-1.1	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.4		
20		-0.7	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.5	-2.0	-1.5
30		-0.2	-0.6	-0.4	-0.3	-0.2	-0.3	-0.2	-0.5		
45		+0.3	-0.6	-0.6	-0.4	-0.2	-0.4	-0.2	-0.5		

DISTANCE

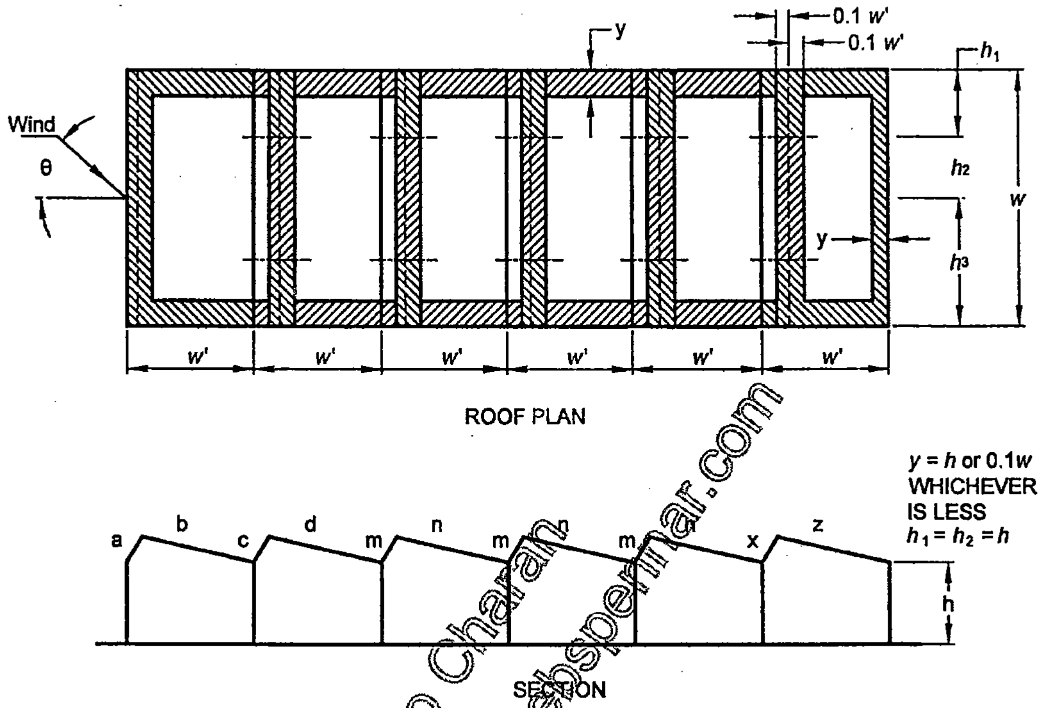
ROOF ANGLE α DEGREES		WIND ANGLE θ DEGREES	h_1	h_2	h_3		
UP TO 45		90	-0.8	-0.6	-0.2		

Frictional drag : When wind angle θ = 0°, horizontal forces due to frictional drag are allowed for in the above values, and When wind angle θ = 90°, allow for frictional drag in accordance with 7.4.1

NOTE — Evidence on these buidings is fragmentary and any departure from the cases given should be investigated separately.

Table 17 External Pressure Coefficients (C_{pe}) for Saw Tooth Roofs of Multispan Buildings (All Spans Equal) with $h < w'$

(*Clause* 7.3.3.4)



WIND ANGLE	FIRST SPAN		FIRST INTERMEDIATE SPAN		OTHER INTERMEDIATE SPANS		END SPAN		LOCAL COEFFICIENT	
θ Degrees	a	b	c	d	m	n	x	z	(hatched symbol 1)	(hatched symbol 2)
0	+0.6	-0.7	-0.7	-0.4	-0.3	-0.2	-0.1	-0.3		
180	-0.5	-0.3	-0.3	-0.3	-0.4	-0.6	-0.6	-0.1	-2.0	-1.5

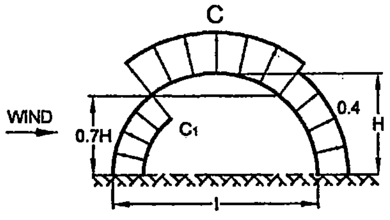
DISTANCE			
WIND ANGLE θ DEGREES	h_1	h_2	h_3
90	-0.8	-0.6	-0.2
270	Similar to 90°, h_1, h_2, h_3, are needed to be reckoned from the windword edge in the same order		

Frictional drag : When wing angle θ = 0°, horizontal forces due to frictional drag are allowed for in the above values, and When wind angle θ = 90°, allow for frictional drag in accordance with **7.4.1**.

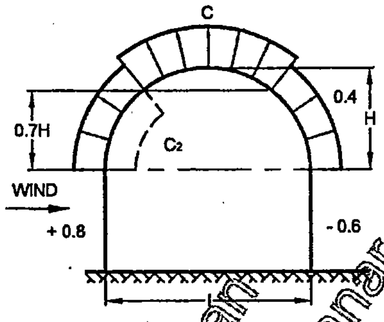
NOTE — Evidence on these buidings is fragmentary and any departure from the cases given should be investigated separately.

Table 18 External Pressure Coefficients (C_{pe}) for Curved Roofs

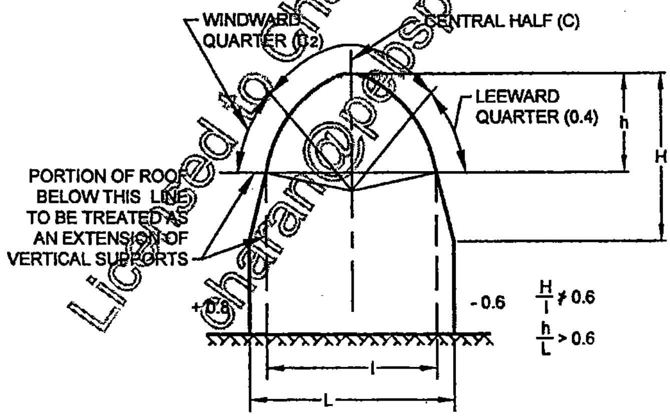
(*Clause* 7.3.3.6)



a) ROOF SPRINGING FROM GROUND LEVEL



b) ROOF ON ELEVATED STRUCTURE



c) DOUBLE CURVED ROOFS

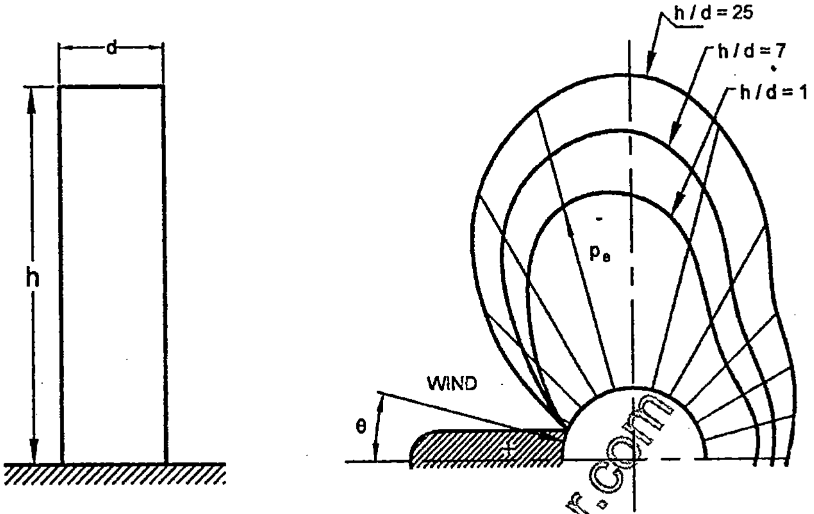
VALUES OF *C*, C_1 and C_2

H/l	C	C_1	C_2
0.1	- 0.8	+ 0.1	+ 0.05
0.2	- 0.9	+ 0.3	+0.1
0.3	- 1.0	+ 0.4	+0.15
0.4	- 1.1	+ 0.6	-
0.5	- 1.2	+ 0.7	-

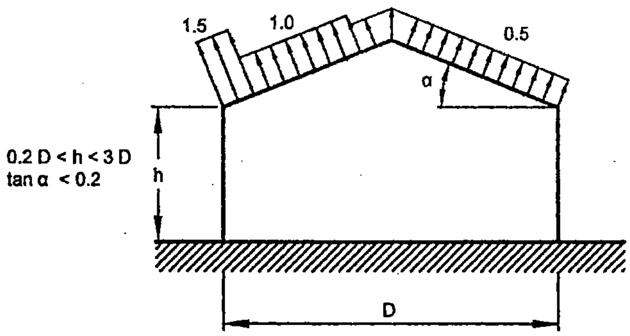
NOTE — When the wind is blowing normal to gable ends. C_{pe} may be taken as equal to –0.7 for the full width of the roof over a length of $l/2$ from the gable ends and –0.5 for the remaining portion.

Table 19 External Pressure Coefficients Around Cylindrical Structures

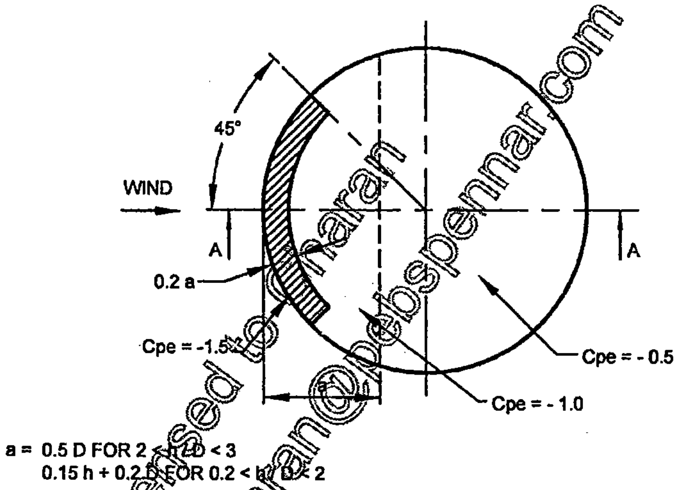
(*Clause* 7.3.3.7)



POSITION OF PERIPHERY, θ IN DEGREES	PRESSURE COEFFICIENTS C_{pe}		
	h / *D* = 25	*h* / *D* = 7	*h* / *D* = 1
0	1.0	1.0	1.0
15	0.8	0.8	0.8
30	0.1	0.1	0.1
45	- 0.9	- 0.8	- 0.7
60	- 1.9	- 1.7	- 1.2
75	- 2.5	- 2.2	- 1.6
90	- 2.6	- 2.2	- 1.7
105	- 1.9	- 1.7	- 1.2
120	- 0.9	- 0.8	- 0.7
135	- 0.7	- 0.6	- 0.5
150	- 0.6	- 0.5	- 0.4
165	- 0.6	- 0.5	- 0.4
180	- 0.6	- 0.5	- 0.4



SECTION AA

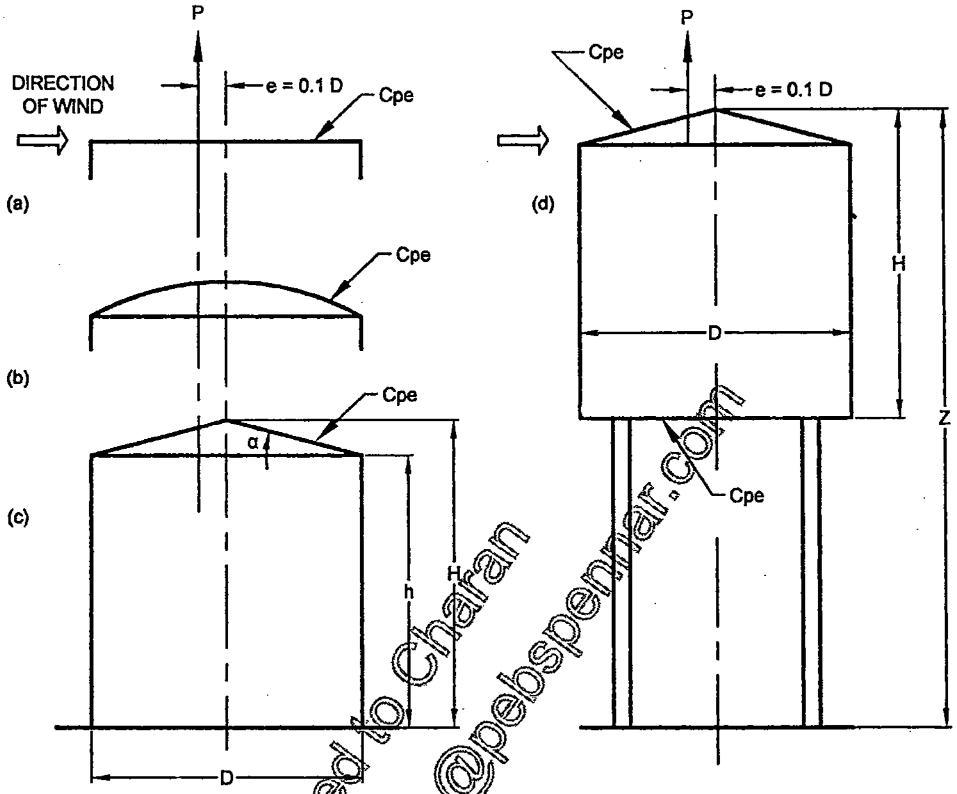


PLAN

[For force coefficient corresponding to shell portion (See Table 25)]

