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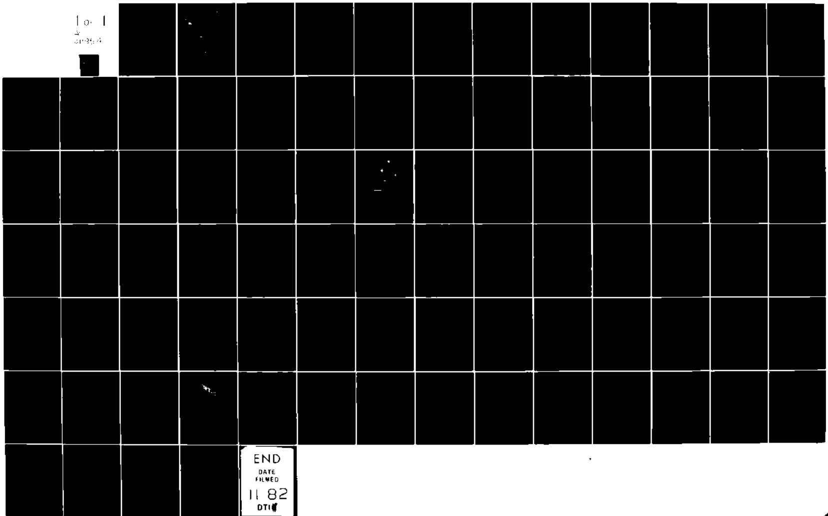

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Criteria for the estimation of loadings to be used in the design of civil engineering structures are presented for use by experienced engineers. Criteria relating to combining loads for purposes of design and suggested limitations on deflections also are presented.

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NOVEMBER 1981
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STRUCTURAL ENGINEERING

LOADS

DESIGN MANUAL 2.2

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NAVAL FACILITIES ENGINEERING COMMAND
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ABSTRACT

Criteria for the estimation of loadings to be used in the design of civil engineering structures are presented for use by experienced engineers. Criteria relating to combining loads for purposes of design and suggested limitations on deflections also are presented.

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FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command, other Government agencies, and the private sector. This manual uses, to the maximum extent feasible, national professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters (Code 04). As the design manuals are revised, they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with the SECNAVINST 5600.16.

W. M. Zobel
Rear Admiral, CEC, U. S. Navy
Commander
Naval Facilities Engineering Command

STRUCTURAL ENGINEERING DESIGN MANUALS

DM No.	Chapter Superseded in Basic DM-2	Title
2.1	-	GENERAL REQUIREMENTS
2.2	1	LOADS
2.3	2	STEEL STRUCTURES
2.4	3	CONCRETE STRUCTURES
2.5	4	TIMBER STRUCTURES
2.6	5, 6, 7, 8	ALUMINUM STRUCTURES MASONRY STRUCTURES COMPOSITE STRUCTURES OTHER STRUCTURAL MATERIALS
2.7	-	SNOW LOADS (TRI-SERVICE)

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LOADS

Section 1. SCOPE AND RELATED CRITERIA

1. SCOPE. This manual prescribes criteria for estimating loadings to be used in the design of civil engineering structures including temporary and prefabricated structures. This manual is not complete in itself. Special loadings and special design criteria relating to specific types of structures (waterfront structures and airport pavements, for example) are presented in the various topical manuals which are a part of this series. These manuals should be consulted in cases where applicable.

2. CANCELLATION. This publication entitled, Structural Engineering: Loads, NAVFAC DM-2.2, cancels and supersedes Chapter 1 of Structural Engineering, NAVFAC DM-2, of October 1970, and Changes 1, 2, 3, and 4.

3. RELATED CRITERIA. Certain criteria related to the estimation of design loads appear in other manuals in the design manual series as follows:

Subject	Source
Structural Engineering: General Requirements......	NAVFAC DM-2.1
Limited life structures	
Structural Engineering: Steel Structures..........	NAVFAC DM-2.3
Pretension forces in guys	
Soil Mechanics, Foundations, and Earth Structures..	NAVFAC DM-7 Series
Weight of soil	
Foundations for vibrating machinery	
Friction between soil and structures	
Piers and Wharves..................................	NAVFAC DM-25.1
Earthquake forces on piers and wharves	
Harbor and Coastal Facilities......................	NAVFAC DM-26
Wind on berthed vessels	
Wave forces and current forces	
Weight-Handling Equipment and Service Craft........	NAVFAC DM-38 Series
Forces on crane runways	
Wind on cranes and derricks	

Section 2. DEAD LOADS

1. DEFINITION. ead load is the term for the weights of all integral materials and equipment (including the structure's own weight) supported in, or on, a structure and intended to remain permanently in place.

2. UNIT WEIGHTS. Unit weights of construction materials are listed in Table 1. Minimum design dead loads for assembled elements of construction are provided in Table 2.

3. ALLOWANCE FOR PARTITIONS. The weights of all partitions shall be considered as dead load. Actual weights of partitions, as shown on the architectural plans for a building, shall be provided for in the design.

a. Uniform Load Equivalents. Except for the following cases 1) bearing partitions; 2) in toilet room areas (other than in one- and two-family residences); 3) in stair, elevator and similar core areas; or 4) in areas where partitions are concentrated, the following uniform load equivalents may be used in lieu of actual partition weights:

Partition Weight (plf)	Equivalent Uniform Load (psf) (To be added to floor dead and live loads)
50 or less	0
51 to 100	6
101 to 200	12
201 to 350	20
Greater than 350	Use actual concentrated live loads.

In office or public buildings, or in other occupancies where partitions are likely to be subject to rearrangement or alteration, the minimum allowance for the weight of partitions shall be a uniform load equivalent of 20 psf.

b. Non-Concurrence. Design live loads may be omitted from the strip of floor area under each partition.

4. SERVICE EQUIPMENT. The dead load shall include the weights of all building service equipment including plumbing stacks, piping, heating and air conditioning equipment, electrical equipment, elevators, elevator machinery, flues, and similar fixed equipment. The weight of equipment that is part of the tenant occupancy of a given area shall be considered as live load.

5. SOIL AND SOIL MOISTURE. Unless test data is available to indicate otherwise, the unit weight of dry soil shall be taken as 110 pcf, and of saturated soil as 135 pcf.

TABLE 1

Unit Weights

Material	pcf	Material	pcf
Metals, alloys, ores:		Hemlock	29
Aluminum, cast, hammered	165	Hickory	49
Brass, cast, rolled	534	Locust	46
Bronze, 7.9 to 14% Sn	509	Maple, hard	43
Bronze, aluminum	481	Maple, white	33
Copper, cast, rolled	556	Oak, chestnut	54
Copper ore, pyrites	262	Oak, live	59
Gold, cast, hammered	1205	Oak, red, black	41
Gold, bars, stacked	1133	Oak, white	46
Gold, coin in bags	1084	Pine, Oregon	32
Iron, cast, pig	450	Pine, red	30
Iron, wrought	485	Pine, white	26
Iron, spiegeleisen	468	Pine, yellow, long-leaf	44
Iron, ferrosilicon	437	Pine, yellow, short-leaf	38
Iron ore, hematite	325	Poplar	30
Iron ore, hematite in bank	160-180	Redwood, California	26
Iron ore, hematite loose	130-160	Spruce, white, black	27
Iron ore, limonite	237	Walnut, black	38
Iron ore, magnetite	315	Walnut, white	26
Iron slag	172	Masonry:	
Lead	710	Cast-stone masonry	
Lead ore, galena	465	(cement, stone, sand)	144
Magnesium, alloys	112	Cinder fill	57
Manganese	475	Concrete plain:	
Manganese ore, pyrolusite	259	Cinder	108
Mercury	849	Expanded-slag aggregate	100
Monel metal	556	Haydite (burned-clay aggregate)	90
Nickel	565	Slag	132
Platinum, cast, hammered	1330	Stone (including gravel)	144
Silver, cast, hammered	656	Vermiculite and perlite	
Silver bars, stacked	590	aggregate non-loading bearing	25-50
Silver coin in bags	590	Other light aggregate, load-	
Steel, cast or rolled	490	bearing	70-105
Tin, cast, hammered	459	Concrete, reinforced:	
Tin ore, cassiterite	418	Cinder	111
Zinc, cast, rolled	440	Slag	138
Zinc ore, blende	253	Stone (including gravel)	150
Timber, U.S. seasoned:		Ashlar masonry:	
Moisture content by weight:		Granite, syenite, gneiss	185
(Seasoned timber, 15 to 20%		Limestone, marble	160
green timber, up to 50%.)		Sandstone, bluestone	140
Ash, white, red	40	Mortar rubble masonry:	
Cedar, white, red	22	Granite, syenite, gneiss	155
Chestnut	41	Limestone, marble	150
Cypress	30	Sandstone, bluestone	130
Fir, Douglas	32	Dry rubble masonry:	
Fir, eastern	25	Granite, syenite, gneiss	130
Elm, white	45	Limestone, marble	125

TABLE 1 (Continued)

Unit Weights

Material	pcf	Material	pcf
Sandstone, bluestone	110	Stone, quarried, filled:	
Brick masonry:		Basalt, granite, gneiss	96
Pressed brick	140	Limestone, marble, quartz	95
Common brick	120	Sandstone	82
Soft brick	100	Shale	92
Concrete masonry:		Greenstone, hornblende	107
Cement, stone, sand	144	Bituminous substances:	
Cement, slag, etc.	130	Asphaltum	81
Cement, cinder, etc.	100	Coal, anthracite	97
Various building materials:		Coal, bituminous	84
Ashes, cinders	40-45	Coal, lignite	78
Cement, portland, loose	90	Coal, peat, turf, dry	47
Cement, portland, set	183	Coal, charcoal, pine	23
Lime, gypsum, loose	53-64	Coal, charcoal, oak	33
Mortar, set	110	Coal, coke	75
Slags, bank slag	67-72	Graphite	131
Slags, bank screenings	98-117	Paraffin	56
Slags, machine slag	96	Petroleum	54
Slags, slag sand	49-55	Petroleum, refined	50
Terra cotta, architectural:		Petroleum, benzine	46
Voids filled	120	Petroleum, gasoline	42
Voids unfilled	72	Pitch	69
Soil:		Tar, bituminous	75
See Section 2, para. 5.		Coal and coke, piled:	
Minerals:		Coal, anthracite	47-58
Asbestos	153	Coal, bituminous, lignite	40-54
Barytes	281	Coal, peat, turf	20-26
Basalt	184	Coal, charcoal	10-14
Bauxite	159	Coal, coke	23-32
Borax	109	Various solids:	
Chalk	137	Cereals, oats-bulk	32
Clay, marl	137	Cereals, barley-bulk	39
Dolomite	181	Cereals, corn, rye-bulk	48
Feldspar, orthoclase	159	Cereals, wheat-bulk	48
Gneiss, serpentine	159	Cork, compressed	14.4
Granite, syenite	175	Cotton, flax, hemp	93
Greenstone, trap	187	Fats	58
Gypsum, alabaster	159	Flour, loose	28
Hornblende	187	Flour, pressed	47
Limestone, marble	165	Glass, common	156
Magnesite	187	Glass, plate or crown	161
Phosphate rock, apatite	200	Glass, crystal	184
Porphyry	172	Hay and straw - bales	20
Pumice, natural	40	Leather	59
Quartz, flint	165	Paper	58
Sandstone, bluestone	147	Potatoes, piled	42
Shale, slate	175	Rubber, caoutchouc	59
Soapstone, talc	169	Rubber goods	94

TABLE 1 (Continued)

Unit Weights

Material	pcf	Material	pcf
Salt, granulated, piled	48	Lye, soda, 66%	106
Saltpeter	67	Oil, vegetable	58
Starch	96	Oil, creosote	65
Sulfur	125	Oil, fuel	60.6
Wool	82	Oil, gasoline	46
Various liquids:		Water, 4°C, max density	62.428
Alcohol 100%	49	Water, sea water	64
Acid, muriatic, 40%	75	Water, ice	56
Acid, nitric, 91%	94	Water, snow, fresh fallen	8
Acid, sulfuric, 87%	112		

TABLE 2

Minimum Design Dead Loads
for Assembled Elements of Construction

Walls(1)	psf	Walls(1)	psf
4-inch clay brick, high absorption	34	4-inch brick, 4-inch load-bearing structural clay tile backing	60
4-inch clay brick, medium absorption	39	4-inch brick, 8-inch load-bearing structural clay tile backing	75
4-inch clay brick, low absorption	46	8-inch brick, 4-inch load-bearing structural clay tile backing	102
4-inch sand-lime brick	38	8-inch load-bearing structural clay tile	42
4-inch concrete brick, heavy aggregate	46	12-inch load-bearing structural clay tile	58
4-inch concrete brick, light aggregate	33	4-inch concrete block, heavy aggregate	30
8-inch clay brick, high absorption	69	8-inch concrete block, heavy aggregate	55
8-inch clay brick, medium absorption	79	12-inch concrete block, heavy aggregate	85
8-inch clay brick, low absorption	89	4-inch concrete block, light aggregate	20
8-inch sand-lime brick	74	8-inch concrete block, light aggregate	35
8-inch concrete brick, heavy aggregate	89	12-inch concrete block, light aggregate	55
8-inch concrete brick, light aggregate	68	2-inch furring tile, one side of masonry wall, add to above figures.	12
12½-inch clay brick, high absorption	100		
12½-inch clay brick, medium absorption	115		
12½-inch clay brick, low absorption	130		
12½-inch sand-lime brick	105		
12½-inch concrete brick, heavy aggregate	130		
12½-inch concrete brick, light aggregate	98		
17-inch clay brick, high absorption	134		
17-inch clay brick, medium absorption	155		
17-inch clay brick, low absorption	173		
17-inch sand-lime brick	138		
17-inch concrete brick, heavy aggregate	174		
17-inch concrete brick, light aggregate	130		
22-inch clay brick, high absorption	168		
22-inch clay brick, medium absorption	194		
22-inch clay brick, low absorption	216		
22-inch sand-lime brick	173		
22-inch concrete brick, heavy aggregate	216		
22-inch concrete brick, light aggregate	160		

(1)See footnote at end of table.

TABLE 2 (Continued)

Minimum Design Dead Loads
for Assembled Elements of Construction

Partitions(1)	psf	Partitions(1)	psf
3-inch clay tile	17	Wood studs, 2 x 4, plastered two sides	20
4-inch clay tile	18	Steel or wood studs, 5/8-inch gypsum board each side	6
6-inch clay tile	28	Steel or wood studs, 2 layers 2" gypsum board each side	9
8-inch clay tile	34	Glass block masonry:	
10-inch clay tile	40	4-inch glass-block walls and partitions	18
2-inch facing tile	15	Steel partitions	4
4-inch facing tile	25	Asbestos hard board (corrugated), per ¼" of thickness	3
6-inch facing tile	38	Stone, 4"	55
2-inch gypsum block	9½	Split furring tile:	
3-inch gypsum block	10½	1½-inch	8
4-inch gypsum block	12½	2-inch	8½
5-inch gypsum block	14	Concrete slabs:	
6-inch gypsum block	18½	Concrete, reinforced-stone, per inch of thickness	12½
2-inch solid plaster	20		
4-inch solid plaster	32	Concrete, reinforced-cinder, per inch of thickness	9½
4-inch hollow plaster	22	Concrete, reinforced, lightweight, per inch of thickness	9
4-inch concrete block, heavy aggregate	30		
6-inch concrete block, heavy aggregate	42	Concrete, plain, lightweight, per inch of thickness	8½
8-inch concrete block, heavy aggregate	55	Concrete, plain stone, per inch of thickness	12
12-inch concrete block, heavy aggregate	85	Concrete, plain cinder, per inch of thickness	9
4-inch concrete block, light aggregate	20		
6-inch concrete block, light aggregate	28		
8-inch concrete block, light aggregate	38		
12-inch concrete block, light aggregate	55		
Wood studs, 2 x 4:			
12-inch o.c.	2.1		
16-inch o.c.	1.7		
24-inch o.c.	1.3		
Wood studs, 2 x 4, plastered one side	12		

(1) See footnote at end of table.

TABLE 2 (Continued)

Minimum Design Dead Loads
for Assembled Elements of Construction

Ribbed Slabs							
Depth in inches (rib depth ± slab thickness)	Width of rib in inches						Add for tapered ends
	psf						
	4	5	6	7	8	9	
20-inch metal fillers:							
6 plus 2½	45	48	50	50	-	-	4
8 plus 2½	51	54	57	60	-	-	5
10 plus 2½	57	60	64	68	-	-	5
12 plus 2½	63	67	72	76	-	-	5
14 plus 2½	-	74	79	84	-	-	5
16 plus 2½	-	-	88	93	98	-	
20 plus 2½	-	-	-	111	118	-	
30-inch metal fillers:							
6 plus 2½	41	43	45	47	-	-	3
8 plus 2½	45	47	50	53	-	-	4
10 plus 2½	49	52	55	58	-	-	4
12 plus 2½	53	57	60	64	-	-	4
14 plus 2½	-	62	66	70	-	-	4
16 plus 2½	-	-	72	76	80	-	
20 plus 2½	-	-	-	90	95	101	
2-way clay tile fillers: (12x12):							
4 plus 2	61	62	64	....			....

Ribbed Slabs						
Depth in inches (rib depth ± slab thickness)	Width of rib in inches					Add for tapered ends
	psf					
	4	5	6	7	8	
6 plus 2	87	89	90	....		....
8 plus 2½	100	103	107	....		....
10 plus 3	121	126	131	....		....
12 plus 3	136	141	146	....		....
2-way metal fillers: (16x16):						
4 plus 2	44	47	50	....		....
6 plus 2	55	60	63	....		....
8 plus 2½	72	78	83	....		....
10 plus 3	91	96	103	....		....
12 plus 3	103	111	118	....		....
14 plus 3	116	125	133	....		....
2-way metal fillers: (20x20):						
4 plus 2	42	44	46	....		....
6 plus 2	50	54	58	....		....
8 plus 2½	66	71	76	....		....
10 plus 3	83	88	94	....		....
12 plus 3	93	100	107	....		....
14 plus 3	105	113	120	....		....

TABLE 2 (Continued)

Minimum Design Dead Loads
for Assembled Elements of Construction

Ribbed Slabs

Depth in inches (rib depth ± slab thickness)	Width of rib in inches (psf) 4	5	6	7	8	Add for tapered ends
12-inch clay tile fillers:						
4 plus 2	49	51	52	54		....
6 plus 2	60	63	65	67		....
8 plus 2½	79	82	85	87		....
10 plus 3	96	100	103	106		....
12 plus 3	108	112	116	120		....

WAFFLE SLABS Depth , in Inches (Rib Depth + Slab Thickness)	Load psf
19 x 19, 5 @ 24	
6 plus 2½	66
8 plus 2½	78
10 plus 2½	85
12 plus 2½	101
30 x 30, 6 @ 36	
8 plus 3	73
10 plus 3	83
12 plus 3	95
14 plus 3	106
16 plus 3	114
20 plus 3	135

Floor finish	Thickness in.	Load psf
1½-inch asphalt mastic flooring	1½	18
3-inch wood block on ½-inch mortar base.	3½	16
Solid flat tile on 1-inch mortar base.	2	23
2-inch asphalt block, ½-inch mortar.	2½	30
1-inch terrazzo, 2-inch stone concrete.	3	38
7/8" hardwood floor on sleepers clipped to concrete without fill	-	5
3/4" ceramic or quarry tile on 2" mortar bed.	1¼	16
3/4" ceramic or quarry tile on 1" mortar bed.	2 3/4	34
¼" linoleum or asphalt tile directly on concrete	-	1
¼" linoleum or asphalt tile on 1" mortar bed.	1¼"	12
Hardwood floor, 7/8" thick	7/8"	4
Subflooring (soft wood)	3/4	2½
Waterproofing:		
Five-ply membrane	½	5
Five-ply membrane, mortar, stone concrete.	5	55
2-inch split tile, 3-inch stone concrete.	5	45

TABLE 2 (Continued)

Minimum Design Dead Loads
for Assembled Elements of Construction

Floor finish	Thickness in.	Load, psf
Floor fill:		
Cinder concrete, per inch	....	9
Lightweight concrete, per inch	....	7
Sand, per inch	....	8
Stone concrete, per inch	....	12

Wood joist floors (no plaster) double wood floor	12-inch spacing, psf	16-inch spacing, psf
Joist sizes, in inches:		
2 x 6	6	5
2 x 8	6	6
2 x 10	7	6
2 x 12	8	7
3 x 6	7	6
3 x 3	8	7
3 x 10	9	8
3 x 12	11	9
3 x 14	12	10

Ceilings	psf
Plaster on tile or concrete	5
Suspended metal lath and gypsum plaster	10
Suspended metal lath and cement plaster	15
Plaster on wood or metal lath	8
½" gypsum board	2
5/8" gypsum board	2½

Ceilings	psf
Acoustical fiber tile directly on concrete blocks or tile	1
Acoustical fiber tile on lath and channel ceiling construction	5
Acoustical fiber tile on suspended wood furring strips	3

Roof and wall coverings:	psf
Clay tile (for mortar add 10 lb):	
2-inch book tile	12
3-inch book tile	20
Roman	12
Spanish	19
Ludovici	10
Composition:	
Three-ply ready roofing	1
Four-ply felt and gravel	5½
Five-ply felt and gravel	6
Cold applied sheet membrane and stone ballast	see mfr.
Copper or tin	1
Corrugated asbestos-cement roofing	4
Corrugated iron	2
Decking (non wood) per inch of thickness:	
Concrete plank	6.5
Insulrock	2.7
Poured gypsum	6.5
Tectum	2.0
Vermiculite concrete	2.6
Fiberboard ½-inch	3/4
Glass	
Windows, glass, frame, and sash	8

TABLE 2 (Continued)

Minimum Design Dead Loads
for Assembled Elements of Construction

Roof and wall coverings	psf
Single strength	1.2
Double strength	1.6
Plate, wired or structural, 1/8 in.	1.6
Insulating, double 1/8 in. plates w/air space	3.5
Insulating, double ¼ in. plates w/air space	7.1
Gypsum sheathing, ½-inch	2
Insulation, per inch of thickness	
Expanded polystyrene	0.2
Fiber glass, rigid	1.5
Foam glass	0.8
Loose	0.5
Urethane	1.0
Cork	1.0
Vegetable fiber boards	1.5
Bats and blankets	0.5
Rigid insulation board	2.5
Insulating concrete	3.
Marble, interior, per inch	14.
Metal deck (22 gauge)	1.9
Metal deck (20 gauge	2¼
Metal deck (18 gauge	3
Corrugated metal (20 gauge)	1½
Plastic, acrylic, ¼ in.	1.5
Porcelain enamel on sheet steel	3
Skylight, metal frame, 3/8-inch wire glass	8
Slate, 3/16-inch	7
Slate, ¼-inch	10
Stucco, 7/8-inch	10.0
Terra cotta tile	25.0
Wood sheathing, per inch thickness	3
Wood shingles	3
Asphalt shingles	2

Roof and wall coverings	psf
Cement asbestos shingles	4
Cement tile	16

Floor finish and fill	Finish floor to top slab in.	Load psf
Linoleum on stone-concrete fill	4	46
Linoleum on stone-concrete fill	5	58
Linoleum on light-concrete fill	4	27
Linoleum on light-concrete fill	5	34
Double 7/8-inch wood on sleepers, light concrete fill.	4	19
Double 7/8-inch wood on sleepers, light concrete fill.	5	26
Double 7/8-inch wood on sleepers, stone-concrete fill.	4	28
Double 7/8-inch wood on sleepers, stone-concrete fill.	5	40
Single 7/8-inch wood on sleepers, light concrete fill.	4	23
Single 7/8-inch wood on sleepers, light concrete fill.	5	30
Single 7/8-inch wood on sleepers, stone-concrete fill.	4	40
Single 7/8-inch wood on sleepers, stone-concrete fill.	5	50
3-inch wood block on mastic, no fill.	3	10

TABLE 2 (Continued)

Minimum Design Dead Loads for Assembled Elements of Construction

Floor finish and fill	Finish floor to top slab in.	Load, psf
7/8-inch wood block on stone-concrete fill.	4	40
1-inch cement finish on stone-concrete fill.	4	48
1-inch terrazzo on stone-concrete fill.	4	48
Clay tile on stone-concrete fill.	4	48
Marble and mortar on stone-concrete fill.	4	50
Hollow core planks	(2)	(2)

(1) For masonry construction add 5 psf for each face plastered.

(2) See manufacturer's data for sizes and weights which are available locally.

6. STABILITY. For stability calculations, estimates of dead load shall be decreased by 10% (0.90 Load Factor indicated in Section 10, para. 3), and the following elements of dead load shall be discounted:

a. Allowances for future addition or future wearing course.

b. Allowances for fills and finishes, where such fills and finishes are intended to be replaced periodically.

c. Weight of overlying soil -- the required factors of safety provided in DM-7 shall be provided with full overlying soil in place. Additionally, a stability factor of 1.05 shall be provided with the weight of the overlying soil discounted. These values apply under the design loads. An exception will be, for cases where the weight (or passive resistance) of the soil clearly would be a design consideration to those contemplating future excavations, in which case lesser stability factors will be permitted.

Section 3. LIVE LOADS (INCLUDING LIVE LOAD REDUCTION)

1. DEFINITION. The live loads shall include all loads (vertically down, vertically up, and lateral) incident to the occupancy and use of the structure, and excluding forces incident to the environment such as snow, wind, rain, earthquake, stream flow, waves, ice, the impact of berthing, and the weight and lateral pressure due to earth. Centrifugal traction, braking, and impact forces shall be considered as incidental to (and a part of) the live load effect. For definitions of Class A, Class B, and Class C Structures, see NAVFAC DM-2.1.

2. CLASS A STRUCTURES. The provisions of the AASHTO and AREA design standards shall apply.

3. CLASS B STRUCTURES.

a. Snow Load. See Section 5.

b. Wind Load. See Section 7.

c. Roof Loads.

(1) Concurrence. Concurrent with snow load, the design of roofs shall provide for loads incident to ponding of rainwater. Non-concurrent with snow load, provide for the loads incident to the weight of people, materials, and equipment necessary to make repairs during the service life of the roof. The weight of people, materials, and equipment necessary to make repairs during the service life of the roof also shall be considered as non-concurrent with the design wind load.

(2) Ponding. The load due to ponding shall be calculated on the basis of the flexibility of the roof structure, the adequacy of the drainage system (the provisions of DM-2.1 notwithstanding, a

storm of 50 year recurrence interval shall be considered), and an initial deviation from a plane or sloped surface of at least 1-1/2 inches.

(3) Minimum Design Load: Allowance shall be made in the design of secondary framing such as roof deck and rafters for a minimum load of 15 psf for roof slopes of 1 vertical to 2 horizontal, or steeper, and 20 psf for flatter roofs; each coupled with a concentrated load of 250 lb. on a 24-inch x 24-inch area. Purpose of this minimum load is to provide for the weight of people, materials, and equipment. For main members such as trusses and arches, the minimum design load may be reduced to 12 psf. These provisions for minimum load shall not apply if special scaffolding, runners, or similar device is provided as a work surface for workmen and materials during construction and repair operations.

d. Uniformly Distributed Loads. The live loads to be assumed in the design of Class B Structures shall be the maximum loads likely to be imposed by the intended use or occupancy, but not less than those indicated in Table 3.

e. Thrusts on Handrails. Stairway and balcony railings, both exterior and interior, shall be designed to resist a simultaneous vertical and horizontal thrust of 50 pounds per linear foot applied to the top rail. For one- and two-family dwellings, the thrusts shall be 20 pounds per linear foot.

f. Concentrated Loads.

(1) Consider application of a concentrated load in the design of a sidewalk. The concentrated load to be considered shall be the maximum wheel load which reasonably could mount the sidewalk, but applied without impact. This concentrated load shall also be used in the design of appurtenant components of sidewalks such as manholes, manhole covers, vault covers, and gratings.

(2) Driveways shall be considered as Class A Structures.

(3) Accessible, open-web steel joists over garages or manufacturing spaces shall be capable of supporting an 800 lb. concentrated load placed at any bottom chord panel point, applied concurrently with the other live loads. This load shall be considered as a load of infrequent occurrence. Note that this requirement normally will require reinforcing the panel point connections of joists of standard design, and that this requirement should be stated on the plans for the construction.

(4) Any single panel point of the lower chord of accessible roof trusses (other than open-web joists) or any point of other accessible primary structural members over commercial garage, manufacturing and storage floors, and maintenance and repair facilities shall be capable of supporting a 2000 lb. concentrated load, applied concurrently with other live loads. This load shall be considered as a load of infrequent occurrence.

TABLE 3

Uniform Live Load Requirements for
Special Occupancy

Occupancy or use	Live load (psf)
Armories (see Drill Halls)	
Assembly area (including theatres)	
Fixed Seats (fastened to floor)	60
Movable seats	100
Lobbies	100
Platforms (assembly)	100
Stage floors	150
Automatic data processing rooms	150
Bag storage	125
Balconies, one- and two-family residences and not exceeding 100 S.F.	60
Balconies, other	100
Bakeries, general area	100
Bakeries, storage area	200
Barber shop	75
Barracks and domitories	
partitioned	40
non-partitioned, including allowances for future partitions	60
corridors	100
Battery charging room	200
Boiler houses	200
Bowling alleys, poolrooms, and similar recreation areas	75
Car wash rooms	75
Canteens, general area	100
Canteens, storage area	200
Catwalks, buildings	25
Catwalks, Marine	50
Chapels	
Aisles, corridors, and lobbies	100
Balconies	60
Fixed seats	60
Offices and miscellaneous rooms	40
Cobbler shop	100
Computer rooms	100
Concentrated loads:	
Elevator machine room grating (on area of 4 sq. inch.)	300 lb.
Finish light floor plate construction (on area of 1 sq. inch.)	200 lb.
Main corridors, large offices, and similar areas (on 2.5 ft. x 2.5 ft.)	2,000 lb.
Scuttles, skylight ribs, and accessible ceilings	200 lb.
Sidewalks (on 2.5 x 2.5 ft.)	8,000 lb.
Stair treads (on center of tread)	300 lb.