FIG. 3 EXTERNAL PRESSURE COEFFICIENTS ON THE UPPER ROOF SURFACE OF CYCLINDRICAL STRUCTURES STANDING ON THE GROUND

Table 20 External Pressure Coefficients for Roofs and Bottoms of Cylindrical Structures
(*Clause* 7.3.3.8)



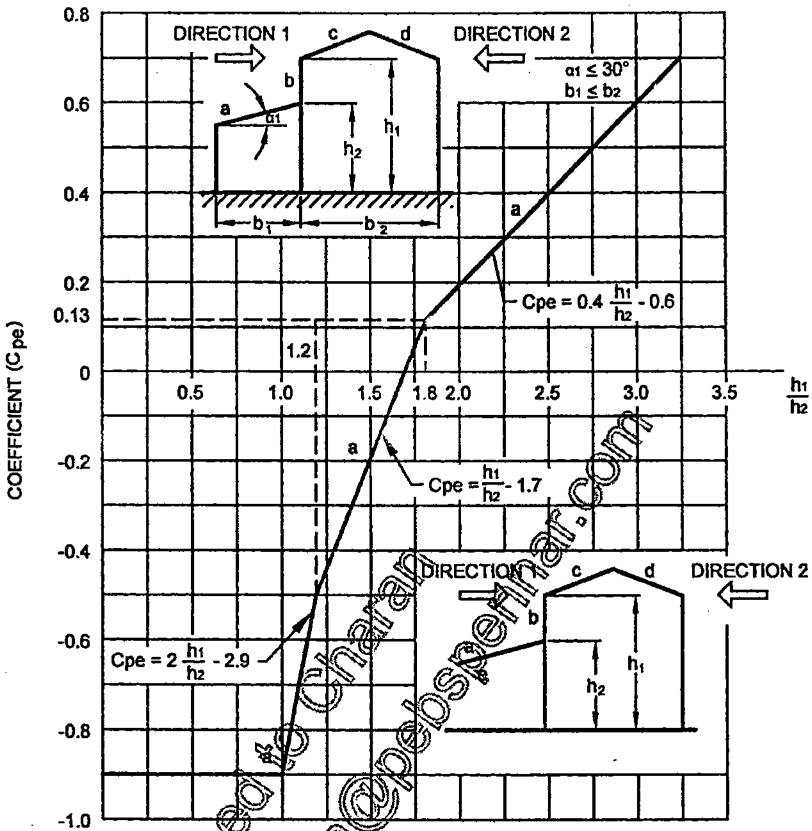
COEFFICIENTS OF EXTERNAL PRESSURE C_{pe}				
STRUCTURE ACCORDING TO SHAPE				
a, b and c		d		
H / D	ROOF	(z / H) - 1	ROOF	BOTTOM
0.5	- 0.65	1.00	- 0.75	- 0.8
1.00	- 1.00	1.25	- 0.75	- 0.7
2.00	- 1.00	1.50	- 0.75	- 0.6

Total force acting on the roof of the structure, $P = 0.785\ D^2\ (C_{pi} - C_{pe})\ p_d$

The resultant of P lies eccentrically, e = 0.1D

Table 21 External Pressure Coefficients (C_{pe}) for Combined Roofs

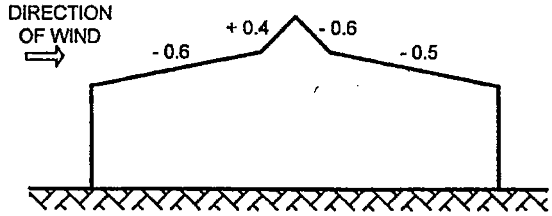
(*Clause* 7.3.3.9)

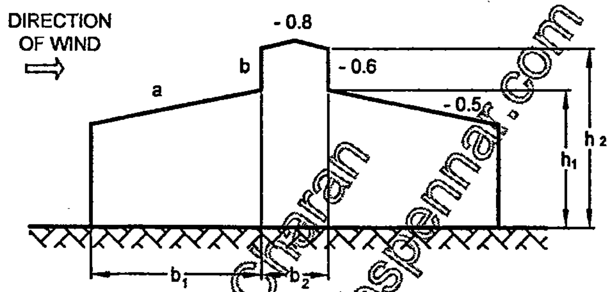


VALUES OF COEFFICIENTS (C_{pe})		
PORTION	DIRECTION 1	DIRECTION 2
a	FROM THE DIAGRAM	- 0.4
b	$C_{pe} = -0.5,\ \frac{h_1}{h_2} \le 1.5$ $C_{pe} = +0.7;\ \frac{h_1}{h_2} > 1.5$	
c and d	See Table 6	
e	See Clause 6.3.3.5	

Table 22 External Pressure Coefficients (C_{pe}) for Roofs with a Sky Light

(*Clause* 7.3.3.10)





b) ROOFS WITH A SKY LIGHT

PORTION	VALUES OF COEFFICIENTS (C_{pe})		
	$b_1 > b_2$		$b_1 \leq b_2$
	a	*b*	*a* and *b*
Cpe	- 0.6	+ 0.7	See Table for combined roofs

7.4 *Force Coefficients*

The value of force coefficients (C_f) apply to a building or structure as a whole, and when multiplied by the effective frontal area A_e of the building or structure and design wind pressure, p_d gives the total wind load (F) on that particular building or structure.

$$F = C_f A_e p_d$$

where F is the force acting in a direction specified in the respective tables and C_f is the force coefficient for the building.

NOTES

1 The value of the force coefficient differs for the wind acting on different faces of a building or structure. In order to determine the critical load, the total wind load should be calculated for each wind direction.

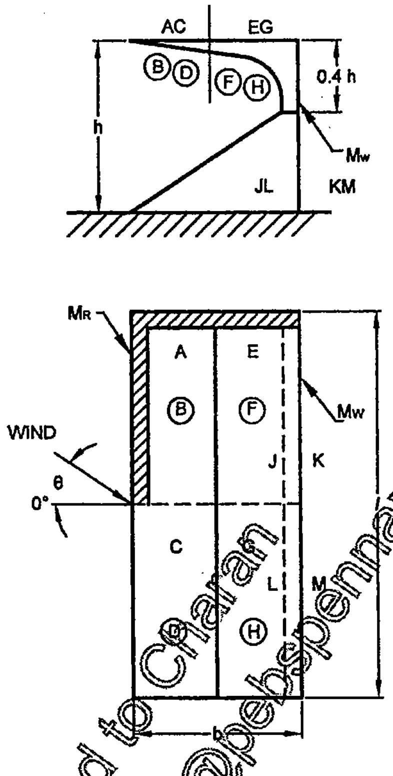
2 If surface design pressure varies with height, the surface area of the building/structure may be sub-divided so that specified pressures are taken over appropriate areas.

3 In tapered buildings/structures, the force coefficients shall be applied after sub-dividing the building/structure into suitable number of strips and the load on each strip calculated individually, taking the area of each strip as A_e.

4 For force coefficients for structures not covered above reference may be made specialist literature on the subject or advice may be sought from specialist in the subject.

Table 23 Pressure Coefficients at Top and Bottom Roof of Grand Stands Open Three Sides (Roof Angle Upto 5°)

(*Clause* 7.3.3.11)

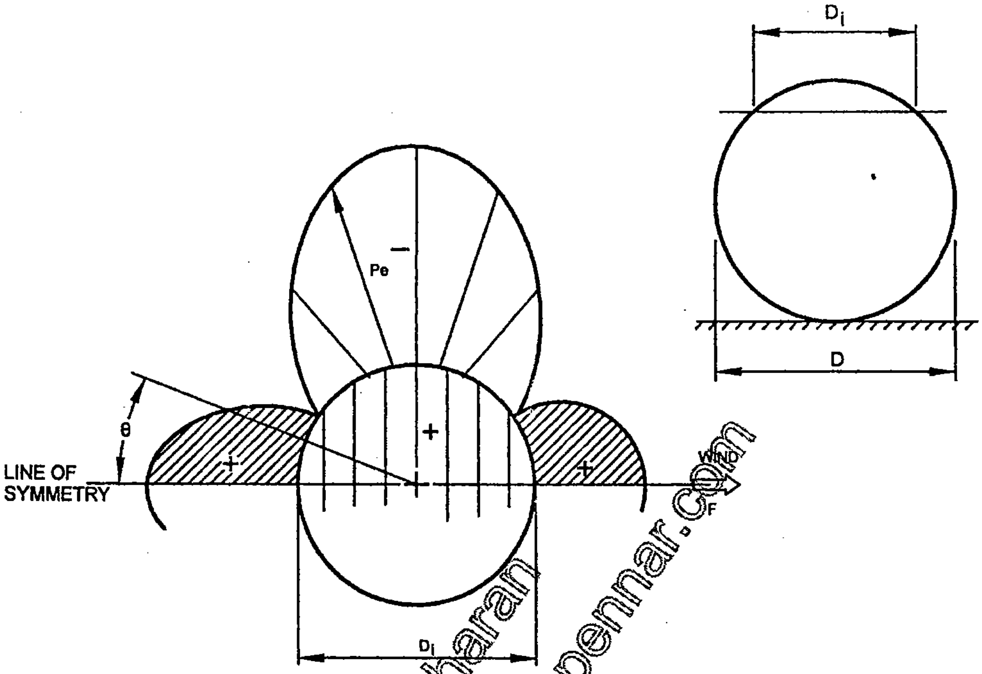


(Shaded area to scale)

FRONT AND BACK OF WALL				
θ	*J*	*K*	*L*	*M*
0°	+ 0.9	- 0.5	+ 0.9	- 0.5
45°	+ 0.8	- 0.6	+ 0.4	- 0.4
135°	- 1.1	+ 0.6	- 1.0	+ 0.4
180°	- 0.3	+ 0.9	- 0.3	+ 0.9
60°	*Mw* - Cp of K = - 1.0			
60°	*Mw* - Cp of J = + 1.0			

TOP AND BOTTOM ROOF								
θ	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
0°	- 1.0	+ 0.9	- 1.0	+ 0.9	- 0.7	+ 0.9	+ 0.7	+ 0.9
45°	- 1.0	+ 0.7	- 0.7	+ 0.4	- 0.5	+ 0.8	- 0.5	+ 0.3
135°	- 0.4	- 1.1	- 0.7	- 1.0	- 0.9	- 1.1	- 0.9	- 1.0
180°	- 0.6	- 0.3	- 0.6	- 0.3	- 0.6	- 0.3	- 0.6	- 0.3
45°	'M_R' - Cp (top) = - 2.0							
45°	'M_R' - Cp (bottom) = + 1.0							

Table 24 External Pressure Distribution Coefficients Around Spherical Structures
(*Clause* 7.3.3.12)



POSITION OF PERIPHERY, θ IN DEGREES	C_{pe}
[illegible]	+ 1.0
15	+ 0.9
30	+ 0.5
45	- 0.1
60	- 0.7
75	- 1.1
90	- 1.2
105	- 1.0
120	- 0.6
135	- 0.2
150	+ 0.1
165	+ 0.3
180	+ 0.4

7.4.1 *Frictional Drag*

In certain buildings of special shape, a force due to frictional drag shall be taken into account in addition to those loads specified in **7.3**. For rectangular clad buildings, this addition is necessary only where the ratio d/h or d/b is more than 4. The frictional drag force, F', in the direction of the wind is given by the following formulae:

a) If $h \leq b$, $F' = C_f'(d - 4h)\, bp_d + C_f'(d - 4b)\, 2h\, p_d$, and

b) If $h > b$, $F' = C_f'(d - 4b)\, bp_d + C_f'(d - 4b)\, 2h\, p_d$

The first term in each case gives the drag on the roof and the second on the walls. The value of C_f' has the following value:

1) $C_f' = 0.01$ for smooth surfaces without corrugations or ribs across the wind direction,
2) $C_f' = 0.02$ for surfaces with corrugations across the wind direction, and
3) $C_f' = 0.04$ for surfaces with ribs across the wind direction.

For other buildings, the frictional drag has been indicated, where necessary, in the tables of pressure coefficients and force coefficients.