TABLE 3 (continued)

Occupancy or use	Live load (psf)
Corridors	
First floor	100
Other floors (same as occupancy served), except as specifically noted, herein.	
Court rooms	80
Dance halls and ballrooms	100
Day rooms	60
Dining rooms and restaurants	100
Kitchen, general area	75
Drawing	100
Drill halls	125
Drum fillings	150
Drum washing	75
File rooms:	
Letter files	80
Card files	125
Drawing files	200
Fire escapes (single family dwellings)	40
Galleys:	
Dishwashing rooms (mechanical)	300
General Kitchen area	75
Provision storage (not refrigerated)	200
Preparation room:	
meat	250
vegetable	100
Garages	
Passenger cars	50
Trucks and buses - see Class A Structures	
Garbage storage rooms	125
Generator rooms	200
Guard house	75
Gymnasiums (main floors and balconies)	100
Hangers	See Footnote (1)
Hospitals	
Operating rooms, laboratories	60
Private rooms	40
Wards	40
Corridors (above first floor)	80
Incinerators; charging floor	150
Laboratories; normal scientific equipment	100
Latrines	75
Laundries; general areas	100
Libraries	
Reading rooms	60
Stock rooms (books and shelving @ 65pcf, but not less than	150
Corridors, above first floor	80
Linen storage	125
Lobbies, vestibules & large waiting rooms	100
Locker rooms	75

(1) Obtain wheel loads of aircraft and impact factors from using agency.

TABLE 3 (continued)

Occupancy or use	Live load (psf)
Lounges, day rooms, small recreation areas	60
Manufacturing	
Light	125
Heavy	250
Marquees and canopies	75
Mechanical equipment rooms (general)	100
Mechanical room (air conditioning)	125
Mechanical telephone and radio equipment rooms	150
Mess halls	100
Morgues	100
Office buildings	
Offices	50
Lobbies	100
File and computer rooms (to be individually evaluated)	
Post exchanges (see Stores)	
Post offices:	
General area	100
Work rooms	125
Power plants	200
Projection booths	100
Promenade roof	60
Pump houses	100
Recreation rooms	100
Receiving rooms (radio) including roof areas supporting antennas and electronic equipment	150
Refrigeration storage rooms:	
Dairy	200
Meat	250
Vegetables	275
Residential:	
One- and two-family dwellings:	
Uninhabitable attics without storage	10
Uninhabitable attics with storage	20
Habitable attics and sleeping areas	30
All other areas	40
Hotel and multi-family houses	
Private rooms and corridors serving them	40
Public rooms and corridors serving them	100
Rubbish storage rooms	100
Scrub decks	75

TABLE 3 (continued)

Occupancy or use	Live load (psf)
Shops:	
Aircraft utility	200
Assembly and repair	250 to 400
Black smith	125
Bombsight	125
Carpenter	125
Drum repair	100
Electrical	300
Engine overhaul	300
Heavy materials assembly	200 to 400
Light materials assembly	125
Machine	300
Mold loft	80
Plate (except storage areas)	300
Public works:	
first floor	125
sheet metal	125
shipfitters	300
structural	300
upper floors	100
Schools:	
Classrooms	40
Corridors, above first floor	80
Shops	60
Sidewalks not subject to trucking	250
Showers and washrooms	60
Stadium and arena bleacher	100
Stairs, balconies, etc. (vertical load)	100
Store houses:	
Aircraft	200
Ammunition (one story)	2,000
Cold Storage:	
first floor	400
upper floors	300
Dry provisions	300
Fuse and detonator (one story)	500
General:	
first floor	600 to 1,000
second floor	400
third floor	300
high explosives (one story)	500
inert materials (one story)	500 to 2,000
light tools	150
paint and oil (one story)	500
pipe and metals (one story)	1,000
pyrotechnics (one story)	500
small arms (one story)	500
subsistence buildings	200
torpedo (one story	350

TABLE 3 (continued)

Occupancy or use	Live load (psf)
Stores (Sales)	
Retail	
First floor	100
Upper floors	75
Wholesale, all floors	125
Tailor shop	75
Telephone exchange rooms	
Normal	150
Locations subject to earth tremors, gunnery practice or other conditions causing unusual vibrations	250
Terminal equipment buildings (all areas other than stairs, toilets, and washrooms)	150
Walkways and elevated platforms (other than exitways)	60
Yards and terraces (pedestrian)	100

(5) For quarters, a concentrated load of 200 lb. on an area of 4 sq. in. shall be considered.

(6) The provisions of Table 3 relating to light floor plate construction shall apply to floor insets, such as registers.

(7) For boiler rooms, allowance should be made for a 3000 lb. concentrated load applied over an area of 20 sq. inches, in areas outside the limits of the boilers, applied non-concurrently with the uniform live load.

(8) Floors in garages or portions of buildings used for storage of motor vehicles shall be designed for the following concentrated loads: (1) for passenger cars accommodating not more than nine passengers, 2000 pounds acting on an area of 20 sq. in.; (2) mechanical parking structures without slab or deck, passenger cars only, 1500 pounds per wheel; and (3) for trucks or buses - maximum axle load on an area of 20 sq. in.

g. Live Load Reduction.

(1) Subject to limitations indicated in the following paragraph, members having an influence area of 400 sq. ft. or more may be designed for a reduced live load determined by applying the following equation:

$$L = L_o \left(0.25 + \frac{15}{\sqrt{A_I}}\right) \qquad (3\text{-}1)$$

in which:

L = reduced design live load per square foot of area supported by the member

L_o = unreduced design live load per square foot of area supported by the member.

A_I = influence area, square feet. The influence area, A_I, is four times the tributary area for a column, two times the tributary area for a beam, and is equal to the panel area for a two-way slab. (See Figure 1.)

(2) Limitations on Live Load Reduction. The reduced design live load shall not be less than 50% of the basic live load (L_o) for members supporting one floor, nor less than 40% of L_o, otherwise. For live loads of 100 psf or less, no reduction shall be made for areas to be occupied as places of public assembly, for garages except as noted below, for one-way slabs, or for roofs except as permitted in para. c. Roof Loads. For live loads that exceed 100 psf and in garages for passenger cars only, design live loads on members supporting more than one floor may be reduced 20 percent, but live loads in other cases shall not be reduced.

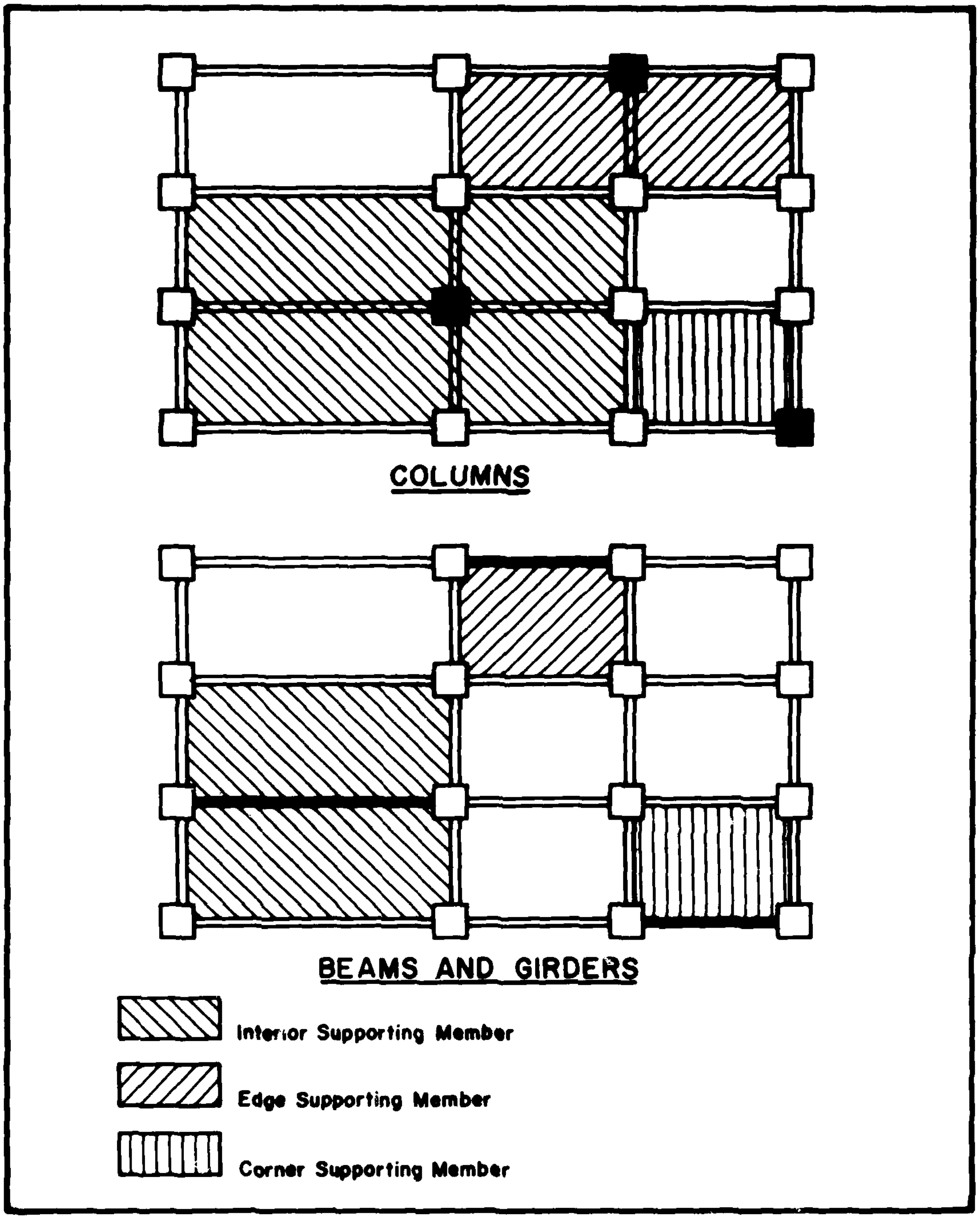


FIGURE 1
Typical Influence Areas

h. Live Loads for Warehouses. See Table 4.

4. CLASS C STRUCTURES. The provisions of the specific manual in the DM Series shall apply.

5. PARTIAL LOADINGS.

a. Pattern Loadings. The provisions of ACI-318 relating to frame analysis and design (arrangement for live load) shall apply.

b. Moving Loads. All structures subject to moving or variable loads shall have each part designed with those live loads on the structure that develop the maximum stresses in the considered part.

c. Unsymmetrical Loadings. Note should be made that for slender compression members and for members which lack torsional rigidity, the torsions and eccentricities induced by unsymmetrical loadings may be more critical than the effects of heavier, symmetric loadings. Several collapses, particularly of light roof structures, have been attributed to this cause. Stresses in cantilever framing also are sensitive to partial, unsymmetrical loading.

d. Prestressing (Including Post-tensioning) Forces. Consideration of partial loading due to unbalanced losses of tension, partial tensioning, and increments of tensioning is required.

Section 4. IMPACT, TRACTION, AND SWAY

1. CLASS A STRUCTURES. The provisions of the AASHTO and AREA standards shall apply.

2. CRANE RUNWAYS AND SUPPORTS - IMPACT. The provisions of Table 5 shall apply.

3. CRANE RUNWAYS AND SUPPORTS - TRACTION AND SWAY. The provisions of Section 6 of Chapter 1 of DM-38 shall apply.

4. MACHINERY SUPPORTS.

	Type of Machinery	Minimum Impact Allowance
1.	Reciprocating Machinery and Heavy Power-Driven Units	50% of weight of machine
2.	Light, Shaft- or Motor-Driven Units	25%(1)
3.	Elevator Machinery	Supporting Beams - 100%(2) Supporting Columns - 80%(2) Foundations - 40%(2)
4.	Escalators	15%(3)

Notes: (1) of total weight of machine.
(2) of total lifted load, including live load.
(3) of weight of moving parts, plus live load.

TABLE 4

Uniform Live Loads for Storage Warehouses

Material	Weight per cubic foot of space (lb)	Height of pile (ft)	Weight per square foot of floor (lb)	Live load (psf)
Building materials:				
Asbestos	50	6	300	
Bricks, building	45	6	270	
Bricks, fire clay	75	6	450	
Cement, natural	59	6	354	300
Cement, portland	72 to 105	6	432 to 630	to
Gypsum	50	6	300	400
Lime and plaster	53	5	265	
Tiles	50	6	300	
Woods, bulk	45	6	270	
Drugs, paints, oil:				
Alum, pearl, in barrels	33	6	198	
Bleaching powder, in hogsheads	31	3½	102	
Blue vitriol, in barrels	45	5	226	
Glycerine, in cases	52	6	312	
Linseed oil, in barrels	36	6	216	
Linseed oil, in iron drums	45	4	180	
Logwood extract, in boxes	70	5	350	
Rosin, in barrels	48	6	288	
Shellac, gum	38	6	228	200
Soaps	50	6	300	to
Soda ash, in hogsheads	62	2¾	167	300
Soda, caustic, in iron drums	88	3⅜	294	
Soda, silicate, in barrels	53	6	318	
Sulphuric acid	60	1⅝	100	
Toilet articles	35	6	210	
Varnishes	55	6	330	
White lead paste, in cans	174	3½	610	
White lead, dry	86	4¾	408	
Red lead and litharge, dry	132	3¾	495	
Dry goods, cotton, wool:				
Burlap, in bales	43	6	258	
Carpets and rugs	30	6	180	
Coir yarn, in bales	33	8	264	
Cotton, in bales, American	30	8	240	
Cotton, in bales, foreign	40	8	320	
Cotton bleached goods, in cases	28	8	224	
Cotton flannel, in cases	12	8	96	
Cotton sheeting, in cases	23	8	184	
Cotton yarn, in cases	25	8	200	
Excelsior, compressed	19	8	152	200
Hemp, Italian, compressed	22	8	176	to
Hemp, Manila, compressed	30	8	240	250
Jute, compressed	41	8	328	
Linen damask, in cases	50	5	250	
Linen goods, in cases	30	8	240	
Linen towels, in cases	40	6	240	
Silk and silk goods	45	8	360	
Sisal, compressed	21	8	168	
Tow, compressed	29	8	232	
Wool, in bales, compressed	48			
Wool, in bales, not compressed	13	8	104	
Wool, worsteds, in cases	27	8	216	

TABLE 4 (Continued)

Uniform Live Loads for Storage Warehouses

Material	Weight per cubic foot of space (lb)	Height of pile (ft)	Weight per square foot of floor (lb)	Live load (psf)
Groceries, wines, liquors:				
Beans, in bags	40	8	320	
Beverages	40	8	320	
Canned goods, in cases	58	6	348	
Cereals	45	8	360	
Cocoa	35	8	280	
Coffee, roasted, in bags	33	8	264	
Coffee, green, in bags	39	8	312	
Dates, in cases	55	6	330	
Figs, in cases	74	5	370	
Flour, in barrels	40	5	200	250
Fruits, fresh	35	8	280	to
Meat and meat products	45	6	270	300
Milk, condensed	50	6	300	
Molasses, in barrels	48	5	240	
Rice, in bags	58	6	348	
Sal soda, in barrels	46	5	230	
Salt, in bags	70	5	350	
Soap powder, in cases	38	8	304	
Starch, in barrels	25	6	150	
Sugar, in barrels	43	5	215	
Sugar, in cases	51	6	306	
Tea, in chests	25	8	200	
Wines and liquors, in barrels	38	6	228	
Hardware:				
Automobile parts	40	8	320	
Chain	100	6	600	
Cutlery	45	8	360	
Door checks	45	6	270	
Electrical goods and machinery	40	8	320	
Hinges	64	6	384	
Locks, in cases, packed	31	6	186	
Machinery, light	20	8	160	
Plumbing fixtures	30	8	240	300
Plumbing supplies	55	6	330	to
Sash fasteners	48	6	288	400
Screws	101	6	606	
Shafting steel	125			
Sheet tin, in boxes	278	2	556	
Tools, small, metal	75	6	450	
Wire cables, on reels			425	
Wire, insulated copper, in coils	63	5	315	
Wire, galvanized iron, in coils	74	4½	333	
Wire, magnet, on spools	75	6	450	
Miscellaneous:				
Automobile tires	30	6	180	
Automobiles, uncrated	8		64	
Books (solidly packed)	65	6	390	
Furniture	20			
Glass and chinaware, in crates	40	8	320	
Hides and leather, in bales	20	8	160	
Leather and leather goods	40	8	320	
Paper, newspaper, and strawboards	35	6	210	

TABLE 4 (Continued)

Uniform Live Loads for Storage Warehouses

Material	Weight per cubic foot of space (lb)	Height of pile (ft)	Weight per square foot of space (lb)	Live load (psf)
Miscellaneous: (Continued)				
Paper, writing and calendared	60	6	360	
Rope, in coils	32	6	192	
Rubber, crude	50	8	400	
Tobacco, bales	35	8	280	

TABLE 5

Crane Runways and Supports, Load Increases for Impact

Capacity of hook load (short tons)	Load increase expressed as percent of maximum crane reaction							
	Speeds 200 fpm or less				Speeds exceeding 200 fpm			
	Overhead traveling crane, traveling wall crane		Fixed revolving cranes	Travel-ing re-volving cranes	Overhead traveling crane, traveling wall crane		Fixed revolving cranes	Travel-ing re-volving cranes
	Runway girders	Columns	Towers	Docks, piers, tracks	Runway girders	Columns	Towers	Docks, piers, tracks
25 or less	15	12	15	12	18	14	18	15
26 to 50	13	10	13	10	15	10	15	12
51 to 80	10	9	10	8	12	12	12	10
81 to 120	9	7	9	6	10	8	10	8
121 to 180	8	6	8	6	9	7	9	8
Over 180	6	5	6	6	8	6	8	8

5. SWAY LOAD ON SPECTATOR STANDS. Provide for a lateral load effect equal to 24 plf of seating applied in a direction parallel to each row of seats and 10 plf of seating applied in a direction perpendicular to the row of seats. These two components of sway load shall be applied simultaneously. The sway load on spectator stands shall be considered to be concurrent with a wind load generated by a wind velocity equal to one-half the velocity of the design wind load, but not more than 50 mph.

6. HANGERS FOR FLOORS AND BALCONIES. Provide for impact equal to one-third of the tension due to the live load.

7. IMPACT DUE TO BERTHING. See DM-25.1 for evaluation of lateral and longitudinal forces.

8. VIBRATIONS. Vibrations are induced in structures by reciprocating and rotating equipment, rapid application and subsequent removal of a load, or by other means. Vibrations take place in flexural, extensional, or torsional modes, or any combination of the three.

a. Resonance. Resonance will occur when the frequency of an applied dynamic load coincides with a natural frequency of the supporting structure. In this condition, vibration deflections increase progressively to dangerous proportions. Prevent resonance by insuring in the design that the natural frequency of a structure and the frequency of load application do not coincide.

b. Foundation Considerations. Foundations for vibratory machinery require careful consideration. (See NAVFAC DM-7 for the reaction of different types of soils to vibratory loading and the determination of the natural frequency of the foundation-soil system.)

(1) Foundation Design. The geometry and mass of the foundation should be selected based on proper analysis satisfying imposed or appropriate restrictions on resulting foundation movements (lateral, vertical, and torsional). Consider foundation material properties and interaction with foundation. For analysis, select dynamic loads based on characteristics of machine operation (preferably measured or provided by manufacturer) and anticipated maintenance.

(2) Isolation of Foundations for Vibrating Machinery. Foundations for heavy vibratory machinery are likely to require isolation from the surrounding structure, floors, and foundations. Depending on conditions, adequate isolation may be achieved by use of insulating pads or springs, or by leaving an open space between the machine base and surrounding structure. The latter method still requires evaluation of whether vibrations can be transmitted to the structure through the foundations. (See DM-7 for further discussion and references.)

c. Collateral Reading. For further information on the solutions of vibratory stresses and deflections, see Vibration Problems in Engineering and Dynamics of Framed Structures. (See References.)

Section 5. SNOW LOAD

1. GENERAL. The provisions of Chapter 3 (Snow Loads) of the Tri-Service Design Criteria shall apply. Snow loads indicated in the Tri-Service Criteria are for a 50-year mean recurrence interval and shall be used for the design of structures, even though an ostensible service life of 25 years is intended (see NAVFAC DM-2.1, para. 5, "Service Life").

2. BASIC ROOF SNOW LOADS - LOCATIONS OTHER THAN THE 50 STATES. See Table 6.

3. INTERIM CRITERIA. Until Tri-Service Design Criteria, Snow Loads for the U.S.A. is published, the criteria may be obtained by requesting ETL-1110-3-317, 5 Feb. 80, available from Department of the Army, Office of the Chief of Engineers, Publications Depot, 890 South Pickett St., Alexandria, VA 22304.

Section 6. LOADS FOR SPECIAL STRUCTURES

1. CRANE RUNWAYS, TRACKAGE, AND SUPPORTS. For impact, traction (including braking), and lateral forces, see Section 4. For other data, see DM-38, Chapter 1.

2. BINS AND BUNKERS. For loads on component parts of bins and bunkers, see Design of Walls, Bins, and Grain Elevators. (See References.)

3. WATERFRONT STRUCTURES. Load criteria for piers, wharves, and waterfront structures are discussed in detail in DM-25.1, DM-25.4, DM-25.5, DM-25.6, and DM-26.

4. ANTENNA SUPPORTS AND TRANSMISSION LINE STRUCTURES. Design shall consider the following loads:

a. Dead Load.

b. Live Load on Stairways and Walkways.

c. Wind Load.

d. Ice Load. The thickness of ice covering on guys, conductors, insulation, and framing supports shall be determined from Figure 2. Exceptions are areas known to have more severe icing conditions, such as coastal and waterfront areas that are subject to heavy sea spray, or high local precipitation. For ice load in these areas, consult cognizant EFD.

TABLE 6

Snow Data for Locations Outside the 50 States

Location	Roof snow load (psf)
AFRICA:	
Libya:	
Wheelus AB	0
Morocco:	
Casablanca	0
Port Lyautey NAS	0
ASIA:	
India:	
Bombay	0
Calcutta	0
Madras	0
New Delhi	0
Japan:	
Itazuke AB	10
Johnson AB	10
Misawa AB	20
Tachikawa AB	10
Tokyo	10
Wakkanai	55
Korea:	
Kimpo AB	20
Seoul	20
Uijongbu	15
Pakistan:	
Peshawar	10
Saudi Arabia:	
Bahrain Island	0
Dhahran AB	0
Taiwan:	
Tainan	0
Taipei	0
Thailand:	
Chiang Mai	0
Bangkok	0
Sattahip	0
Turkey:	
Ankara	20
Karamursel	15

TABLE 6 (Continued)

Snow Data for Locations Outside the 50 States

Location	Roof snow load (psf)
ASIA-Continued	
Viet Nam:	
Saigon	0
ATLANTIC OCEAN AREA:	
Ascension Island	0
Azores:	
Lajes Field	0
Bermuda:	
CARIBBEAN SEA:	
Bahama Islands:	
Eleuthera Island	0
Grand Bahama Island	0
Grand Turk Island	0
Great Exuma Island	0
Cuba:	
Guantanamo NAS	0
Leeward Islands:	
Antigua Island	0
Puerto Rico:	
Boringuen Field	0
San Juan and Sabana Seca	0
Vieques Island and Roosevelt Roads	0
Virgin Islands	0
Trinida Island:	
Port of Spain	0
Trinidad NS	0
CENTRAL AMERICA:	
Canal Zone:	
Albrook AFB	0
Balboa	0
Coco Solo	0
Colon	0
Cristobal	0
France AFB	0
EUROPE:	
England:	
Birmingham	15
London	15
Mildenhall AB	15
Plymouth	10

TABLE 6 (Continued)

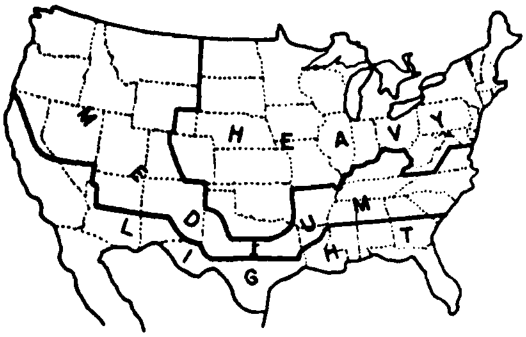
Snow Data for Locations Outside the 50 States

Location	Roof snow load (psf)
EUROPE-Continued	
Sculthorpe AB	15
Southport	10
South Shields	15
Spurn Head	15
France:	
Nancy	15
Paris/Le Bourget	20
Rennes	15
Vichy	25
Germany:	
Bremen	25
Munich-Riem	40
Rhein-Main AB	25
Stuttgart AB	45
Greece:	
Athens	5
Iceland:	
Reflavik	30
Thorshofn	30
Italy:	
Aviano AB	10
Brindisi	5
Scotland:	
Aberdeen	15
Edinburgh	15
Edzell	15
Glasgow/Renfrew Airfield	15
Lerwick, Shetland Islands	15
Londonderry	15
Prestwick	15
Stornoway	15
Thurso	15
Spain:	
Madrid	10
Rota	5
San Pablo	5
Zaragoza	10

TABLE 6 (Continued)

Snow Data for Locations Outside the 50 States

Location	Roof snow load (psf)
NORTH AMERICA:	
Canada:	
Argentia NAS, Newfoundland	47
Churchill, Manitoba	66
Cold Lake, Alberta	41
Edmonton, Alberta	27
E. Harmon AFB, Newfoundland	86
Fort William, Ontario	73
Frobisher, N.W.T.	50
Goose Airport, Newfoundland	100
Ottawa, Ontario	60
St. John's, Newfoundland	72
Toronto, Ontario	40
Winnipeg, Manitoba	45
Greenland:	
Narsarssuak AB	30
Simiutak AB	25
Sondrestrom AB	20
Thule AB	25
PACIFIC OCEAN AREA:	Zero, unless local experience indicates otherwise



(a) GEOGRAPHIC DISTRIBUTION

LOADING DISTRICT	RADIAL THICKNESS OF ICE (in)
HEAVY	0.50
MEDIUM	0.25
LIGHT	NONE

(b) THICKNESS OF ICE COVERING

FIGURE 2

Ice Load on Antenna Supports and Transmission Line Structures

e. Thermal Changes. Consider changes in guy or cable sag or both due to temperature changes. (See Section 10.)

f. Pretension Forces. Consider pretension forces in guys and wires as per Part 3, para. 3 of DM-2.3.

g. Broken Wires. Design support structures to resist the unbalanced pull or torsion resulting from broken guys as per Part 3, para. 3 of DM-2.3 and for any reasonable incidence of broken transmission wires.

h. Erection Loads. Temporary erection loads are important in the design of antenna supports and transmission line structures.

5. TURBINE GENERATOR FOUNDATIONS. Design shall consider the following loads:

a. Vertical Loads. For component weights of the turbine generator and distribution of these weights, refer to the manufacturer's machine outline drawings. Increase machine loads for impact 25 percent for machines with speeds up to and including 1,800 revolutions per minute (rpm), and 50 percent for those with higher speeds. Consider additional loads (such as auxiliary equipment, pipes, and valves) supported by the foundations.

b. Steam Condenser Load. The condenser or vacuum load shall be determined from the method of mounting the condenser.

c. Torque Loads. Torque loads are produced by magnetic reactions of electric motors and generators which tend to retard rotation. Use five times the normal torque in the design of the supporting members. For turbine generators, normal torque may be computed by the following equation:

$$\text{torque (ft lb)} = \frac{7{,}040\ (\text{kw}).}{\text{rpm}} \qquad (6\text{-}1)$$

For other types of rotating machinery, similar formulas may be used.

d. Horizontal Loads on Support Framing.

(1) Longitudinal force. Assume a longitudinal force of 20 to 50 percent of the machine weight applied at the shaft centerline.

(2) Transverse force. Assume a transverse force at each bent of 20 to 50 percent of the machine weight supported by the bent and applied at the machine centerline.

(3) Longitudinal and transverse forces. Longitudinal and transverse forces shall not be assumed to act simultaneously.

e. Horizontal Forces Within Structure. Assume horizontal forces to be equal in magnitude to the vertical loads of the generator stator and turbine exhaust hood, as given on the manufacturer's machine outline drawings. Apply these forces at the top flange of the supporting girders; assume the forces to be equal and opposite.

f. Assumed Forces on Centerline Guides. Refer to machine outline drawing for magnitude and points of application. Support beams for guide brackets shall have sufficient rigidity to limit the displacements relative to the main foundation to 0.005 inch under the action of the assumed forces.

g. Temperature Variation. Consider forces acting within the foundation due to temperature changes.

h. External Piping. Provisions shall be made to withstand loads from pipe thrusts, relief valves, and the weight of piping and fittings.

Section 7. WIND LOADS

1. GENERAL. The procedures given in this section together with the various equations, coefficients, and correction factors are intended to apply to structures of regular shape and regularly used for human occupancy or containing valuable properties. Tornados have not been considered in developing these criteria. Exceptions for minor and limited life structures are presented in DM-2.1. Conditions at variance with the above should be the subject of special consideration. The criteria contained in this Section are based on ANSI Standard A58.1, modified for simplicity of application and interpretation.

2. WIND PRESSURE. Buildings and other structures shall be designed to withstand applicable wind pressure.

a. Velocity Pressure. Velocity pressure (q) is determined by:

$$q = 0.00256 \, V^2 C_h \qquad (7\text{-}1)$$

where

q = velocity pressure of wind (psf)
C_h = height correction factor
V = wind velocity (mph)

(1) Wind Velocity. Peak gust wind speeds are given for the contiguous United States in Figure 3 and Table 7, and for locations outside the States in Table 8. Use a minimum of 80 miles per hour wind velocity for design.