7.4.2 *Force Coefficients for Clad Buildings*

7.4.2.1 *Clad buildings of uniform section*

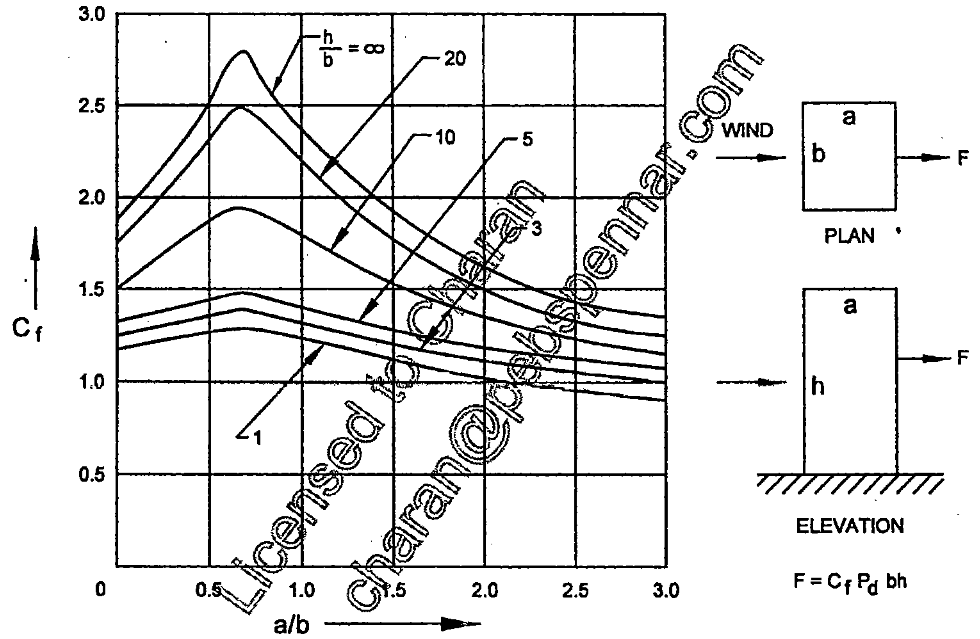
The overall force coefficients for rectangular clad buildings of uniform section with flat roofs in uniform flow shall be as given in Fig. 4 and for other clad buildings of uniform section (without projections, except where otherwise shown) shall be as given in Table 25.

NOTE — Structures that are in the supercritical flow regime, because of their size and design wind velocity, may need further calculation to ensure that the greatest loads do not occur at some wind speed below the maximum when the flow will be sub critical. The coefficients are for buildings without projections, except where otherwise shown.

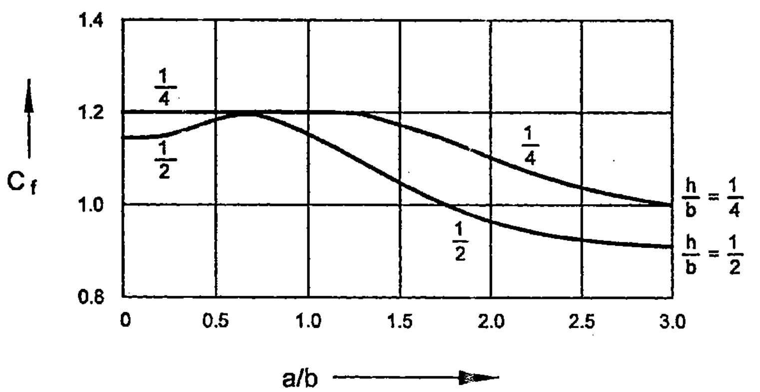
In Table 25, $\bar{V}_d\, b$ is used as an indication of the airflow regime.

7.4.2.2 *Buildings of circular shapes*

Force coefficients for buildings of circular cross-section shapes shall be as given in Table 25. However more precise estimation of force coefficients for circular shapes of infinite length can be obtained from Fig. 5



a) Values of C_f versus a / b for h / b ≥ 1



b) Values of C_f versus a / b for h / b < 1

FIG. 4 FORCE COEFFICIENT FOR RECTANGULAR CLAD BUILDING IN UNIFORM FLOW

Table 25 Force Coefficients C_f for Clad Buildings of Uniform Section
(Acting in the Direction of Wind)
(*Clause* 7.4.2.2)

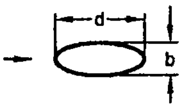
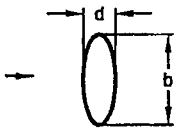
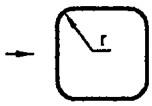
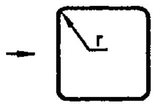
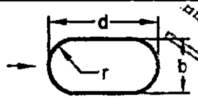
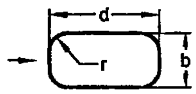
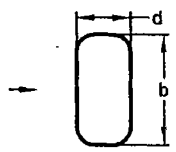
PLAN SHAPE	$\overline{V}_d\,b$ m²/s	C_f FOR HEIGHT / BREADTH RATIO UPTO 1/2	1	2	5	10	20	∞
WIND $\overline{V}_d$  See also Appendix D	ALL SURFACES < 6; ROUGH or WITH PROJECTION ≥ 6	0.7	0.7	0.7	0.8	0.9	1.0	1.2
	SMOOTH ≥ 6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 Ellipse b/d = 1/2	< 10	0.5	0.5	0.5	0.5	0.6	0.6	0.7
	≥ 10	0.2	0.2	0.2	0.2	0.2	0.2	0.2
 Ellipse b/d = 2	< 8	0.8	0.8	0.9	1.0	1.1	1.3	1.7
	≥ 8	0.8	0.8	0.9	1.0	1.1	1.3	1.5
 b/d = 1, r/b = 1/3	< 4	0.6	0.6	0.6	0.7	0.8	0.8	1.0
	≥ 4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
 b/d = 1, r/b = 1/6	< 10	0.7	0.8	0.8	0.9	1.0	1.0	1.3
	≥ 10	0.5	0.5	0.5	0.5	0.6	0.6	0.6
 b/d = 1/2, r/b = 1/2	< 3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
	≥ 3	0.2	0.2	0.2	0.2	0.3	0.3	0.3
 b/d = 1/2, r/b = 1/6	All values	0.5	0.5	0.5	0.5	0.6	0.6	0.7
 b/d = 2, r/b = 1/12	All values	0.9	0.9	1.0	1.1	1.2	1.5	1.9

Table 25 — (*Continued*)

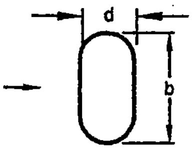
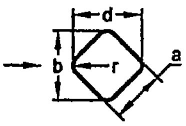
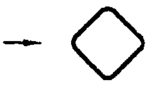
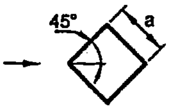
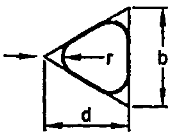
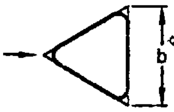
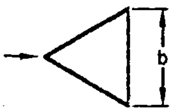
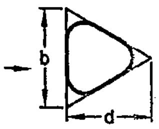
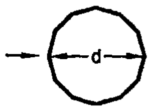
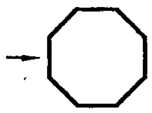
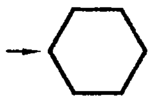
PLAN SHAPE	$\bar{V}_d$ b m²/s	C_f FOR HEIGHT / BREADTH RATIO						
		UPTO 1/2	1	2	5	10	20	∞
 b/d = 2 r/b = 1/4	< 6	0.7	0.8	0.8	0.9	1.0	1.2	1.6
	≥ 6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 r/a = 1/3	< 10	0.8	0.8	0.9	1.0	1.1	1.3	1.5
	≥ 10	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 r/a = 1/12	All values	0.9	0.9	0.9	1.1	1.2	1.3	1.6
 r/a = 1/48	All values	0.9	0.8	0.9	1.1	1.2	1.3	1.6
 r/b = 1/4	< 11	0.7	0.7	0.7	0.8	0.9	1.0	1.2
	≥ 11	0.4	0.4	0.4	0.4	0.5	0.5	0.5
 r/b = 1/12	All values	0.8	0.8	0.8	1.0	1.1	1.2	1.4
 r/b = 1/48	All values	0.7	0.7	0.8	0.9	1.0	1.1	1.3
 r/b = 1/4	< 8	0.7	0.7	0.8	0.9	1.0	1.1	1.3
	≤ 8	0.4	0.4	0.4	0.4	0.5	0.5	0.5

Table 25 — *(Concluded)*

PLAN SHAPE	$\bar{V}_d b$ m²/s	C_f FOR HEIGHT / BREADTH RATIO						
		UPTO 1/2	1	2	5	10	20	∞
 1/48 < r/b < 1/12	All values	1.2	1.2	1.2	1.4	1.6	1.7	2.1
 12 SIDED POLYGON	< 12	0.7	0.7	0.8	0.9	1.0	1.1	1.3
	≥ 12	0.7	0.7	0.7	0.7	0.8	0.9	1.1
 OCTAGON	All values	1.0	1.0	1.1	1.2	1.2	1.3	1.4
 HEXAGON	All values	1.0	1.1	1.2	1.3	1.4	1.4	1.5

taking into account the average height of surface roughness ε. When the length is finite the values obtained from Fig. 5 shall be reduced by the multiplication factor K (*see* Table 28 and Annex D).

7.4.2.3 *Free standing walls and hoardings*

Force coefficients for free standing walls and hoardings shall be as given in Table 26.

To allow for oblique winds, the design shall also be checked for net pressure normal to the surface varying linearly from a maximum of 1.7 C_f at the windward edge to 0.44 C_f at the leeward edge.

The wind load on appurtenances and supports for hoardings shall be accounted for separately by using the appropriate net pressure coefficients. Allowance shall be made for shielding effects of one element on another.

7.4.2.4. *Solid circular shapes mounted on a surface*

The force coefficients for solid circular shapes mounted on a surface shall be as given in Table 27.

7.4.3 *Force Coefficients for Unclad Buildings*

7.4.3.1 This section applies to permanently unclad buildings and to frameworks of buildings while temporarily unclad. In the case of buildings whose surfaces are well-rounded, such as those with elliptic, circular or oval cross-sections, the total force can be more at a wind speed much less than maximum due to transition in the nature of boundary layer on them. Although this phenomenon is well known in the case of circular cylinders, the same phenomenon exists in the case of many other well-rounded structures, and this possibility must be checked.

7.4.3.2 *Individual members*

a) The force coefficient given in Table 29 refers to members of infinite length. For members of finite length, the coefficients should be multiplied by a factor K that depends on the ratio l/b where l is the length of the member and b is the width across the direction of wind. Table 28 gives the required values of K. The following special cases must be noted while estimating K.

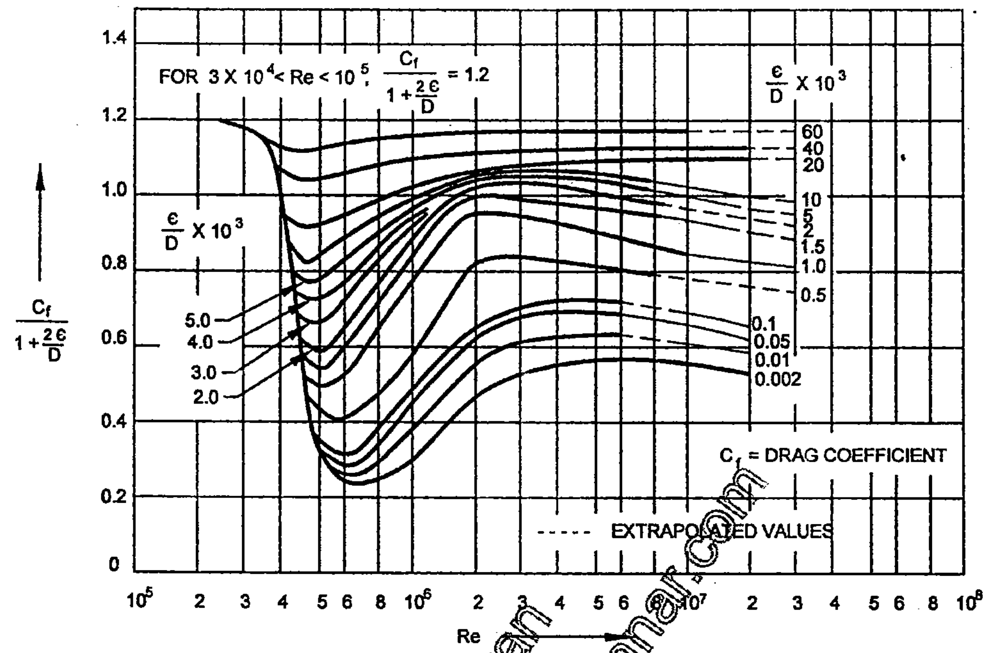
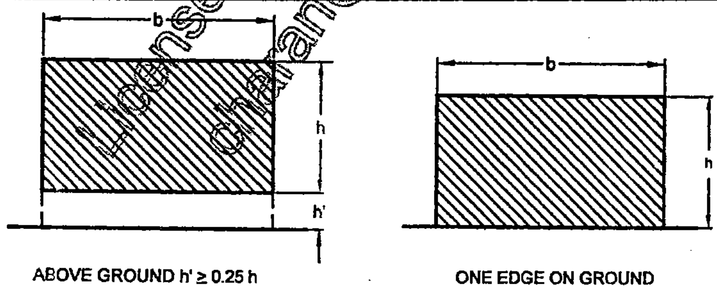


FIG. 5 VARIATION OF $\frac{C_f}{1+\frac{2\varepsilon}{D}}$ WITH $R_e > 3 \times 10^4$ FOR CIRCULAR SECTIONS

Table 26 Force Coefficients for Low Walls or Hoardings (< 15m High)

(*Clause* 7.4.2.2)



(WIND NORMAL TO FACE)

WIDTH TO HEIGHT RATIO, *b/h*		DRAG COEFFICIENT C_f
WALL ABOVE GROUND	WALL ON GROUND	
FROM 0.5 TO 6	FROM 1 TO 12	1.2
10	20	1.3
16	32	1.4
20	40	1.5
40	80	1.75
60	120	1.8
80 OR MORE	160 OR MORE	2.0

1) when any member abuts on to a plate or wall in such a way that free flow of air around that end of the member is prevented, then the ratio of l/b shall be doubled for the purpose of determining *K*; and
2) when both ends of a member are so obstructed, the ratio shall be taken as infinity for the purpose of determining *K*.

b) *Flat-sided members* — Force coefficients for wind normal to the longitudinal axis of flat-sided structural members shall be as given in Table 29.

The force coefficients are given for two mutually perpendicular directions relative to a reference axis on the structural member. They are denoted by C_{fn} and C_{ft} and give the forces normal and transverse respectively, to the reference plane as shown in Table 29.

Table 27 Force Coefficients for Solid Shapes Mounted on a Surface
(*Clause* 7.4.2.4)

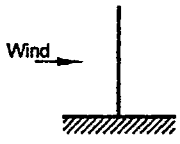
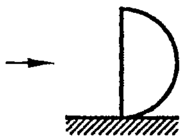
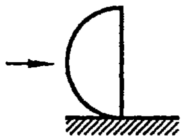
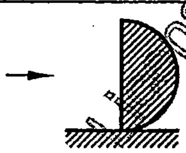
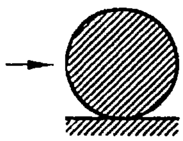
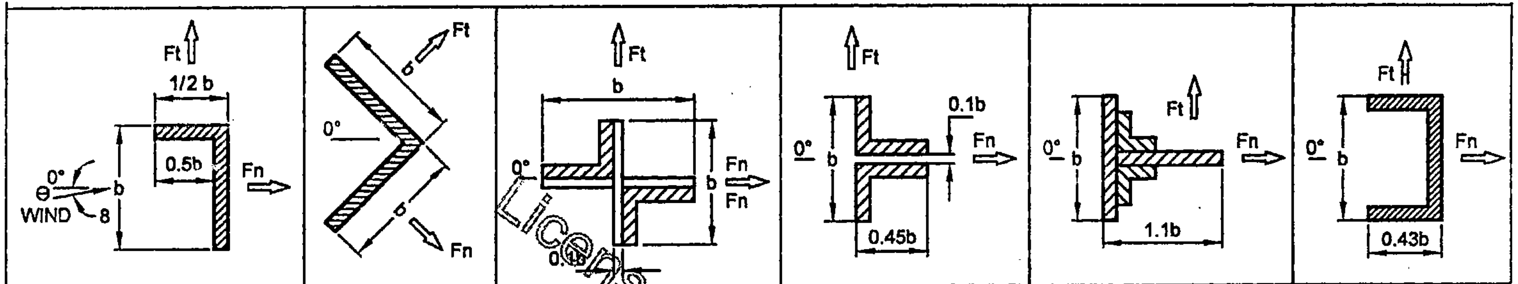
SIDE ELEVATION	DESCRIPTION OF SHAPE	C_f
	CIRCULAR DISC	1.2
	HEMISPHERICAL BOWL	1.4
	HEMISPHERICAL BOWL	0.4
	HEMISPHERICAL SOLID	1.2
	SPHERICAL SOLID	0.5 FOR $V_z D < 7$ 0.2 FOR $V_z D \geq 7$

Table 28 Reduction Factor K for Individual Members
[(*Clauses* 7.4.2.2, 7.4.3.2(a)]

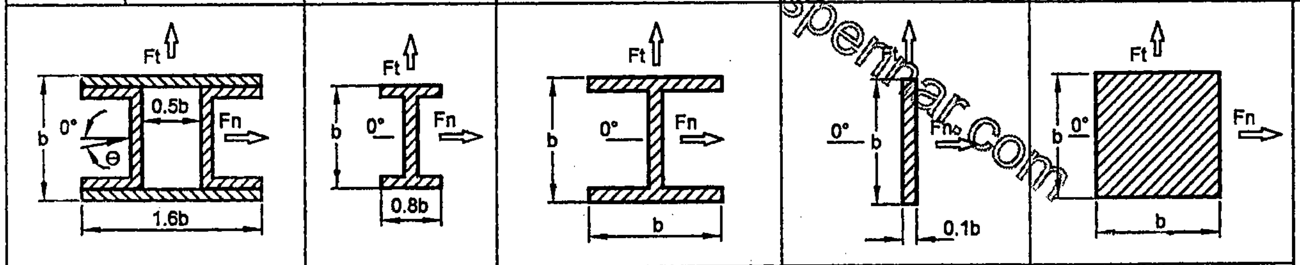
Sl No.	l/b or l/D	2	5	10	20	40	50	100	∞
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Circular cylinder, subcritical flow	0.58	0.62	0.68	0.74	0.82	0.87	0.98	1.00
ii)	Circular cylinder, supercritical flow ($D\,\bar{U}_z \geq 6\,m^2/s$)	0.80	0.80	0.82	0.90	0.98	0.99	1.00	1.00
iii)	For plate perpendicular to wind ($b\,\bar{U}_z \geq 6\,m^2/s$)	0.62	0.66	0.69	0.81	0.87	0.90	0.95	1.00

Table 29 Force Coefficients C_f for Individual Structural Members of Infinite Length

[*Clause* 7.4.3.2(b)]



θ DEGREE	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}
0	+ 1.9	+ 0.95	+ 1.8	+ 1.8	+ 1.75	+ 0.1	+ 1.6	0	+ 2.0	0	+ 2.05	0
45	+ 1.8	+ 0.8	+ 2.1	+ 1.8	+ 0.85	+ 0.85	+ 1.5	- 0.1	+ 1.2	+ 0.9	+ 1.85	+ 0.6
90	+ 2.0	+ 1.7	- 1.9	- 1.0	+ 0.1	+ 1.75	- 0.95	+ 0.7	- 1.6	+ 2.15	0	+ 0.6
135	- 1.8	- 0.1	- 2.0	+ 0.3	- 0.75	+ 0.75	- 0.5	+ 1.05	- 1.1	+ 2.4	- 1.6	+ 0.4
180	- 2.0	+ 0.1	- 1.4	- 1.4	- 1.75	- 0.1	- 1.5	0	- 1.7	+ 2.1	- 1.8	0



θ DEGREE	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}
0	+ 1.4	0	+ 2.05	0	+ 1.6	0	+ 2.0	0	+ 2.0	0
45	+ 1.2	+ 1.6	+ 1.95	+ 0.6	+ 1.5	+ 1.5	+ 1.8	+ 0.1	+ 1.55	+ 1.55
90	0	+ 2.2	+ 0.5	+ 0.9	0	+ 1.9	0	+ 0.1	0	+ 2.0

Normal force, $F_n = (C_{fn}\, p_d\, K)/b$

Transverse force, $F_t = (C_{ft}\, p_d\, K)/b$

c) *Circular sections* — Force coefficients for members of circular section shall be as given in Table 25 *see* also Annex D.

d) Force coefficients for wires and cables shall be as given in Table 30 according to the diameter (*D*), the design wind speed (V_d) and the surface roughness.

7.4.3.3 *Single frames*

Force coefficients for a single frame having either,

a) all flat sided members; or
b) all circular members in which all the members of the frame have either:
   1) $D\,\bar{V}_d$ less than 6 m²/s, or
   2) $D\,\bar{V}_d$ more than or equal to 6 m²/s,

shall be as given in Table 31 according to the type of the member, the diameter (D), the design hourly mean wind speed ($\bar{V}_d$) and the solidity ratio (Φ).

Force coefficients for a single frame not complying with the above requirements shall be calculated as follows:

$$C_f = \gamma C_{f_{super}} + (1-\gamma)\frac{A_{cir\,sub}}{A_{sub}}C_{f_{sub}} + (1-\gamma)\frac{A_{flat}}{A_{sub}}C_{f_{flat}}$$

where

$C_{f\,super}$ = force coefficient for the supercritical circular members as given in Table 31 or Annex D,

$C_{f\,sub}$ = force coefficient for subcritical circular members as given in Table 31or Annex D,

$C_{f\,flat}$ = force coefficient for the flat sided members as given in Table 31,

$A_{circ\,sub}$ = effective area of subcritical circular members,

A_{flat} = effective area of flat-sided members,

A_{sub} = $A_{circ\,sub} + A_{flat}$, and

γ = (Area of the frame in a supercritical flow)/ A_e

7.4.3.4 *Multiple frame buildings*

This section applies to structures having two or more parallel frames where the windward frames may have a shielding effect upon the frames to leeward side. The windward frame and any unshielded parts of other frames shall be calculated in accordance with **7.4.3.3**, but the wind load on the parts of frames that are sheltered should be multiplied by a shielding factor which is dependent upon the solidity ratio of the windward frame, the types of members comprising the frame and the spac-ing ratio of the frames. The values of the shielding factors are given in Table 32.

Table 30 Force Coefficients for Wires and Cables (L/D = 100)
[*Clause* 7.4.3.2(d)]

Sl No.	Flow Regime	Force Coefficient, C_f for			
		Smooth Surface	Moderately Smooth Wire (Galvanized or Painted)	Fine Stranded Cables	Thick Stranded Cables
(1)	(2)	(3)	(4)	(5)	(6)
i)	$D\,\bar{V}_d < 6$ m²/s	1.2	1.2	1.2	1.3
ii)	$D\,\bar{V}_d \geq 6$ m²/s	0.5	0.7	0.9	1.1

Table 31 Force Coefficients for Single Frames
(*Clause* 7.4.3.3)

Solidity Ratio	Force Coefficient C_f for		
	Flat Sided Members	Circular sections	
		Subcritical Flow ($D\bar{V}_d$ < 6 m²/s)	Super Critical Flow ($D\ \bar{V}_d$ 6 m²/s)
(1)	(2)	(3)	(4)
0.1	1.9	1.2	0.7
02	1.8	1.2	0.8
0.3	1.7	1.2	0.8
0.4	1.7	1.1	0.8
0.5	1.6	1.1	0.8
0.75	1.6	1.5	1.4
1.00	2.0	2.0	2.0

NOTE — Linear interpolation between the values is permitted.

Table 32 Shielding Factor *H* for Multiple Frames

(*Clause* 7.4.3.4)

Effective Solidity Ratio Φ_e	Frame Spacing Ratio				
	< 0.5	1.0	2.0	4.0	> 8.0
(1)	(2)	(3)	(4)	(5)	(6)
0	1.0	1.0	1.0	1.0	1.0
0.1	0.9	1.0	1.0	1.0	1.0
0.2	0.8	0.9	1.0	1.0	1.0
0.3	0.7	0.8	1.0	1.0	1.0
0.4	0.6	0.7	1.0	1.0	1.0
0.5	0.5	0.6	0.9	1.0	1.0
0.7	0.3	0.6	0.8	0.9	1.0
1.0	0.3	0.6	0.6	0.8	1.0

NOTE — Linear interpolation between the values is permitted.

Where there are more than two frames of similar geometry and spacing, the wind load on the third and subsequent frames should be taken as equal to that on the second frame. The loads on the various frames shall be added to obtain total load on the structure.

a) The frame spacing ratio is equal to the centre to centre distance between the frames, beams or girders divided by the least overall dimension of the frames, beam or girder measured in a direction normal to the direction of wind. For triangular framed structures or rectangular framed structures diagonal to the wind, the spacing ratio should be calculated from the mean distance between the frames in the direction of the wind.

b) Effective solidity ratio, Φ_e:

$\Phi_e = \Phi$ for flat-sided members.

Φ_e is to be obtained from Fig. 6 for members of circular cross-sections.

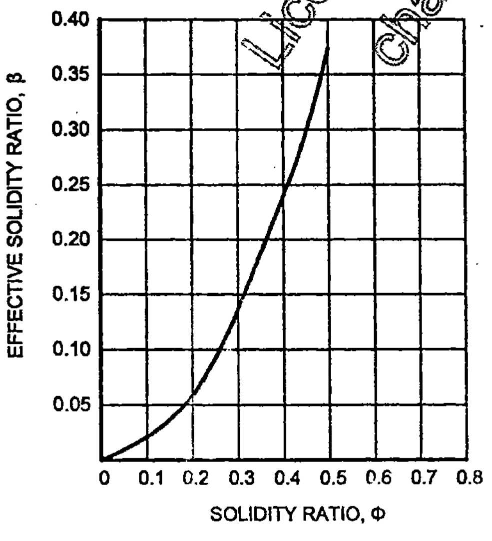


FIG. 6 EFFECTIVE SOLIDITY RATIO, FOR CIRCULAR SECTION MEMBERS

7.4.3.5 *Lattice towers*

a) Force coefficient for lattice towers of square or equilateral triangle section with flat-sided members for wind blowing against any face shall be as given in Table 33.

b) For square lattice towers with flat-sided members the maximum load, which occurs when the wind blows into a corner, shall be taken as 1.2 times the load for the wind blowing against a face.

c) For equilateral triangle lattice towers with flat-sided members, the load may be assumed to be constant for any inclination of wind to a face.

d) Force coefficients for lattice towers of square section with circular members, all in the same flow regime, may be as given in Table 34.

e) Force coefficients for lattice towers of equilateral-triangle section with circular members all in the same flow regime may be as given in Table 35.