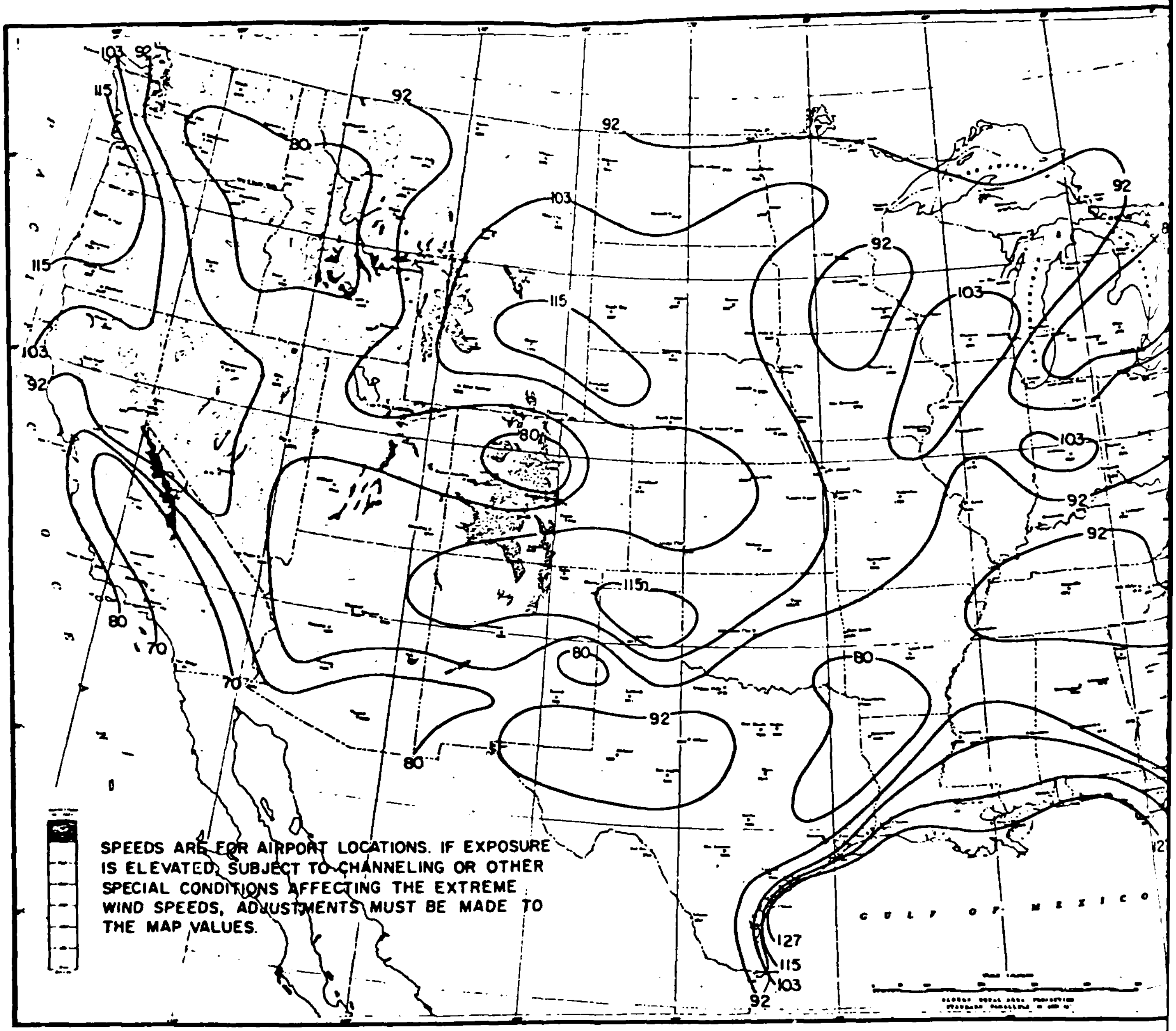
(2) Gust Factors. Gust factors are incorporated in the peak gust wind speeds given in Figure 3 and Tables 7 and 8. Use of the peak gust speed eliminates the need for estimation of the gust factor. The gust factor is variable, dependent on the general wind speed level at the particular location. The peak gust velocity indicated is assumed to be sustained for an interval of 2 to 3 seconds, and therefore ordinarily will be treated as a steady wind because the natural response period of most structures is less than 1.5 seconds. When the response period of the structure exceeds 1.5 seconds, appropriate methods of analyses for dynamic forces shall be used.

(3) Correction Coefficient for Height. Use curve A of Figure 4 to obtain the correction coefficient for velocity pressures above 30 feet. Curve A is a plot of Equation 7-2. The correction factor, C_h, below 30 feet is equal to 1.0.

$$C_h = \left(\frac{h}{30}\right)^{2/7} \qquad (7\text{-}2)$$

(4) Correction for Exposure Conditions. Correction coefficients for exposure are not to be used with criteria in this Section except with specific approval of NAVFACHQ.

b. Design Wind Pressure. The design wind pressure for elements of buildings and other structures shall be determined by the applicable velocity pressure q (obtained in accordance with Equation 7-1 or Figure 4 and considering the correction coefficient for height multiplied by the applicable pressure coefficient (Tables 9 through 18 and Figures 5 through 8).


SPEEDS ARE FOR AIRPORT LOCATIONS. IF EXPOSURE IS ELEVATED, SUBJECT TO CHANNELING OR OTHER SPECIAL CONDITIONS AFFECTING THE EXTREME WIND SPEEDS, ADJUSTMENTS MUST BE MADE TO THE MAP VALUES.
GULF OF MEXICO
103
92
115
80
70
127

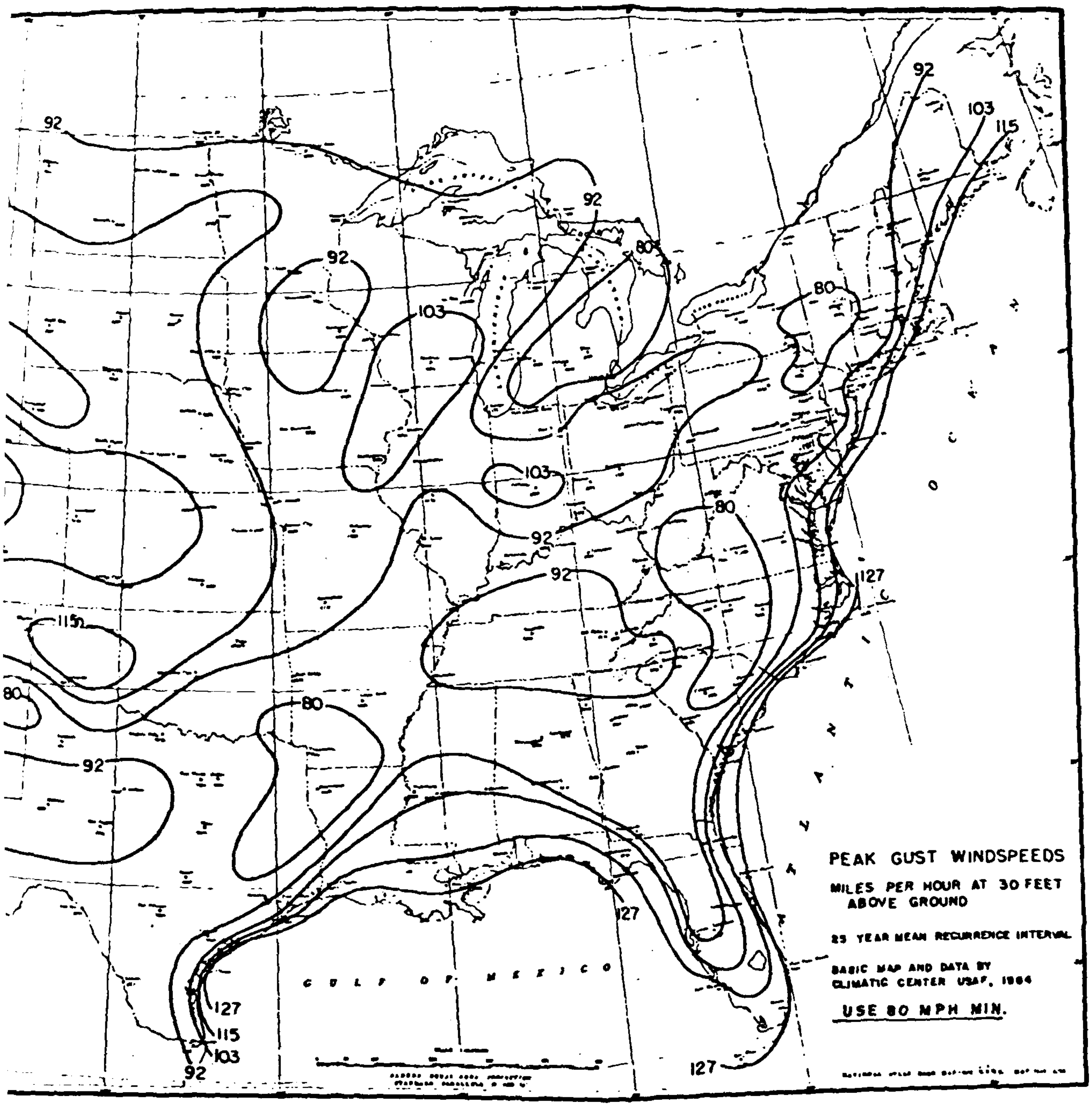


FIGURE 3

Peak Gust Windspeeds (mph)
at 30 Feet Above Ground
(25-Year Recurrence Interval)

TABLE 7

Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
ALABAMA:		
Brookley AFB, Mobile	121	6
Maxwell AFB, Montgomery	91	9
Mobile	121	6
Montgomery	91	6
ARIZONA:		
Davis Monthan AFB Tucson	76	91
Luke AFB, Phoenix	91	7
Williams AFB, Phoenix	78	7
Phoenix	81	7
ARKANSAS:		
Little Rock AFB Little Rock	90	15
CALIFORNIA:		
Castle AFB, Merced	61	5
Hamilton AFB, San Francisco	84	5
March AFB, Riverside	59	5
Mather AFB, Sacramento	101	5
Travis AFB, Fairfield	74	5
Vandenberg AFB, Lompoc	72	5
San Diego	64	0
Pasadena	72	0
Long Beach	72	0
San Francisco	85	5
Oakland	85	5
Mare Island	84	5
Sacramento	107	5
Stockton	92	5
China Lake	70	5
COLORADO:		
Lowry AFB, Denver	70	60
Denver	70	60
CONNECTICUT:		
New London	81	35
New Haven	81	35
DELAWARE:		
Dover AFB, Dover	93	20
Lewes	115	20

TABLE 7 (Continued)

Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
FLORIDA:		
Eglin AFB, Valparaiso	127	5
Homestead AFB, Homestead	127	0
McDill AFB, Tampa	91	2
Patrick AFB, Cocoa	125	2
Jacksonville	104	2
Miami	125	0
Key West	122	0
Pensacola	127	2
Tampa	87	2
GEORGIA:		
Hunter AFB, Savannah	104	5
Robins AFB, Warner Robins	78	5
Turner AFB, Albany	83	5
Augusta	83	5
Atlanta	86	7
Savannah	104	3
Macon	85	5
IDAHO:		
Mountain Home AFB Mountain Home	83	40
ILLINOIS:		
Chanute AFB, Rantoul	93	35
Scott AFB, Belleville	82	35
Chicago	40	83
INDIANA:		
Fort Wayne	88	40
Indianapolis	104	30
IOWA:		
Sioux City	102	54
KANSAS:		
Forbes AFB, Topeka	108	30
Schilling AFB, Salina	102	24
KENTUCKY:		
Lexington	91	18
Louisville	91	18

TABLE 7 (Continued)

Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
LOUISIANA:		
Barksdale AFB, Shreveport	67	5
Chennault AFB, Lake Charles	121	4
New Orleans	121	2
MAINE:		
Dow AFB, Bangor	98	75
Loring AFB, Caribou	92	75
Portland	99	65
Bangor	98	72
MARYLAND:		
Andrews AFB Washington, D.C.	87	25
Baltimore	90	22
Lexington Park	104	22
MASSACHUSETTS:		
L.G. Hanscom Field Boston	108	50
Otis AFB, Cape Cod	121	50
Westover AFB, Springfield	86	70
Boston	108	50
Springfield	86	70
MICHIGAN:		
Kinchelow AFB Sault Ste. Marie	97	65
Selfridge AFB, Detroit	79	50
Detroit	76	50
MINNESOTA:		
Minn.-St. Paul IAP	90	75
Minneapolis	90	75
Duluth	98	75
MISSISSIPPI:		
Jackson	104	3
Meridan	104	5
Gulfport	127	5
MISSOURI:		
Kansas City	89	28
St. Louis	81	27

TABLE 7 (Continued)

Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
MONTANA:		
Malmstrom AFB, Great Falls	83	75
NEBRASKA:		
Offutt AFB, Omaha	97	55
Omaha	97	55
Hastings	104	53
NEBADA:		
Nellis AFB, Las Vegas	90	8
Stead AFB, Reno	92	23
Fallon	92	12
Hawthorne	92	30
Reno	95	23
NEW HAMPSHIRE:		
Pease AFB, Portsmouth	105	60
Portsmouth	104	60
NEW JERSEY:		
McGuire AFB, Trenton	85	30
Atlantic City	99	20
Bayonne	84	30
NEW MEXICO:		
Cannon AFB, Clovis	78	15
Holloman AFB, Alamogordo	81	20
Walker AFB, Roswell	86	15
Alburquerque	99	17
NEW YORK:		
Griffis AFB, Rome	82	50
Plattsburg AFB, Plattsburg	91	70
Stewart AFB, Newburgh	88	45
Buffalo	91	35
Albany	79	54
New York	84	40
Syracuse	82	56
NORTH CAROLINA:		
Pope AFB, Fayetteville	74	9
Charlotte	90	8
Wilmington	132	5
Cape Hatteras	132	5
Cherry Point	115	5
Camp LeJeune	115	5

TABLE 7 (Continued)

Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
NORTH DAKOTA:		
Grand Forks AFB, Grand Forks	99	25
Minot AFB, Minot	99	15
OHIO:		
Wright-Patterson AFB, Dayton	92	15
Columbus	92	15
Cincinnati	92	10
OKLAHOMA:		
Tinker AFB, Oklahoma City	92	20
OREGON:		
Portland Int. Apt.	115	6
Portland	115	6
PENNSYLVANIA:		
Olmstead AFB, Harrisburg	72	35
Harrisburg	85	30
Pittsburgh	83	38
Philadelphia	81	30
RHODE ISLAND:		
Providence	114	45
SOUTH CAROLINA:		
Paris Is.	120	6
Charleston	122	3
SOUTH DAKOTA:		
Ellsworth AFB, Rapid City	106	55
TENNESSEE:		
Sewart AFB, Smyrna	95	10
Memphis	92	10
TEXAS:		
Amarillo AFB, Amarillo	120	20
Bergstrom AFB, Austin	86	4
Biggs AFB, El Paso	92	6
Carswell AFB, Ft. Worth	85	12
Dyess AFB, Abilene	100	10
Ellington AFB, Houston	90	3
Kelley AFB, San Antonio	88	4
Kingsville NAS, Kingsville	105	4
Reese AFB, Lubbock	86	15

TABLE 7 (Continued)

Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
TEXAS (cont'd)		
Sheppard AFB, Wichita Falls	85	15
Corpus Christi	115	2
El Paso	92	6
Fort Worth	79	10
Galveston	101	3
Houston	92	3
San Antonio	75	4
Amarillo	120	20
UTAH:		
Hill AFB, Ogden	93	35
Salt Lake City	88	35
VERMONT:		
Burlington	91	35
VIRGINIA:		
Langley AFB, Hampton	109	6
Newport News	106	10
Norfolk	106	10
Richmond	88	14
Virginia Beach Coast	115	14
Yorktown	100	14
WASHINGTON:		
Fairchild AFB, Spokane	65	91
Larson AFB, Moses Lake	72	35
McChord AFB, Tacoma	83	10
Bremerton	83	8
Seattle	83	8
Spokane	91	30
Pasco	75	25
Tacoma	83	8
WEST VIRGINIA:		
Charleston	81	30
WISCONSIN:		
Truax Field, Madison	114	50
Milwaukee	112	54
Green Bay	100	54
WYOMING:		
Francis E. Warren AFB, Cheyenne	99	70
WASHINGTON, D.C.	92	20

TABLE 8

Wind and Frost Penetration Data for Locations Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
AFRICA:		
Libya:		
Wheelus AB	84	0
Morocco:		
Casablanca	84	0
Port Lyautey NAS	84	0
ASIA:		
India:		
Bombay	85	00
Calcutta	106	0
Madras	86	0
New Delhi	85	0
Japan:		
Itazuke AB	92	6
Johnson AB	104	6
Misawa AB	94	18
Tachikawa AB	98	6
Tokyo	98	6
Wakkanai	115	36
Korea:		
Kimpo AB	72	30
Seoul	72	30
Uijongbu	59	36
Pakistan:		
Peshawar	82	6
Saudi Arabia:		
Bahrain Island	81	0
Dhahran AB	81	0
Taiwan:		
Tainan	120	0
Taipei	130	0
Thailand:		
Chiang Mai	78	0
Bangkok	78	0
Sattahip	85	0
Udonthani	63	
Turkey:		
Ankara	92	24
Karamursel	105	12
Viet Nam:		
Da Nang	120	
Nha Trang	94	
Saigon	94	0

TABLE 8 (Continued)

Wind and Frost Penetration Data for Locations Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
ATLANTIC OCEAN AREA:		
Ascension Island	62	0
Azores:		
Lajes Field	117	
Bermuda:	127	0
CARIBBEAN SEA:		
Bahama Islands:		
Eleuthera Island	138	0
Grand Bahama Island	138	0
Grand Turk Island	150	
Great Exuma Island	138	0
Cuba:		
Guantanamo NAS	90	0
Leeward Islands:		
Antigua Island	138	0
Puerto Rico:		
Ramey Air Force Base	93	0
San Juan and Sabana Seca	116	0
Vieques Island and Roosevelt Rds.	138	0
Trinidad Island:		
Port of Spain	55	0
Trinidad NS	55	0
CENTRAL AMERICA:		
Canal Zone:		
Albrook AFB	62	0
Balboa	62	0
Coco Solo	52	0
Colon	58	0
Cristobal	58	0
France AFB	58	0
EUROPE:		
England:		
Birmingham	83	12
London	88	12
Mildenhall AB	97	12
Plymouth	87	12
Sculthorpe AB	92	12
Southport	97	12
South Shields	92	12
Spurn Head	92	12

TABLE 8 (Continued)

Wind and Frost Penetration Data for Locations Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
EUROPE-Continued		
France:		
Nancy	81	18
Paris/LeBourget	94	18
Rennes	102	18
Vichy	114	24
Germany:		
Bremen	79	30
Munich-Riem	91	36
Rhein-Main AB	79	30
Stuttgart AB	84	36
Greece:		
Athens	86	0
Souda Bay	80	
Italy:		
Aviano AB	74	18
Brindisi	102	6
La Maddalena	80	
Sigonella-Catania	90	
Scotland:		
Aberdeen	84	12
Edinburgh	92	12
Edzell	84	12
Glasgow/Renfrew Airfield	92	12
Lerwick, Shetland Islands	104	18
Londonderry	124	12
Prestwick	93	12
Stornoway	112	12
Thurso	98	12
Spain:		
Madrid	77	6
Rota	87	0
San Pablo	109	6
Zaragoza	109	6
NORTH AMERICA:		
Alaska:		
Adak, Aleutian Islands	124	24
Anchorage	97	60
Annette	94	24
Attu	178	24
Barrow	109	Permafrost
Bethel	94	60
Cold Bay	110	36
Cordova	94	48

TABLE 8 (Continued)

Wind and Frost Penetration Data for Locations Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
NORTH AMERICA-Continued		
Eielson AFB	75	60
Elmendorf AFB	93	60
Fairbanks	75	60
Gambell	130	48
Juneau	92	36
King Salmon	115	60
Kodiak	116	48
Kotzebue	122	Permafrost
McGrath	85	84
Middleton Island AFS	125	48
Nikolski, Umnak Island	129	36
Nome	120	Permafrost
Northeast Cape AFS		
St. Lawrence Island	133	48
Shemya Island	178	24
St. Paul Island	105	36
Umiat	112	Permafrost
Wales	105	Permafrost
Yakutat	99	36
Canada:		
Argentia NAS, Newfoundland	107	36
Churchill, Manitoba	100	Permafrost
Cold Lake, Alberta	75	72
Edmonton, Alberta	78	60
E. Harmon AFB, Newfoundland	105	60
Fort William, Ontario	75	60
Frobisher, N.W.T.	100	Permafrost
Goose Airport, Newfoundland	83	60
Ottawa, Ontario	84	48
St. John's, Newfoundland	106	36
Toronto, Ontario	84	36
Winnipeg, Manitoba	76	60
Greenland:		
Narsarssuak AB	129	60
Simiutak AB	154	60
Sondrestrom AB	112	Permafrost
Thule AB	132	Permafrost
Iceland:		
Keflavik	115	24
Thorshofn	136	36
PACIFIC OCEAN AREA:		
Australia:		
H.E. Holt, NW Cape	130	0

TABLE 8 (Continued)

Wind and Frost Penetration Data for Locations Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	Frost Penetration (inches)
PACIFIC OCEAN AREA-Continued		
Caroline Islands:		
Koror, Palau Islands	95	0
Ponape	109	0
Hawaii:		
Barber's Point	67	0
Hickam AFB	79	0
Kaneohe Bay	84	0
Wheeler AFB	63	0
Hawaiian Islands:		
Hawaii		0
Kahoolawe		0
Kauai		0
Lanai		0
Maui		0
Molokai		0
Niihau		0
Oahu		0
Johnston Island	72	0
Mariana Islands:		
Agana, Guam	155	0
Andersen AFB, Guam	155	0
Kwajalein	104	0
Saipan	150	0
Tinian	150	0
Marcus Island	150	0
Midway Island	87	0
Okinawa:		
Kadena AB	184	0
Naha AB	178	0
Philippine Islands:		
Clark AFB	87	0
Sangley Point	68	0
Subic Bay	77	0
Samoa Islands:		
Apia, Upolu Island	147	0
Tutuila, Tutuila Island	147	0
Volcano Islands:		
Iwo Jima AB	206	0
Wake Island	86	0

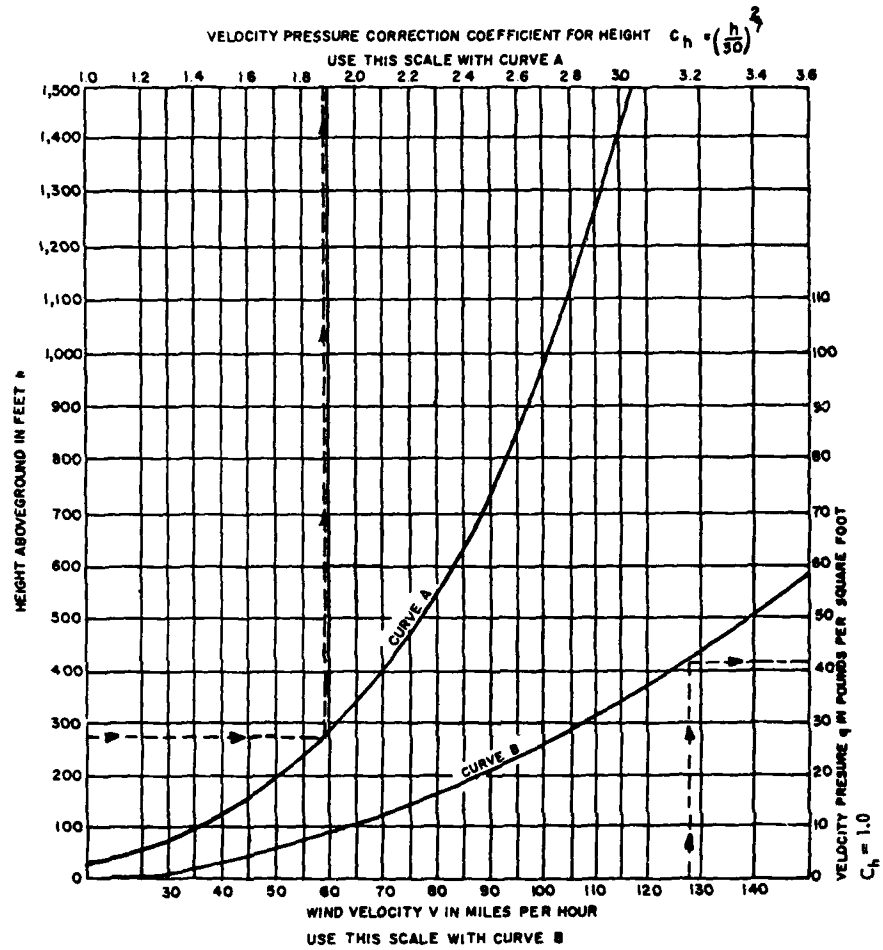
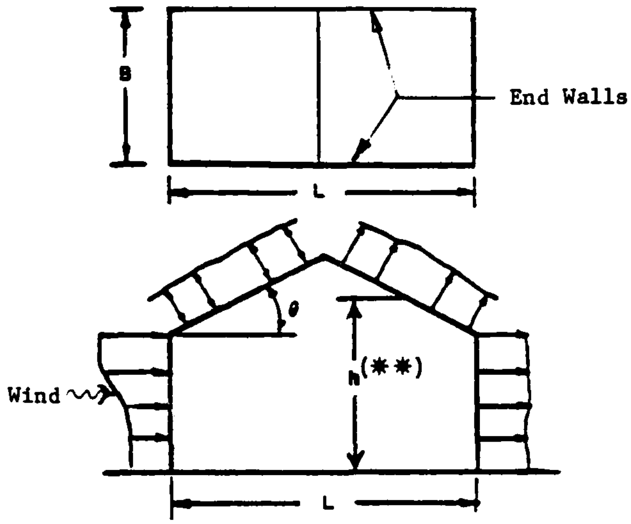


FIGURE 4
Velocity Pressure and Variation of Velocity Pressure with Height Above Ground

TABLE 9

External Pressure Coefficient (C_p) for Average Loads on Main Wind - Force Resisting System



WALL PRESSURE COEFFICIENTS

SURFACE	L/B	Cp
WINDWARD WALL	ALL VALUES	0.8
LEEWARD WALL	0-1 2 ≥4	-0.5 -0.3 -0.2
END WALLS	ALL VALUES	-0.7

ROOF PRESSURE COEFFICIENTS Cp

WIND DIRECTION	WINDWARD								LEEWARD
	h/L	ANGLE θ DEGREES							
		0	10-15	20	30	40	50	≥ 60	
NORMAL TO RIDGE	< 0.3	-0.7	0.2(*)	0.2	0.3	0.4	0.5	0.01θ	-0.7 for all values of h/L
	0.5	-0.7	-0.9	-0.75	-0.2	0.3	0.5	0.01θ	
	1.0	-0.7	-0.9	-0.75	-0.2	0.3	0.5	0.01θ	
	> 1.5	-0.7	-0.9	-0.9	-0.9	-0.35	0.21	0.01θ	
PARALLEL TO RIDGE	h/B or h/L < 2.5	-0.7							-0.7
	h/B or h/L > 2.5	-0.8							-0.8

(*) The coefficient of -0.9 shall be used for roofs rising from ground level. Roofs with other slopes and/or buildings with other h/L values are to be designed using the same pressure values whether the roof rises from the ground or the roof begins above ground.

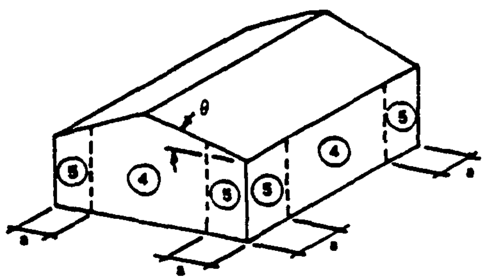
(**) h: Mean roof height in ft. except that eave height may be used for $\theta < 10°$

NOTES:

1. Refer to Table 14 for arched roof, Tables 10 and 11 for components and cladding and Table 13 for internal pressures.
2. + and - signs signify pressures acting toward and away from the surfaces, respectively.
3. Linear interpolation may be used for values of θ and h/L ratios other than those shown.

TABLE 10

External Pressure Coefficient (C_p) for Loads on Building Components and Cladding for Buildings With Mean Roof Height h≤60 ft. - Walls



NOTES:

1. Notes apply to both Table 10 and Table 11.

2. Notations:

   a =10% of minimum width or 0.4h, whichever is smaller, but not less than 4% of minimum width or 3 ft.

   + and - signs signify pressures acting toward and away from the surfaces respectively.

3. When θ≤10°, C_p may be reduced by 10%.

4. Tributary area for a component is surface area that would be supported by the component to transmit the wind loads and is not the same as influence area considered for live loads.