7.4.3.6 *Tower appurtenances*

The wind loading on tower appurtenances, such as ladders, conduits, lights, elevators, etc, shall be calculated using appropriate net pressure coefficients

Table 33 Overall Force Coefficients for Towers Composed of Flat Sided Members

[*Clause* 7.4.3.5(a)]

Sl No.	Solidity Ratio Φ	Force Coefficient	
		Square Towers	Equilateral Triangular Towers
(1)	(2)	(3)	(4)
i)	< 0.1	3.8	3.1
ii)	0.2	3.3	2.7
iii)	0.3	2.8	2.3
iv)	0.4	2.3	1.9
v)	0.5	2.1	1.5

Table 34 Overall Force Coefficients for Square Towers Composed of Circular Members
[(*Clause* 7.4.3.5 (d)]

Sl No.	Solidity Ratio of Front Face Φ	Force Coefficient			
		Subcritical Flow ($D\ \bar{V}_d < 6$ m²/s)		Supercritical Flow ($D\ \bar{V}_d \geq 6$ m²/s)	
		Onto Face	Onto Corner	Onto Face	Onto Corner
(1)	(2)	(3)	(4)	(5)	(6)
i)	< 0.05	2.4	2.5	1.1	1.2
ii)	0.1	2.2	2.3	1.2	1.3
iii)	0.2	1.9	2.1	1.3	1.6
iv)	0.3	1.7	1.9	1.4	1.6
v)	0.4	1.6	1.9	1.4	1.6
vi)	0.5	1.4	1.9	1.4	1.6

for these elements. Allowance may be made for shielding effect from other elements.

8 INTERFERENCE EFFECTS

8.1 General

Wind interference is caused by modification in the wind characteristics produced by the obstruction caused by an object or a structure in the path of the wind. If such wind strikes another structure, the wind pressures usually get enhanced, though there can also be some shielding effect between two very closely spaced buildings/structures. The actual phenomenon is too complex to justify generalization of the wind forces/pressures produced due to interference which can only be ascertained by detailed wind tunnel/CFD studies. However, some guidance can be provided for the purpose of preliminary design. To account for the effect of interference, a wind interference factor (IF) has been introduced as a multiplying factor to be applied to the design wind pressure/force. Interference effects can be more significant for tall buildings. The interference factor is defined as the ratio between the enhanced pressure/force in the grouped configuration to the corresponding pressure/force in isolated configuration. Since the values of IF can vary considerably based on building geometry and location, the given values of IF are a kind of median values and are meant only for preliminary design estimates. The designer is advised that for assigning values of IF for final design particularly for tall buildings, specialist literature be consulted or a wind tunnel study carried out.

8.2 Roof of Low-Rise Buildings

Maximum increase in wind force on the roof due to interference from similar buildings in case of closely spaced low-rise buildings with flat roofs may be up to 25 percent for c/c distance (x) between the buildings of 5 times the dimension (b) of the interfering building normal to the direction of wind (*see* Fig. 7). Interference effect beyond 20b may be considered to be negligible. For intermediate spacing linear interpolation may be used.

8.3 Tall Buildings

Based on studies on tall rectangular buildings, Fig. 8 gives various zones of interference. The interference factor (IF), which needs to be considered as a multiplication factor for wind loads corresponding to

Table 35 Overall Force Coefficients for Equilateral Triangular Towers Composed of Circular Members
[*Clause* 7.4.3.5(e)]

Sl No.	Solidity Ratio of Front Face Φ	Force Coefficient	
		Subcritical Flow ($D\ \bar{V}_d < 6$ m²/s) All wind Directions	Supercritical Flow ($D\ \bar{V}_d \geq 6$ m²/s) All wind Directions
(1)	(2)	(3)	(4)
i)	< 0.05	1.8	0.8
ii)	0.1	1.7	0.8
iii)	0.2	1.6	1.1
iv)	0.3	1.5	1.1
v)	0.4	1.5	1.1
vi)	0.5	1.4	1.2

isolated building, may be assumed as follows, for preliminary estimate of the wind loads under interference caused by another interfering tall building of same or more height located at different zones Z1 to Z4 as shown in Fig. 8:

Zone	Z1	Z2	Z3	Z4
IF	1.35	1.25	1.15	1.07

The interference effect due to buildings of height less than one-third of the height of the building under consideration may be considered to be negligible while for interference from a building of intermediate height, linear interpolation may be used between one-third and full height.

9 DYNAMIC EFFECTS

9.1 General

Flexible slender structures and structural elements shall be investigated to ascertain the importance of wind induced oscillations or excitations in along wind and across wind directions.

In general, the following guidelines may be used for examining the problems of wind-induced oscillations.

a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0, or

b) Buildings and structures whose natural frequency in the first mode is less than 1.0 Hz.

Any building or structure which satisfies either of the above two criteria shall be examined for dynamic effects of wind.

NOTES

1 The fundamental time period (T) may either be established by experimental observations on similar buildings or calculated by any rational method of analysis. In the absence of such data, T may be determined as follows for multi-storied buildings:

a) For moment resisting frames without bracings or shear walls resisting the lateral loads,

$T = 0.1\ n$

where

n = number of storeys including basement storeys; and

b) for all others

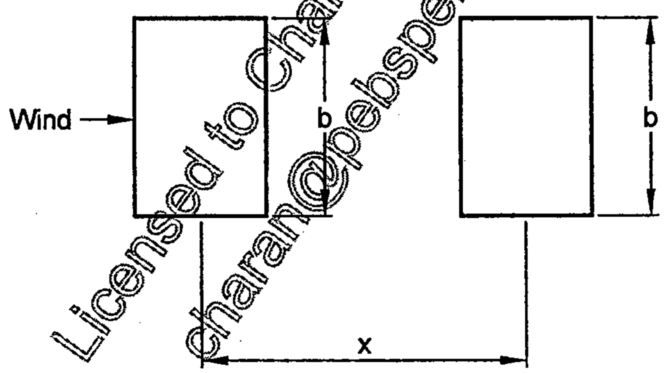
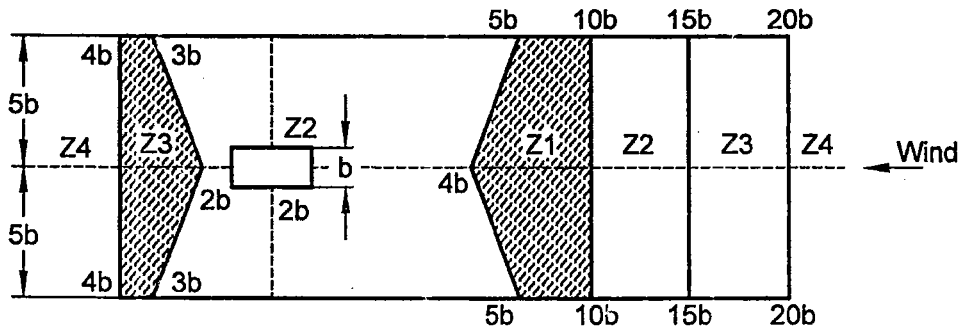


FIG. 7 LOW-RISE BUILDINGS IN TANDEM CAUSING INTERFERENCE EFFECT



Z1 - Zone of high interference

Z2 - Zone of moderate interference

Z3 - Zone of low interference

Z4 - Zone of insignificant interference

FIG. 8 INTERFERENCE ZONES FOR TALL RECTANGULAR BUILDINGS OF SAME OR GREATER HEIGHT (CLAUSE 7.3)

$$T = \frac{0.09H}{\sqrt{d}}$$

where

H = total height of the main structures of the building, in m; and

d = maximum base dimension of building in meters in a direction parallel to the applied wind force.

2 If preliminary studies indicate that wind-induced oscillations are likely to be significant, investigations should be pursued with the aid of analytical methods or if necessary, by means of wind tunnel tests on models.

3 Across-wind motions may be due to lateral gustiness of the wind. unsteady wake flow (for example, vortex shedding), negative aerodynamic damping or due to a combination of these effects. These cross-wind motions may become critical in the design of tall buildings/structures.

4 Motions in the direction of wind (known also as buffeting) are caused by fluctuating wind force associated with gust. The excitation depends on gust energy available at the resonant frequency.

5 The eddies shed from an upstream body may intensify motion in the direction of the wind and may also affect cross-wind motion.

6 The designer should also be aware of the following three forms of wind-induced motion which are characterized by increasing amplitude of oscillation with the increase of wind speed.

i) Galloping — Galloping is transverse oscillations of some structures due to the development of aerodynamic forces which are in phase with the motion. It is characterized by the progressively increasing amplitude of transverse vibration with increase of wind speed. The cross-sections which are particularly prone to this type of excitation include the following:

   1) All structures with non-circular cross-sections, such as triangular, square, polygons, as well as angles, crosses and T sections.

   2) Twisted cables and cables with ice encrustations.

ii) Flutter — Flutter is unstable oscillatory motion of a structure due to coupling between aerodynamic force and elastic deformation of the structure. Perhaps the most common form is oscillatory motion due to combined bending and torsion. Although oscillatory motion in each degree of freedom may be damped, instability can set in due to energy transfer from one mode of oscillation to another and the structure is seen to execute sustained or divergent oscillations with a type of motion which is a combination of the individual modes of vibration. Such energy transfer takes place when the natural frequencies of modes taken individually are close to each other (ratio being typically less than 2.0). Flutter can set in at wind speeds much less than those required for exciting the individual modes of motion. Long span suspension bridge decks or any member of a structure with large values of d/t (where d is the length of the member and t is its dimension parallel to wind stream) are prone to low speed flutter. Wind tunnel testing is required to determine critical flutter speeds and the likely structural response. Other types of flutter are single degree of freedom stall flutter, torsional flutter, etc.

iii) Ovalling — Thin walled structures with open ends at one or both ends such as oil storage tanks and natural draught cooling towers in which the ratio of the diameter or minimum lateral dimension to the wall thickness is of the order of 100 or more are prone to ovalling oscillations. These oscillations are characterized by periodic radial deformation of the hollow structure.

7 Buildings and structures that may be subjected to significant wind excited oscillations. It is to be noted that wind induced oscillations may occur at wind speeds lower than the design wind speed.

8 Analytical methods for the evaluation of response of dynamic structures to wind loading can be found in the special publications.

9 In assessing wind loads due to such dynamic phenomenon as galloping, flutter and ovalling, in the absence of the required information either in the special publications or other literature, expert advice should be sought including experiments on models in boundary layer wind tunnels.

9.2 Motion due to Vortex Shedding

9.2.1 *Slender Structures*

For a structure, the vortex shedding frequency f_s shall be determined by the following formula:

$$f_s = \frac{S_t \bar{V}_{z,H}}{b}$$

where

S_t = Strouhal number,

$\bar{V}_{z,H}$ = hourly mean wind speed at height z, and

b = breadth of a structure or structural member normal to the wind direction in the horizontal plane

a) *Circular structures* — For structures of circular in cross-section:

S_t = 0.20 for $D\bar{V}_{z,H}$ less than 6 m²/s, and

= 0.25 for $D\bar{V}_{z,H}$ more than or equal to 6 m²/s.

b) *Rectangular structures* — For structures of rectangular cross-section:

$S_t = 0.10$

NOTES

1 Significant cross wind motions may be produced by vortex shedding if the natural frequency of the structure or structural element is equal to the frequency of the vortex shedding within the range of expected wind speeds. In such cases, further analysis should be carried out on the basis of special publications.

2 Unlined welded steel chimney stacks and similar structures are prone to excitations by vortex shedding.

3 Intensification of the effects of periodic vortex shedding has been reported in cases where two or more similar structures are located in close proximity, for example at less than 20b apart, where b is the dimension of the structure normal to the wind.

4 The formulae given in 8.2.1 (a) is valid for infinitely long cylindrical structures. The value of S_t decreases slowly as the ratio of length to maximum transverse width decreases, the reduction being up to about half the value, if the structure is only three times higher than its width. Vortex shedding need not be considered if the ratio of length to maximum transverse dimension is less than 2.0.

10 DYNAMIC WIND RESPONSE

10.1 General

Tall buildings which are 'wind sensitive' shall be designed for dynamic wind loads. Hourly mean wind speed is used as a reference wind speed to be used in dynamic wind analysis. For calculation of along wind loads and response (bending moments, shear forces, or tip deflections) the Gust Factor (GF) method is used as specified in **10.2**. The across wind design peak base overturning moment and tip deflection shall be calculated using **10.3**.