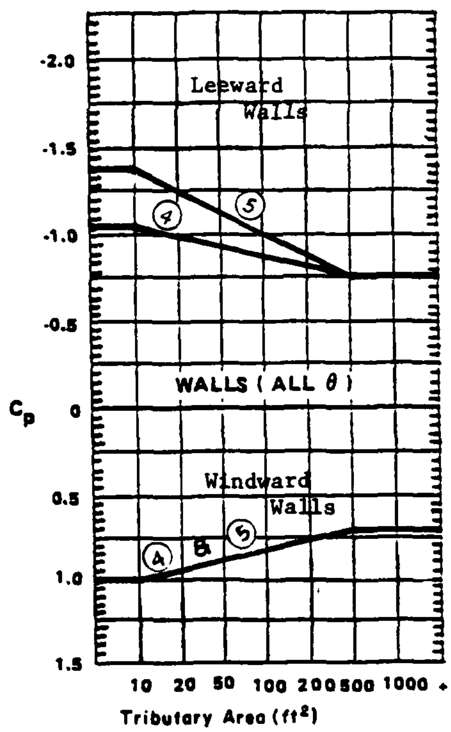


TABLE 11 (See notes, Table 10)

External Pressure Coefficients for Loads on Building Components and Cladding for Buildings With Mean Roof Height h < 60 ft. - Roofs

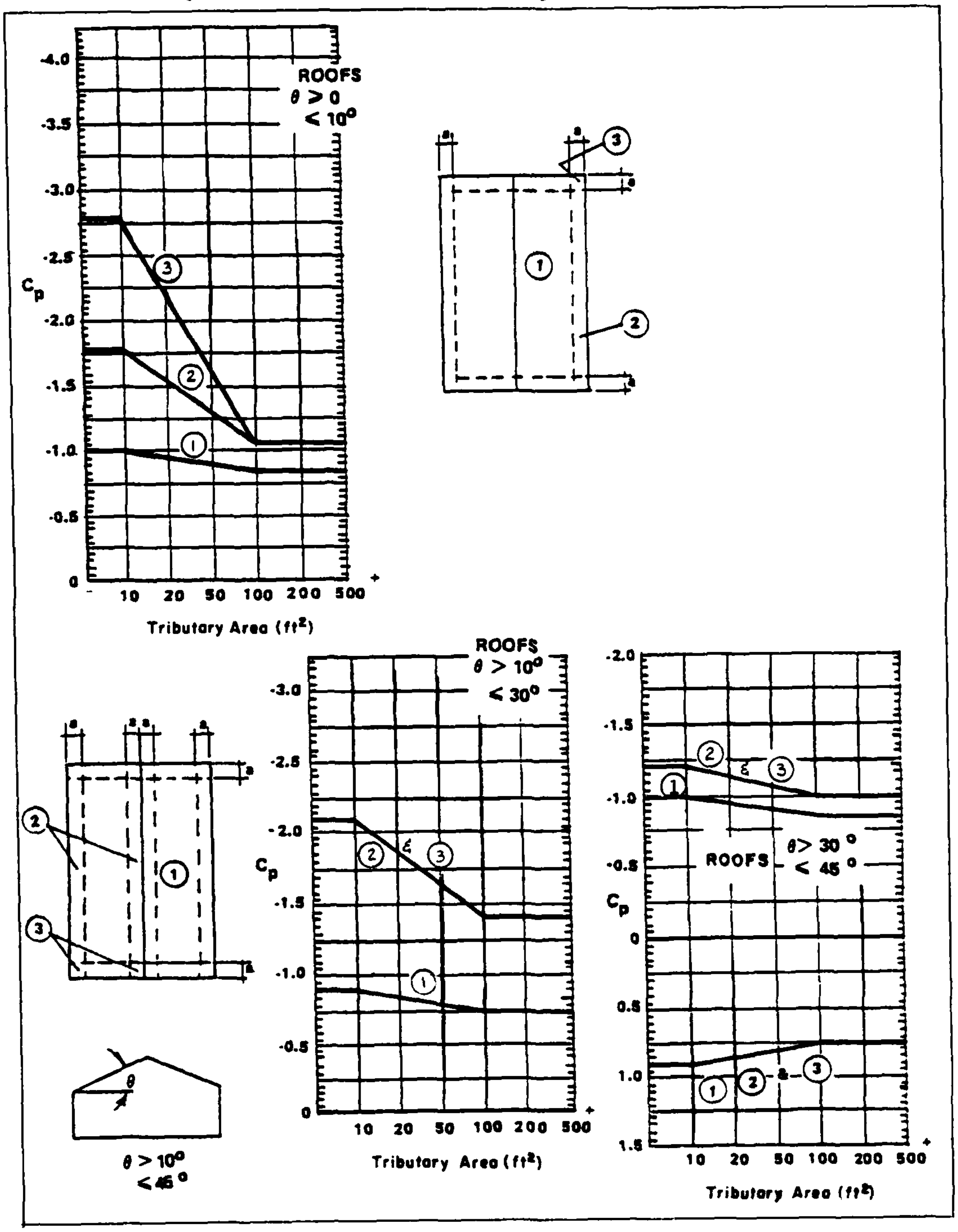


TABLE 12

External Pressure Coefficients for Loads on Building Components and Cladding for Buildings with Mean Roof Height h > 60 ft. - Roofs and Walls.

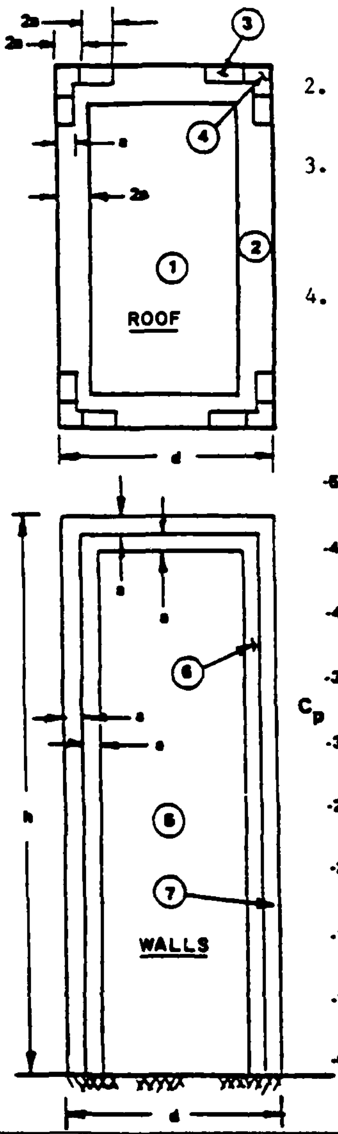
NOTES:

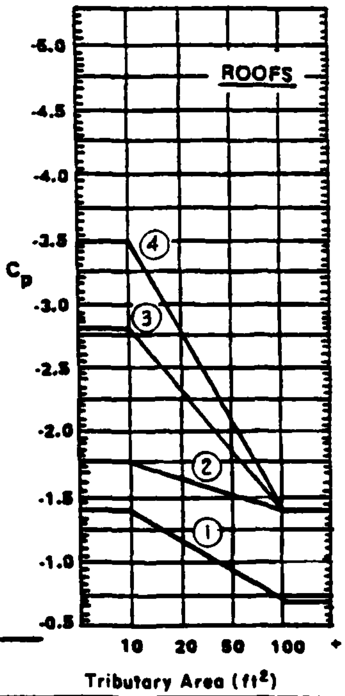
1. If a parapet is provided around the roof perimeter, Zones 3 and 4 may be treated as Zone 2. Minimum parapet height required to realize these reduced pressures is 24 inches.

2. For roofs with slope of more than 10°, use (C_p) from Tables 10 and 11.

3. Notations:
   a: 5% of minimum width or 0.5h, whichever is smaller,
   + and - signs signify pressures acting toward and away from the surfaces respectively.

4. Tributary area for a component is surface area that would be supported by the component to transmit the wind loads and is not the same as influence area considered for live loads.





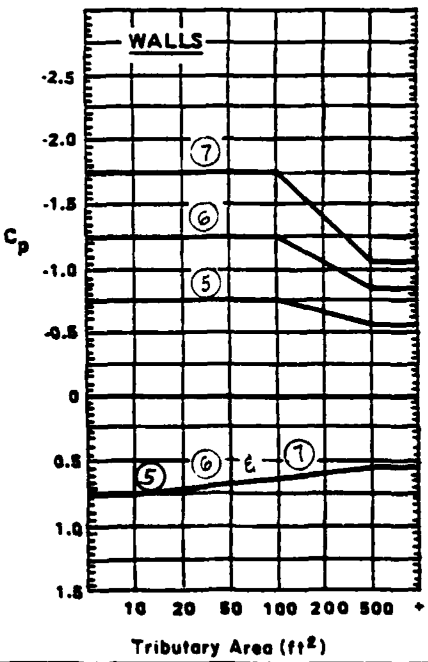


TABLE 13

Internal Pressure Coefficients for Buildings (*)

Condition	C_p
1. Percentage of opening area in one wall exceeds that of all other walls by 10% or more, and opening area in all other walls *do not* exceed 20% of respective wall areas:	+0.50 -0.17
2. All other cases:	±0.17

(*) Internal pressures are additive to external pressures in accordance with $q_{total} = q_{external} + (-q_{internal})$

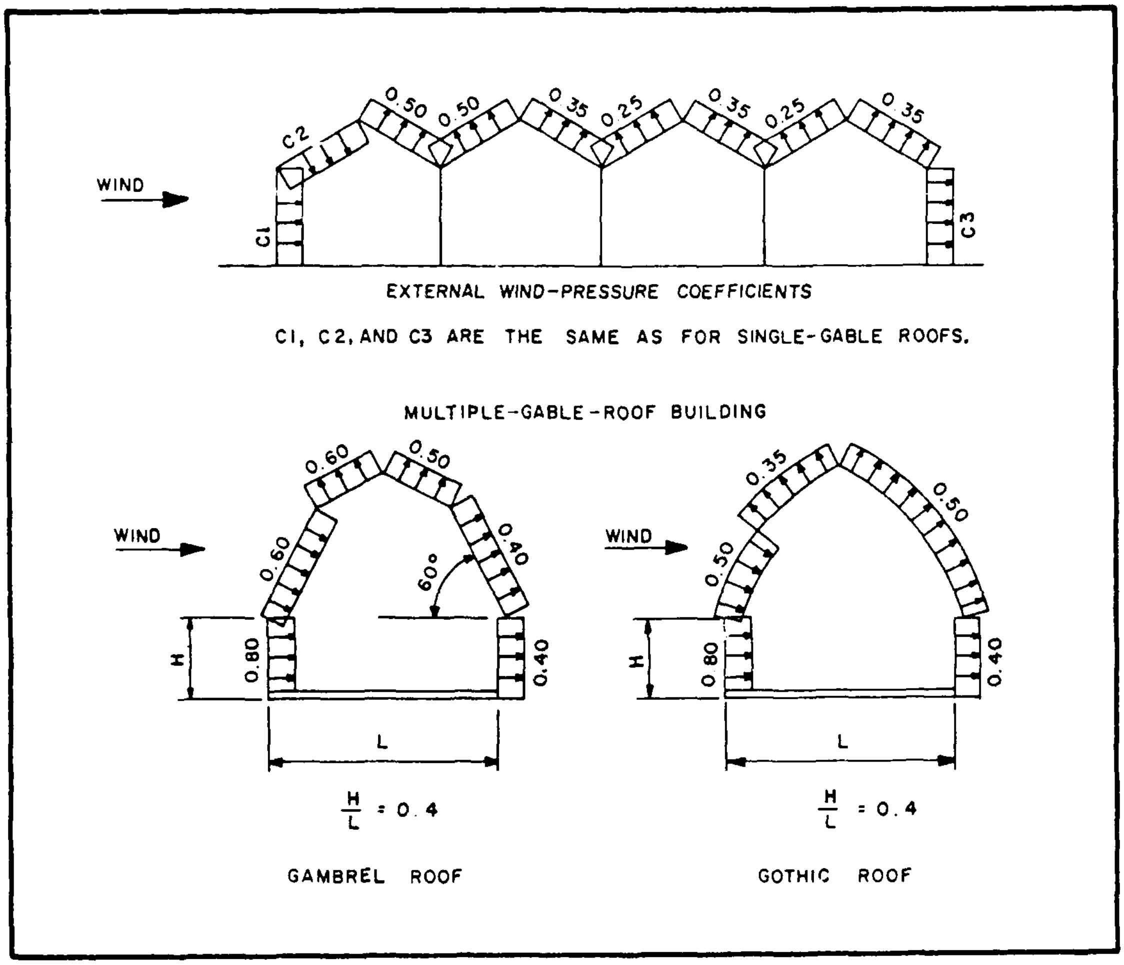


FIGURE 5
Pressure Coefficients for Compound Roof Shapes

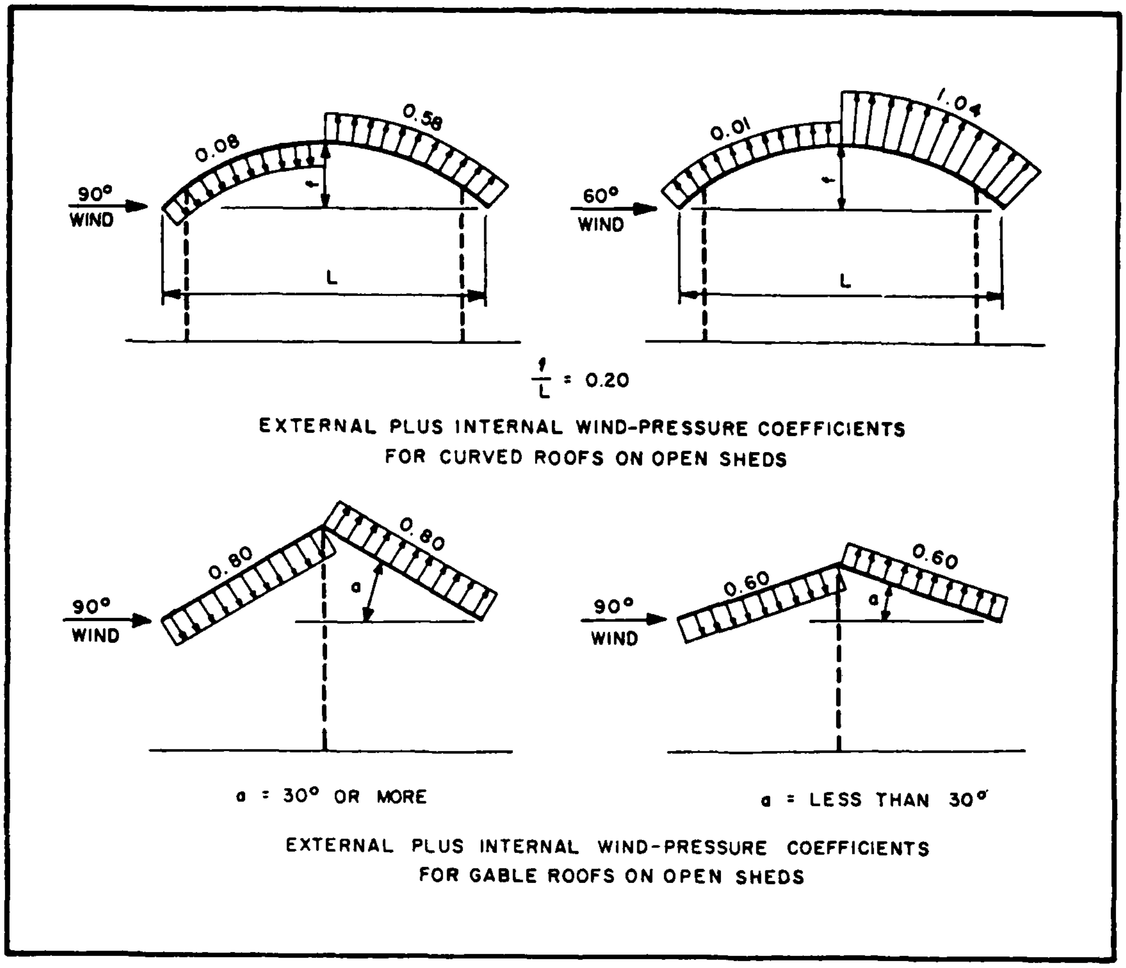


FIGURE 6
Pressure Coefficients for Open Sheds

TABLE 14

External Pressure Coefficients for Arched Roofs

	Rise-to-Span Ratio, r	Windward Quarter	Center Half	Leeward Quarter
Roof on elevated structure	$0<r<0.2$	-0.9	(-0.7-r)	-0.50
	$0.2\le r<0.3$	(1.5r-0.3)*	(-0.7-r)	-0.50
	$0.3\le r\le 0.6$	(2.75r-0.7)	(-0.7-r)	-0.50
Roof springing at ground level	$0<r\le 0.6$	1.4	(-0.7-r)	-0.50

*When the rise-to-span ratio is $(0.2\le r\le 0.3)$, alternative coefficients given by (6r-2.1) also shall be used for the windward quarter.