10.2 Along Wind Response

For calculation of along-wind load effects at a level s on a building/structure, the design hourly mean wind pressure at height z shall be multiplied by the Gust Factor (GF). This factor is dependent on both the overall height h and the level s under consideration (*see* Fig. 9). For calculation of base bending moment and deflection at the top of the building/structure s should be taken as zero.

The design peak along wind base bending moment (M_a) shall be obtained by summing the moments resulting from design peak along wind loads acting at different heights, z, along the height of the building/structure and can be obtained from,

$$M_a = \Sigma F_z Z$$

$$F_z = C_{f,z} A_z \bar{p}_d G$$

where

F_z = design peak along wind load on the building/structure at any height z

A_z = the effective frontal area of the building/structure at any height z, in m²

$\bar{p}_d$ = design hourly mean wind pressure corresponding to $\bar{V}_{z,d}$ and obtained as $0.6\,\bar{V}_{z,d}^2$ (N/m²)

$\bar{V}_{z,d}$ = design hourly mean wind speed at height z, in m/s (see **6.4**)

$C_{f,z}$ = the drag force coefficient of the building/structure corresponding to the area A_z

G = Gust Factor and is given by.

$$= 1 + r\sqrt{\left[g_v^2 B_s (1+g)^2 + \frac{H_s g_R^2 SE}{\beta}\right]}$$

where

r = roughness factor which is twice the longitudinal turbulence intensity, $I_{h,i}$ (see **6.5**),

g_v = peak factor for upwind velocity fluctuation,

= 3.0 for category 1 and 2 terrains, and

= 4.0 for category 3 and 4 terrains,

B_s = background factor indicating the measure of slowly varying component of fluctuating wind load caused by the lower frequency wind speed variations

$$\frac{1}{\left[1 + \frac{\sqrt{0.26(h-s)^2 + 0.46 b_{sh}^2}}{L_h}\right]}$$

where

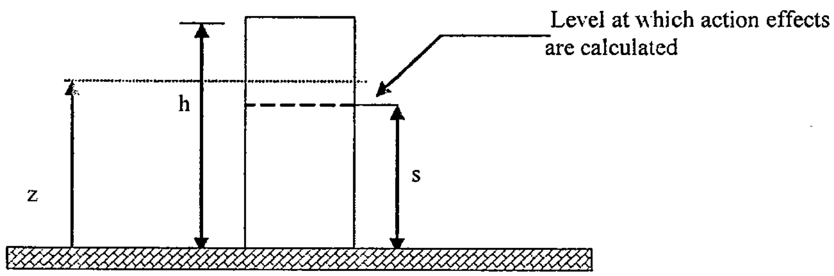
b_{sh} = average breadth of the building/structure between heights s and h

L_h = measure of effective turbulence length scale at the height, h, in m

$$= 85\left(\frac{h}{10}\right)^{0.25} \quad \text{for terrain category 1 to 3}$$

$$= 70\left(\frac{h}{10}\right)^{0.25} \quad \text{for terrain category 4}$$

ϕ = factor to account for the second order turbulence intensity



NOTE — $0 < s < h$, and $s < z < h$

FIG. 9 NOTATIONS FOR HEIGHTS

$= \frac{g_v I_{h,i} \sqrt{B_s}}{2}$

$I_{h,i}$ = turbulence intensity at height h in terrain category i

H_s = height factor for resonance response

$= 1 + \left(\frac{s}{h}\right)^2$

S = size reduction factor given by:

$$= \frac{1}{\left[1 + \frac{3.5 f_a h}{\overline{V}_{h,d}}\right]\left[1 + \frac{4 f_a b_{0h}}{\overline{V}_{h,d}}\right]}$$

where

b_{0h} = average breadth of the building/structure between 0 and h.

E = spectrum of turbulence in the approaching wind stream

$$= \frac{\pi N}{\left(1 + 70.8 N^2\right)^{5/6}}$$

where

N = effective reduced frequency

$= \frac{f_a L_h}{\overline{V}_{h,d}}$

f_a = first mode natural frequency of the building/structure in along wind direction, in Hz

$\overline{V}_{h,d}$ = design hourly mean wind speed at height, h in m/s (*see* **6.4**)

β = damping coefficient of the building/structure (*see* Table 36)

g_R = peak factor for resonant response

$= \sqrt{\left[2 \ln\left(3\,600 f_a\right)\right]}$

Table 36 Suggested Values of Structural Damping Coefficients

(*Clause* 10.2)

Sl No. (1)	Kind of Structure (2)	Damping Coefficient, β (3)
i)	Welded steel structures	0.010
ii)	Bolted steel structures/RCC structures	0.020
iii)	Prestressed concrete structures	0.016

10.2.1 *Peak Acceleration in Along Wind Direction*

The peak acceleration at the top of the building/structure in along wind direction ($\hat{\ddot{x}}$ in m/s^2) is given by the following equation:

$$\hat{\ddot{x}} = \left(2\pi f_a\right)^2 \overline{x}\, g_R r \sqrt{\frac{SE}{\beta}}$$

where

$\overline{x}$ = mean deflection at the position where the acceleration is required. Other notations are same as given in **10.2**.

For computing the peak acceleration in the along wind direction, a mean wind speed at the height of the building/structure, $\overline{V}_h$ corresponding to a 5 year mean return period shall be used. A reduced value of 0.011 is also suggested for the structural damping, β for reinforced concrete structures.

10.3 Across Wind Response

This section gives method for determining equivalent static wind load and base overturning moment in the across wind direction for tall enclosed buildings and towers of rectangular cross-section. Calculation of across wind response is not required for lattice towers.

The across wind design peak base bending moment M_c for enclosed buildings and towers shall be determined as follows:

$$M_c = 0.5 g_h \overline{p}_h b h^2 \left(1.06 - 0.06\,k\right) \sqrt{\left(\frac{\pi C_{fs}}{\beta}\right)}$$

where

g_h = a peak factor,

$= \sqrt{\left[2 \ln\left(36\,00 f_c\right)\right]}$ in cross wind direction;

$\overline{p}_h$ = hourly mean wind pressure at height h, in Pa;

b = the breadth of the structure normal to the wind, in m;

h = the height of the structure, in m;

k = a mode shape power exponent for representation of the fundamental mode shape as represented by:

$$\psi(z) = \left(\frac{z}{h}\right)^k$$

f_c = first mode natural frequency of the building/structure in across wind direction, in Hz.

The across wind load distribution on the building/structure can be obtained from M_c using linear distribution of loads as given below:

$$F_{z,c} = \left(\frac{3M_c}{h^2}\right)\left(\frac{z}{h}\right)$$

where $F_{z,c}$ = across wind load per unit height at height z.

10.3.1 *Peak Acceleration in Across Wind Direction*

The peak acceleration at the top of the building/structure in across-wind direction ($\hat{\ddot{y}}$ in m/s^2) with approximately constant mass per unit height shall be determined as follows:

$$\hat{\ddot{y}} = 1.5\frac{g_h \bar{p}_h b}{m_0}(0.76+0.24k)\sqrt{\left(\frac{\pi C_{fs}}{\beta}\right)}$$

Typical values of the mode shape power exponent, k are as follows:

a) uniform cantilever, $k = 1.5$
b) slender framed structure (moment resisting), $k = 0.5$
c) building with a central core and moment resisting façade, $k = 1.0$
d) lattice tower decreasing in stiffness with height, or a tower with a large mass at the top, $k = 2.3$

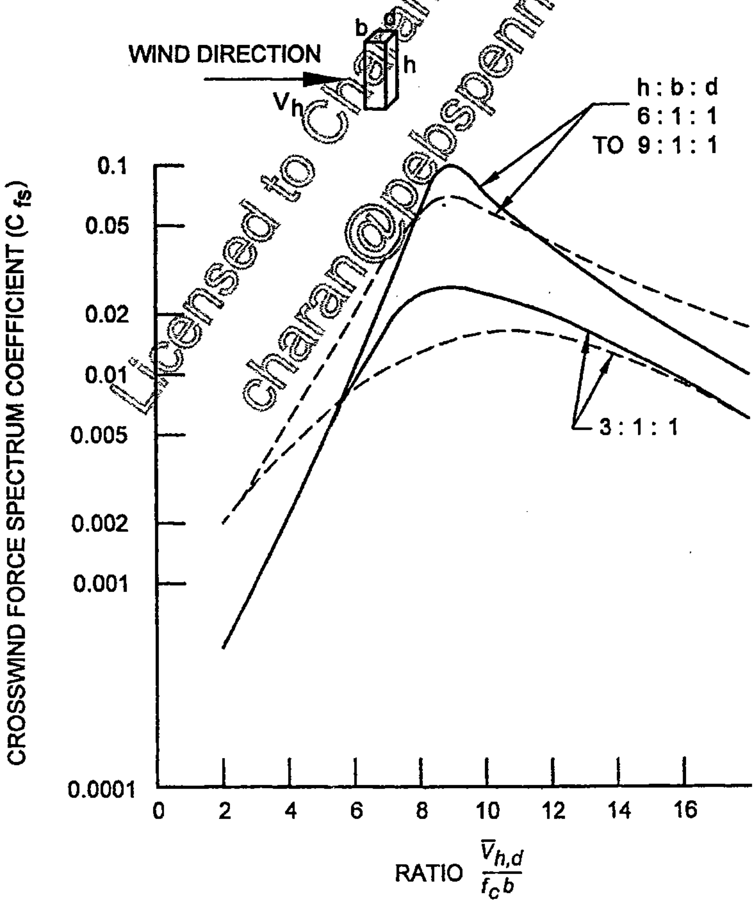
C_{fs} = across wind force spectrum coefficient generalized for a linear mode. (*see* Fig. 10 and Fig. 11).

β = damping coefficient of the building/structure (*see* Table 36).

m_0 = the average mass per unit height of the structure in, kg/m.

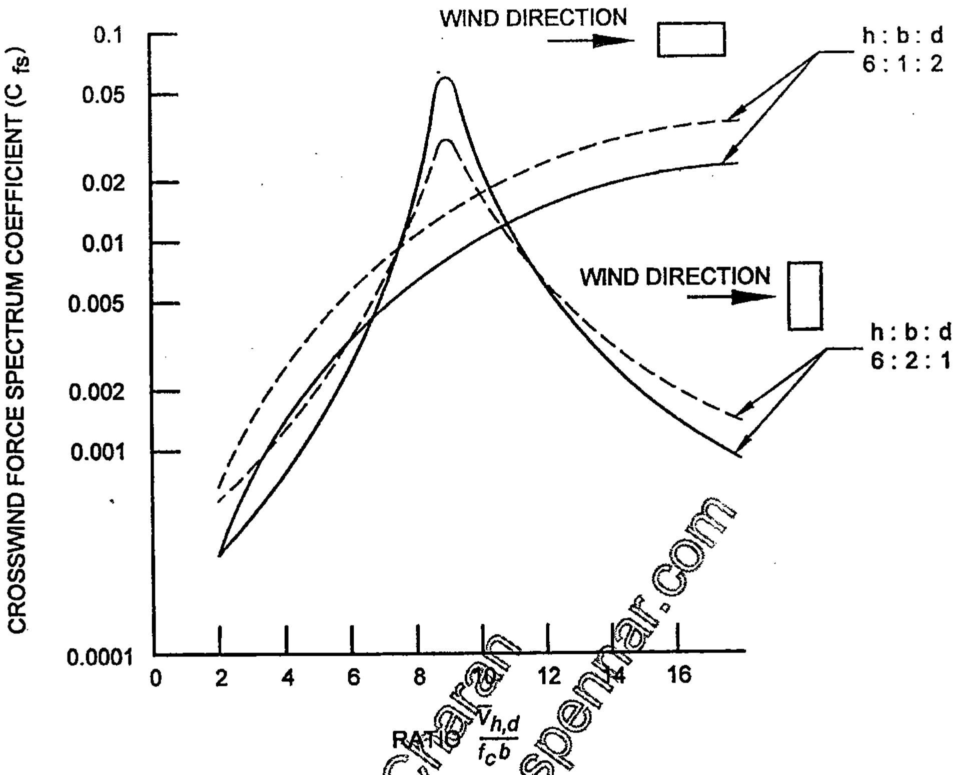
10.4 Combination of Along Wind and Across Wind Load Effects

The along wind and across wind loads have to be applied simultaneously on the building/structure during design.



Legend:
— Turbulence Intensity of 0.12 at 2/3 h
- - Turbulence Intensity of 0.20 at 2/3 h

FIG. 10 VALUES OF THE CROSS WIND FORCE SPECTRUM COEFFICIENT FOR SQUARE SECTION BUILDINGS



Legend:
— Turbulence Intensity of 0.12 at 2/3 h -- Turbulence Intensity of 0.20 at 2/3 h

FIG. 11 VALUES OF THE CROSS WIND FORCE SPECTRUM COEFFICIENT FOR 2:1 AND 1 : 2 RECTANGULAR SECTION BUILDINGS

ANNEX A

(*Clause* 6.2)

BASIC WIND SPEED AT 10 m HEIGHT FOR SOME IMPORTANT CITIES / TOWNS

City/Town	Basic wind Speed m/s	City/Town	Basic wind Speed m/s
Agra	47	Kanpur	47
Ahmedabad	39	Kohima	44
Ajmer	47	Kolkata	50
Almora	47	Kozhikode	39
Amritsar	47	Kurnool	39
Asansol	47	Lakshadweep	39
Aurangabad	39	Lucknow	47
Bahraich	47	Ludhiana	47
Bengaluru	33	Madurai	39
Barauni	47	Mandi	39
Bareilly	47	Mangalore	39
Bhatinda	47	Moradabad	47
Bhilai	39	Mumbai	44
Bhopal	39	Mysore	33
Bhubaneshwar	50	Nagpur	44
Bhuj	50	Nainital	47
Bikaner	47	Nasik	39
Bokaro	47	Nellore	50
Chandigarh	47	Panjim	39
Chennai	50	Patiala	47
Coimbatore	39	Patna	47
Cuttack	50	Puducherry	50
Darbhanga	55	Port Blair	44
Darjeeling	47	Pune	39
Dehradun	47	Raipur	39
Delhi	47	Rajkot	39
Durgapur	47	Ranchi	39
Gangtok	47	Roorkee	39
Guwahati	50	Rourkela	39
Gaya	39	Shimla	39
Gorakhpur	47	Srinagar	39
Hyderabad	44	Surat	44
Imphal	47	Tiruchirappalli	47
Jabalpur	47	Trivandrum	39
Jaipur	47	Udaipur	47
Jamshedpur	47	Vadodara	44
Jhansi	47	Varanasi	47
Jodhpur	47	Vijayawada	50
		Vishakapatnam	50

ANNEX B

[*Clause* 6.3.2.4 (b)(ii)]

CHANGES IN TERRAIN CATEGORIES

B-1 LOW TO HIGH TERRAIN CATEGORY NUMBER

In cases of transition from a low terrain category number (corresponding to a low terrain roughness) to a higher terrain category number (corresponding to a rougher terrain), the velocity profile over the rougher terrain shall be determined as follows:

a) Below height h_x, the velocities shall be determined in relation to the rougher terrain; and

b) Above height h_x, the velocities shall be determined in relation to the less rough (more distant) terrain.

B-2 HIGH TO LOW TERRAIN CATEGORY NUMBER

In cases of transition from a more rough to a less rough terrain, the velocity profile shall be determined as follows:

a) Above height h_x, the velocities shall be determined in accordance with the rougher (more distant) terrain; and

b) Below height h_x, the velocity shall be taken as the lesser of the following:

1) that determined in accordance with the less rough terrain, and

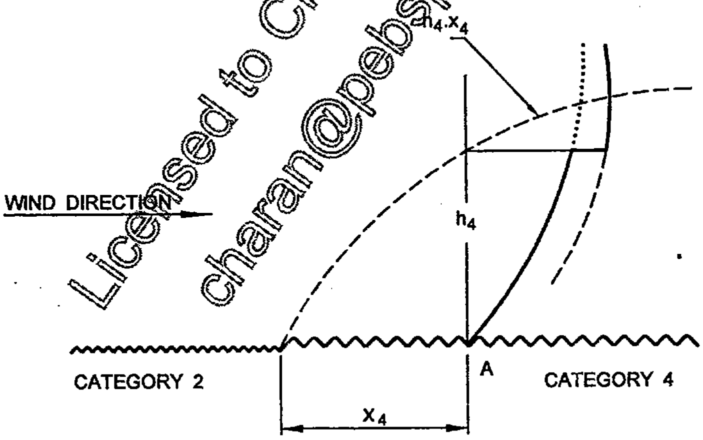
2) the velocity at height h_x as determined in relation to the rougher terrain

NOTE — Examples of determination of velocity profiles in the vicinity of a change in terrain category are shown in Figs.12a and 12b.

B-3 MORE THAN ONE CATEGORY

Terrain changes involving more than one category shall be treated in similar way to that described in **B-1** and **B-2**.

NOTE — Examples involving three terrain categories are shown in Fig. 12c.



x_4 = FETCH, h_4 = HEIGHT FOR CATEGORY 4

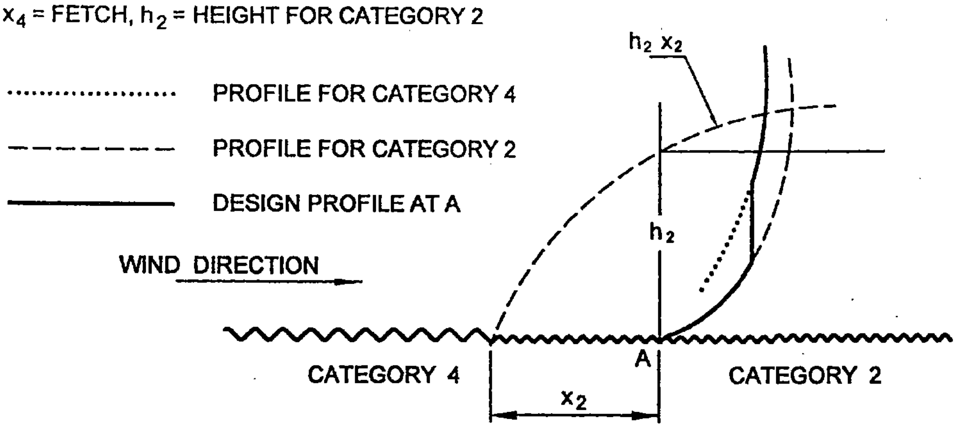
.... PROFILE FOR CATEGORY 4

- - - - - - - - PROFILE FOR CATEGORY 2

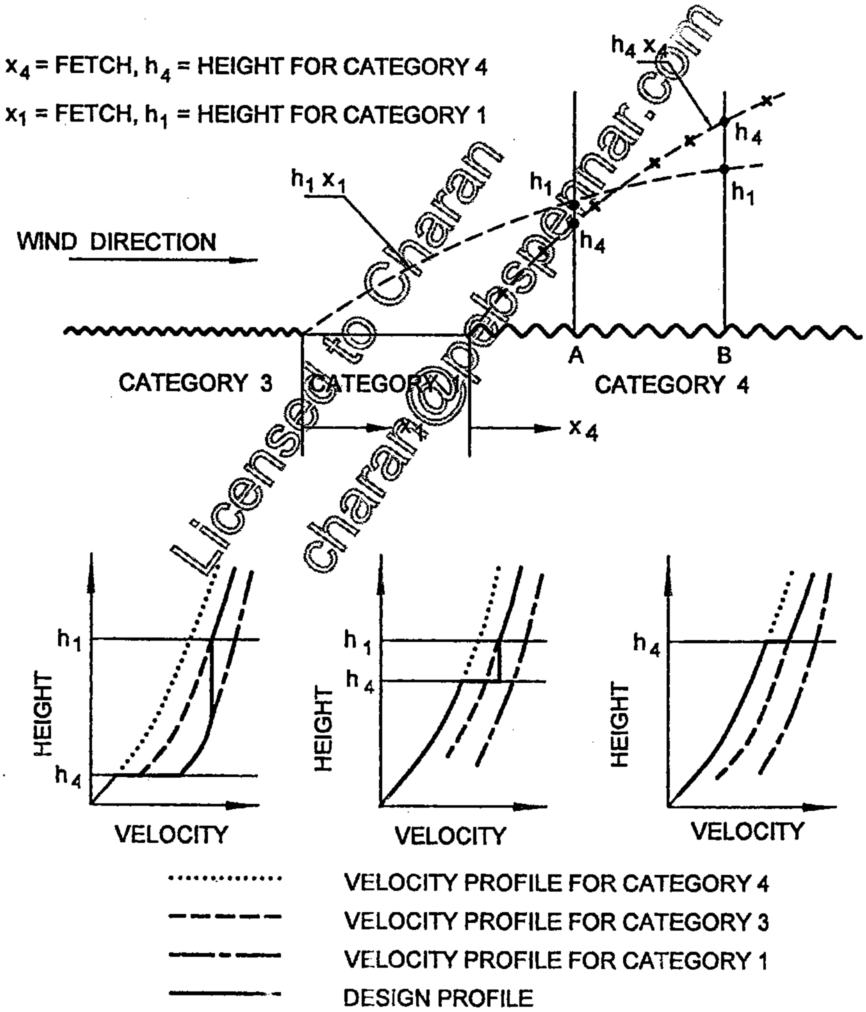
———— DESIGN PROFILE AT A

a) DETERMINATION OF VELOCITY PROFILE NEAR A CHANGE IN TERRAIN CATEGORY
(Less rough to more rough)

FIG. 12 VELOCITY PROFILES IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY



b) Determination of Velocity Profile Near a Change in Terrain Category (More rough to less rough)



c) Determination of Design Profile Involving more than One Change in Terrain Category

FIG. 12 VELOCITY PROFILES IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY

ANNEX C

(*Clause* 6.3.3.1)

EFFECT OF A CLIFF OR ESCARPMENT ON EQUIVALENT HEIGHT ABOVE GROUND (k_3 FACTOR)

C-1 The influence of the topographic feature is considered to extend 1.5 L_e upwind and 2.5 L_e downwind of the summit of crest of the feature where L_e is the effective horizontal length of the hill depending on slope as indicated below (see Fig. 13).

Slope	L_e
$3° < \theta_s \leq 17°$	L
$\theta_s > 17°$	$Z / 0.3$

where

L = actual length of the upwind slope in the wind direction,

Z = effective height of the topography feature, and

θ_s = upwind slope in the wind direction.

In case, the zone in downwind side of the crest of the feature is relatively flat ($\theta_s < 3°$) for a distance exceeding L_e, then the feature should be treated as an escarpment. Otherwise the feature should be treated as a hill or ridge. Examples of typical features are given in Fig. 13.

NOTES

1 No difference is made, in evaluating k_3 between a three dimensional hill and two dimensional ridge.

2 In undulating terrain, it is often not possible to decide whether the local topography to the site is significant in terms of wind flow. In such cases, the average value of the terrain upwind of the site for a distance of 5 km should be taken as the base level from wind to assess the height, Z, and the upwind slope θ, of the feature.

C-2 TOPOGRAPHY FACTOR, k_3

The topography factor k_3 is given by the following:

$$k_3 = 1 + C s_0$$

where C has the following values:

Slope	*C*
$3° < \theta_s \leq 17°$	1.2 (Z/L)
$\theta s > 17°$	0.36

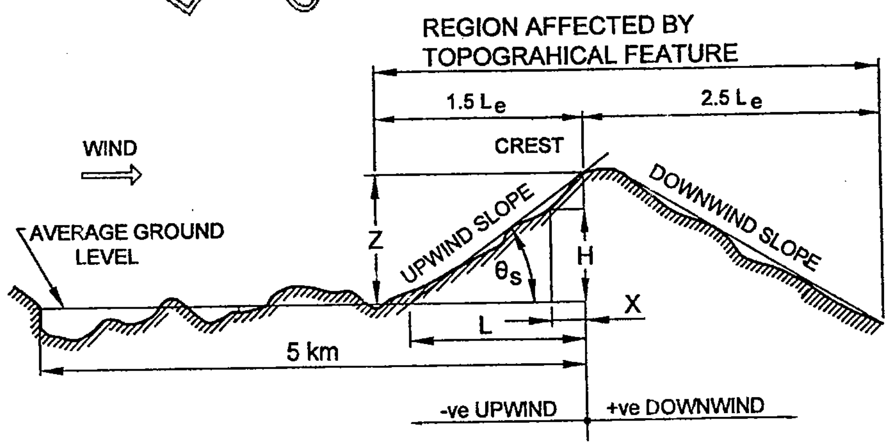
and s_0 is a factor derived in accordance with **C-2.1** appropriate to the height, H above mean ground level and the distance, x, from the summit or crest relative to the effective length, Le

C-2.1 The factor, s_0 should be determined from:

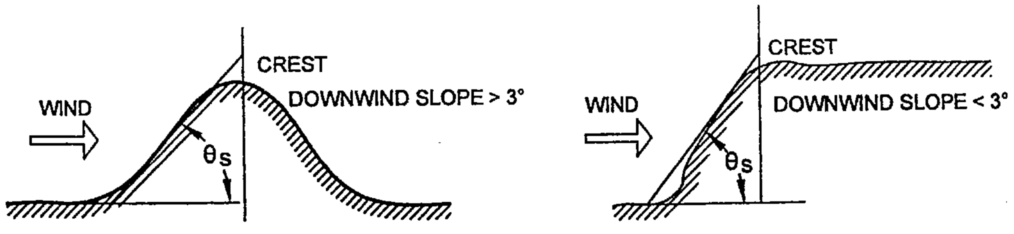
a) Fig. 14 for cliffs and escarpments, and

b) Fig. 15 for ridges and hills.

NOTE – Where the downwind slope of a hill or ridge is more than 3°, there will be large regions of reduced accelerations or even shelter and it is not possible to give general design rules to cater for these circumstances. Values of s_0 from Fig. 15 may be used as upper bound values.



13 (a) GENERAL NOTATIONS



13 (b) HILL AND RIDGE

13 (c) CLIFF AND ESCARPMENT

Fig. 13 Topographical Dimensions

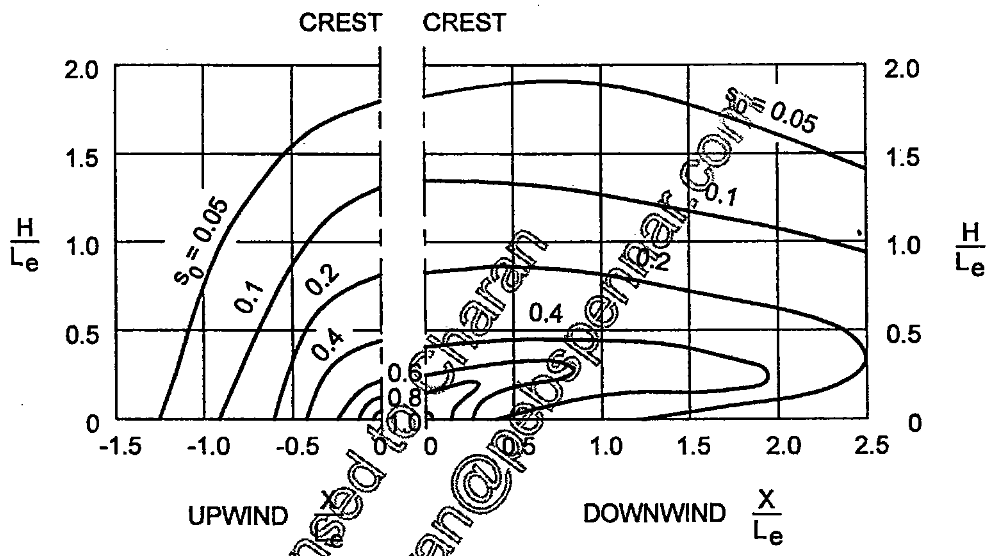


Fig. 14 Factor s for Ridge and Hill

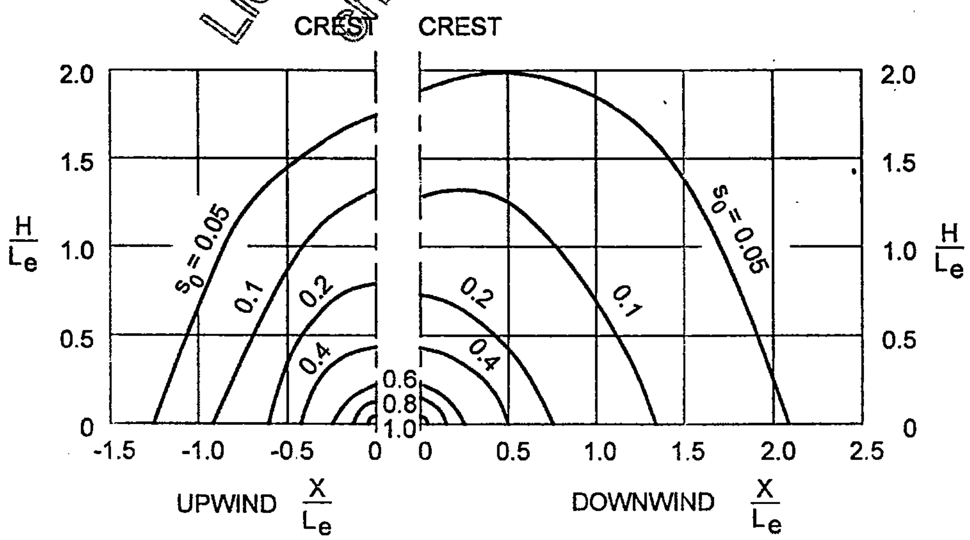


Fig. 15 Factor s for Cliff and Escarpment

ANNEX D

(*Clauses* 7.4.2.2, 7.4.3.2 *and* 7.4.3.3)

WIND FORCE ON CIRCULAR SECTIONS

D-1 The wind force on any object is given by:

$F = C_f A_e p_d$

where

C_f = force coefficient,

A_e = effective area of the object normal to the wind direction, and

p_d = design pressure of the wind.

For most shapes, the force coefficient remains approximately constant over the whole range of wind speeds likely to be encountered. However, for objects of circular cross-section, it varies considerably.

For a circular section, the force coefficient depends on the way in which the wind flows around it and is dependent upon the velocity and kinematic viscosity of the wind and diameter of the section. The force coefficient is usually quoted against a non-dimensional parameter, called the Reynolds number, which takes into account of the velocity and viscosity of the flowing medium (in this case the wind), and the member diameter.

Reynolds number, $Re = D\bar{V}_d / \nu$

where

D = diameter of the member

$\bar{V}_d$ = design hourly mean wind speed

ν = kinematic viscosity of the air which is 1.46 × 10^{-5} m^2/s at 15°C and standard atmospheric pressure.

Since in most natural environments likely to be found in India, the kinematic viscosity of the air is fairly constant, it is convenient to use $D\bar{V}_d$ as the parameter instead of Reynolds number and this has been done in this code.

The dependence of a circular section's force coefficient on Reynolds number is due to the change in the wake developed behind the body.

At a low Reynolds number, the wake is as shown in Fig. 16 and the force coefficient is typically 1.2. As Reynolds number is increased, the wake gradually changes to that shown in Fig. 17; that is, the wake width d_w decreases and the separation point denoted as sp, moves from front to the back of the body.

As a result, the force coefficient shows a rapid drop at a critical value of Reynolds number followed by a gradual rise as Reynolds number is increased still further.

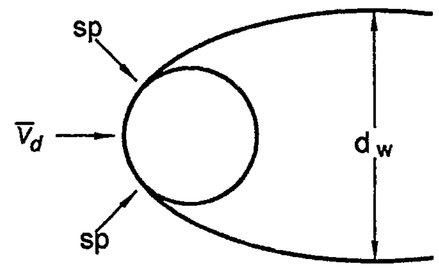


FIG. 16 WAKE IN SUB CRITICAL FLOW

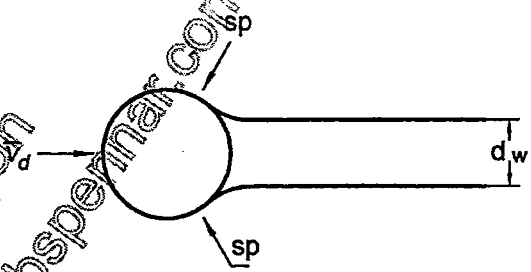


FIG. 17 WAKE IN SUPER CRITICAL FLOW

The variation of C_f with parameter $D\bar{V}_d$ is shown in Fig. 5 for infinitely long circular cylinders having various values of relative surface roughness (ε/D) when subjected to wind having an intensity and scale of turbulence typical of built-up urban areas. The curve for a smooth cylinder (ε/D) = 1 × 10^{-5} in a steady air stream, as found in a low-turbulence wind tunnel, is also shown for comparison.

It can be seen that the main effect of free-stream turbulence is to decrease the critical value of the parameter $D\bar{V}_d$. For subcritical flows, turbulence can produce a considerable reduction in C_f below the steady air-stream values. For supercritical flows, this effect becomes significantly smaller.

If the surface of the cylinder is deliberately roughened such as by incorporating flutes, riveted construction, etc, then the data given in Fig. 5 for appropriate value of $\varepsilon/D > 0$ shall be used.

NOTE — In case of uncertainty regarding the value of ε to be used for small roughness, ε/D shall be taken as 0.001.

ANNEX E

(Foreword)

COMMITTEE COMPOSITION

(Excluding Water Resources Development Division) Sectional Committee, CED 37

Organization	*Representative(s)*
In personal capacity (*80, SRP Colony, Peravallur, Chennai 600 082*)	Dr N. Lakshmanan (***Chairman***)
Atomic Energy Regulatory Board, Mumbai	Shri L. R. Bishnoi Shri A. D. Roshan (*Alternate*)
Bharat Heavy Electricals Limited, New Delhi	Shri S. S. Mani
Central Building Research Institute (CSIR), Roorkee	Dr A. K. Pandey Dr Rajesh Deoliya (*Alternate*)
Central Electricity Authority, New Delhi	Shri R. B. Walimbe Shri S. K. Roy Chowdhury (*Alternate*)
Central Public Works Department, New Delhi	Shri A. K. Garg Shri Rajesh Khare (*Alternate*)
Central Water Commission, New Delhi	Director C&MDD (E&NE) Director C&MDD (N&W) (*Alternate*)
Engineer-in-Chief's Branch (MES), NewDelhi	Brig Sandeep Rawat Shri V. K. Jatav (*Alternate*)
Engineers India Limited, New Delhi	Shri Vinay Kumar Shri Sudhir Chaturvedi (*Alternate*)
Gammon India Limited, Mumbai	Shri S. W. Deshpande Shri Avinash Y. Mahendrakar (*Alternate*)
Indian Institute of Technology Madras, Chennai	Dr Devdas Menon Dr A Meher Prasad (*Alternate*)
Indian Institute of Technology Kanpur, Kanpur	Dr Vinay K. Gupta
Indian Institute of Technology Roorkee, Roorkee	Dr Prem Kishan Dr S.K.Kaushik (*Alternate*)
Indian Metrological Department, New Delhi	Shri K. Ratnam
M.N. Dastur & Company Limited, Kolkata	Shri A. Das Gupta Shri Satyaki Sen (*Alternate*)
MECON Limited, Ranchi	Shri Onkar Sahay Shri A. K. Beg (*Alternate*)
Ministry of Shipping, Road Transport & Highways, New Delhi	Shri S. K. Puri Shri Satish Kumar, SE (P-9) (*Alternate*)
Muncipal Corporation of Greater Mumbai, Mumbai	Deputy Municipal Commissioner (ENGG) City Engineer (*Alternate*)
National Buildings Construction Corporation Limited, New Delhi	Shri Rakesh Marya Shri L. P. Singh (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora Shri S. Sharma (*Alternate*)
National Thermal Power Corporation, Noida	Shri H. Kundu Shri Masoom Ali (*Alternate*)
Research, Designs & Standards Organization, Lucknow	Joint Director Standards (B&S) JT Director Stnds (B&S) SB-I (*Alternate*)
RITES Limited, Gurgaon	Shri Ashok Kumar Mathur
Structural Engineering Research Centre (CSIR), Chennai	Dr S. Selvi Rajan Dr P. Harikrishna (*Alternate*)
TCE Consulting Engineers Limited, Mumbai	Shri A. P. Mull Shri A. Dutta (*Alternate*)
The Institution of Engineers (India) Ltd, New Delhi	Shri K. B. Rajoria

(*Continued from second cover*)

f) Provisions to account for effects of directionality, area averaging and correlation of pressures on the design wind pressure have been included.

g) Guidelines to account for the wind induced interference for tall buildings and low rise buildings have been included for use in preliminary design. It is however recommended to carry out detailed boundary layer wind tunnel tests/CFD (Computational Fluid Dynamics) studies for final design of important structures.

h) In the Gust Factor Method for evaluating along wind response, equations have been suggested for background factor, size reduction factor, energy ratio and length scale of turbulence.

j) A method for computing across wind response of tall buildings and lattice towers, which is in line with some of the international codes of practice, has been included.

The Committee observed that there has been a growing awareness among the consultants, academicians, researchers and practice engineers for design and construction of wind sensitive structures. In order to augment the available limited good quality meteorological wind data and structural response data, it is necessary to conduct full scale measurements in the field. Thus as emphasized in the previous revision, all individuals and organizations responsible for putting-up of tall structures are encouraged to provide instrumentation in their existing and new structures (transmission towers, chimneys, cooling towers, buildings, etc) at different elevations (at least at two levels) to continuously measure and monitor wind data. The instruments are required to collect data on wind direction, wind speed and structural response of the structure due to wind (with the help of accelerometer, strain gauges, etc). It is also the opinion of the Committee that such instrumentation in tall structures shall not in any way affect or alter the functional behaviour of such structures. The data so collected shall be very valuable in evolving more accurate wind loading of structures.

The Committee responsible for the formulation of this standard has taken into account the prevailing practice in regard to loading standards followed in this country by the various authorities and has also taken note of the developments in a number of other countries. In the formulation of this code, the following overseas standards have also been examined:

a) BS EN 1991-1-4:2005 Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions

b) Joint Australian/New Zealand Standard AS/NZS 1170.2:2002 Structural design actions, Part 2: Wind actions

c) ASCE 7-05 American Standard Building Code Requirements for Minimum Design Loads for Buildings and Other Structures.

d) AIJ 2004 — Architecture Institute of Japan (AIJ) Recommendations for Loads on Buildings.

The composition of the Committee responsible for the formulation of this Code is given at Annex E.

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 specified value in this standard.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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