Notes

1. Values shown are for average loads on main wind-force resisting system.

2. + and - signs signify pressure acting toward and away from the surface respectively.

3. For components and cladding:

   a. At roof perimeter, use external pressure coefficients in Tables 10 and 11, with θ based on spring line slope.

   b. In remaining roof areas, use external pressure coefficients of this table, multiplied by 1.2.

TABLE 15

Pressure Coefficients for Flat Roofs Over Open Buildings
and Other Structures

θ	Pressure Coefficient						
	B/L						
	1/5	1/3	1/2	1	2	3	5
10°	0.2	0.25	0.3	0.45	0.55	0.7	0.75
15°	0.35	0.45	0.5	0.7	0.85	0.9	0.85
20°	0.5	0.6	0.75	0.9	1.0	0.95	0.9
25°	0.7	0.8	0.95	1.15	1.1	1.05	0.95
30°	0.9	1.0	1.2	1.3	1.2	1.1	1.0

Location of Center of Pressure, X/L

θ	B/L		
	1/5 to 1/2	1	2 to 5
10°	0.35	0.3	0.3
15°	0.35	0.3	0.3
20°	0.35	0.3	0.3
25°	0.35	0.35	0.4
30°	0.35	0.4	0.45

Notes:

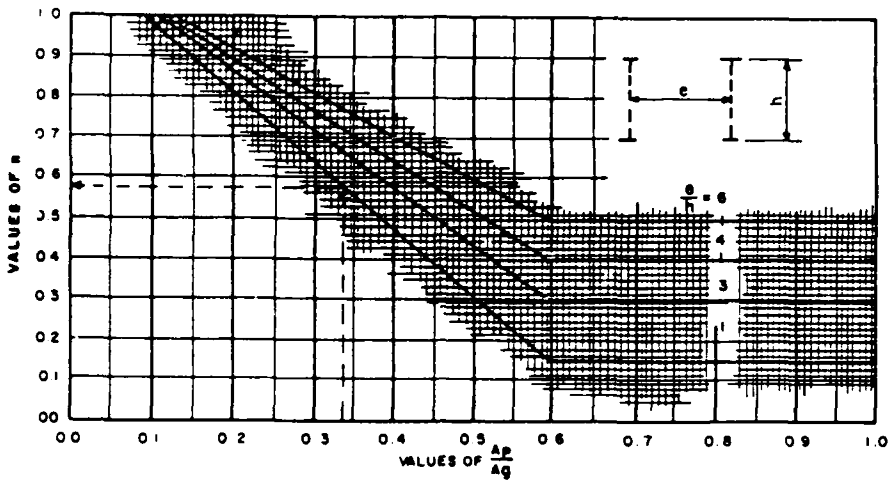
1. Wind forces act normal to surface and may be directed inward or outward.
2. The wind shall be assumed to deviate by $\pm 10^{\circ}$ from horizontal.
3. Notation:

   θ: angle between wind and plane of roof.

   X: distance to center of pressure from windward edge of roof.

   B: Building plan dimension, perpendicular to wind direction

   L: Building plan dimension, parallel to wind direction.



Ap = TOTAL PROJECTED AREA OF MEMBERS ON ONE SIDE OF THE STRUCTURE.

Ag = TOTAL AREA WITHIN THE LIMITING LINES FOR ONE SIDE OF THE STRUCTURE.

n IN THE DIAGRAM APPLIES TO TRUSSES AND LATTICED MEMBERS EXCEPT TRIANGULAR TOWERS.

TYPE OF STRUCTURES	PRESSURE COEFFICIENT ON PROJECTED AREA
DOUBLE PARALLEL SOLID GIRDER	1:10
DOUBLE PARALLEL TRUSSES AND DOUBLE PARALLEL LATTICED MEMBERS	1.6(1+n)
GIRDERS AND TRUSSES WITH m PARALLEL MEMBERS WHERE m IS MORE THAN 2	1.5+(m-2)0.5
TOWERS	
SQUARE CROSS SECTION, WIND ON FACE → □	1.6(1+n)
SQUARE CROSS SECTION, WIND ON CORNER → ◇	1.92(1+n)
TRIANGULAR CROSS SECTION, WIND ON FACE → ▷	2.28
TRIANGULAR CROSS SECTION, WIND ON CORNER → ◁	1.93

<u>NOTE</u>:
FOR SINGLE, OPEN-LATTICE FRAMEWORKS, SEE TABLE 18

FIGURE 7
Pressure Coefficients for Structures Having Multiple Presentments

TABLE 16

Pressure Coefficients for Chimneys, Tanks, and Similar Structures

Shape	Type of Surface	h/D		
		1	7	25
Square (wind normal to a face)	All	1.3	1.4	2.0
Square (wind along diagonal)	All	1.0	1.1	1.5
Hexagonal or octagonal ($D\sqrt{q} > 2.5$)	All	1.0	1.2	1.4
Round ($D\sqrt{q} > 2.5$)	Moderately smooth	0.5	0.6	0.7
	Rough (D'/D=0.02)	0.7	0.8	0.9
	Very rough (D'/D=0.08)	0.8	1.0	1.2
Round ($D\sqrt{q} \leqslant 2.5$)	All	0.7	0.8	1.2

Notes:

1. The design wind force shall be calculated based on the area of the structure projected on a plane normal to the wind direction. The force shall be assumed to act parallel to the wind direction.

2. Linear interpolation may be used for h/D values other than shown.

3. Notation:

   D: diameter or least horizontal dimension in ft

   D': depth of protruding elements such as ribs and spoilers in ft

   h: height of structure in ft

   g: from Equation 7-1.

TABLE 17

Pressure Coefficients for Solid Signs

At Ground Level							
ν	≤ 3	5	8	10	20	30	≥ 40
C_f	1.2	1.3	1.4	1.5	1.75	1.85	2.0
Above Ground Level							
M/N	≤ 6	10	16	20	40	60	≥ 80
C_f	1.2	1.3	1.4	1.5	1.75	1.85	2.0

Notes:

1. Signs with openings of less than 30% of gross area shall be considered solid signs.

2. Signs for which the distance from ground to bottom edge is less than 0.25 times the vertical dimension shall be considered to be at ground level.

3. To allow for both normal and oblique wind directions, two cases shall be considered:

   a) Normal wind actions at geometric center, and
   b) The same, total normal force as in a) acting at the level of the geometric center, but at a distance from windward edge of 0.3 times the horizontal dimension of the sign.

4. Notation:

   ν: height to width ratio
   M: larger dimension of sign in ft
   N: smaller dimension of sign in ft

TABLE 18

Pressure Coefficients for Open Signs and Latticed Frameworks

Ratio of Solid Area to Gross Area (ε)	Flat-Sided Members	Rounded Members	
		$D\sqrt{q} < 2.5$	$D\sqrt{q} > 2.5$
Less than 0.1	2.0	1.2	0.8
0.1 to 0.29	1.8	1.3	0.9
0.3 to 0.7	1.6	1.5	1.1

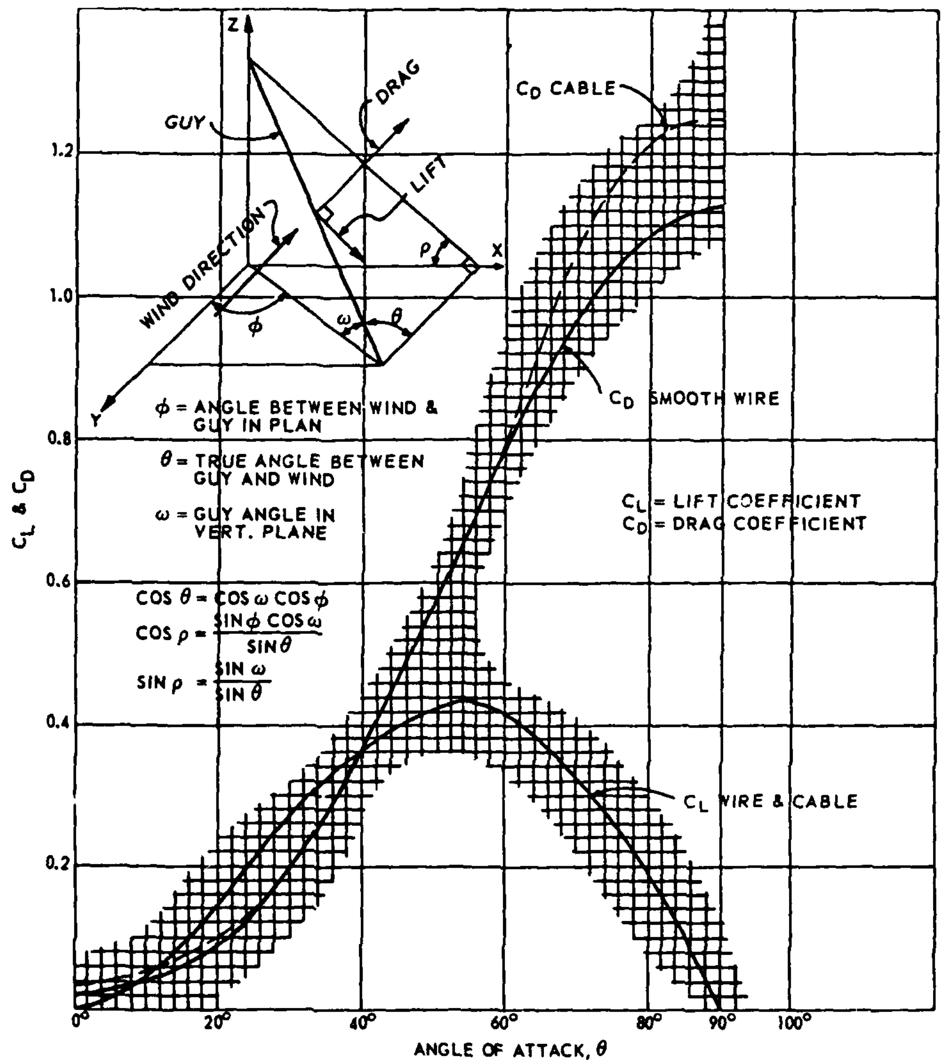
Notes:

1. Signs with openings of 30% or more of gross area are classified as open signs.

2. The design wind forces shall be calculated based on the area of all exposed members and elements projected on a plane normal to the wind direction. Forces shall be assumed to act parallel to the wind direction.

3. Notation:

   ε: ratio of solid area to gross area
   D: diameter of a typical round member in ft
   q: from Equation 7-1.



Drag and Lift Coefficients for Wire and Cable

DRAG & LIFT FORCES

DRAG = 2.133 (c d v^2) $C_D \times 10^{-7}$ Kips
LIFT = 2.133 (c d v^2) $C_L \times 10^{-7}$ Kips

where c = chord length of cable in feet
d = diameter of cable in inches
v = wind velocity in mph (usually taken as velocity at mid-height of cable)

Note: LIFT for leeward cable is positive acting upward.

FIGURE 8
Wind Forces on Guy Wires and Cables

3. PURLINS, GIRTS, SHEATHING, SIDING, FASTENINGS, WALLS AND DOORS. The design loading for purlins, girts, sheathing, siding, fastenings walls and doors consider:

a. Negative external pressure (suction) plus internal pressure acting outward as a bursting force.

b. External pressure, plus internal pressure acting inward as an internal suction.

c. In the above loading combinations, the internal pressures are assumed to be uniformly distributed over the interior surface of the building.

4. EAVES AND CORNICES. Overhanging eaves and cornices shall be designed for an upward pressure of twice the external pressure.

5. CLASS A STRUCTURES. Criteria on wind loads and their effect on bridge structures are contained in the AASHTO Standards and the AREA Manual.

6. SPECIAL CONDITIONS.

a. Wind on Berthed Vessel. See DM-26.

b. Prefabricated Buildings of Standard Manufacture. Nothing in this publication shall preclude the acquisition of prefabricated buildings of standard manufacture. However, such buildings shall be designed for adequacy under loading combinations specified in this publication including snow, wind, and seismic.

c. Mobile Home Tie-Downs.

(1) Hurricanes that have hit the Gulf Coast area caused extensive damage to mobile homes. Many of these units apparently did not employ any tie-downs device. Some had rods that anchored the chassis to the foundation but internal connections in the superstructure were unable to resist the wind forces. It is believed that over-the-roof ties would have prevented most of this loss.

(2) Similar damage resulted from hurricane Camile (1969) and other major storms. To reduce damage due to high winds, mobile homes should be adequately anchored. Over-the-roof anchorage appears to be preferable. If anchor connections are at the first floor level, the units should be analyzed to determine the adequacy of floor to wall and floor to roof connections.

d. Wind-Induced Vibrations.

(1) In general, tanks, towers, and stacks are drag-sensitive structures. Consequently, in the design of such structures, the effects of wind-induced vibration shall be investigated. For further information, see Wind-Induced Vibrations in Antenna Members, ASCE (see References).

(2) Failure of standard types of structural members has been attributed to wind-induced vibrations. Little information is available on vibrations in members of I and WF shapes. However, to avoid vortex-shedding phenomenon, rectangular beams and girders should have a width (parallel to wind direction)-to-depth (perpendicular to wind direction) ratio of less than 0.75 or greater than 3.5.

e. Cranes and Derricks. For nonoperating conditions, design cranes and derricks for external wind pressures as described above. For criteria for operating conditions, see DM-38.

Section 8. EARTHQUAKE FORCES

1. CLASS A STRUCTURES. The provisions of the AASHTO design standard shall apply.

2. CLASS B STRUCTURES. Criteria and guidance for the design of buildings in seismic areas shall be in accordance with Tri-Service Engineer Manual for Seismic Design for Buildings, NAVFAC P-355.

a. Serviceability. The criteria in P-355 is intended to provide for reasonable life-safety. However, structures designed to this criteria may sustain appreciable damage if exposed to a large earthquake. Designs should incorporate materials and details of construction that will minimize damage that would result from strong ground motion and the corresponding destruction and displacement in the structure. If there is a stated requirement for the structure to remain functional after a large earthquake, additional attention should be devoted to the design. For important structures, such as hospitals, it may be appropriate to establish a site specific response spectra (NAVFAC HQ guidance should be sought).

b. Parts or Components. For forces on parts or components of a structure, the value computed in accordance with NAVFAC P-355 shall be used.

c. Earthquake Zones. Earthquake Zones are indicated in NAVFAC P-355.

d. Existing Structures. Existing structures are considered to provide adequate safety if they were designed for a base shear at least 80% of that prescribed by P-355 for new construction or if they are adequate to resist collapse when exposed to an earthquake with an 80% probability of not being exceeded in 50 years. Structures designed in accordance with the 1976 edition of the Uniform Building Code, or equivalent criteria, shall be considered to be in substantial conformance with minimum safety requirements.

3. CLASS C STRUCTURES. Criteria relating to earthquake forces on piers and wharves are presented in DM-25.1. Criteria relating to other types of Class C Structures await development. In the interim, criteria for Class B Structures should be used to the extent applicable.

Section 9. OTHER LOADS

1. EARTH PRESSURES AND FOUNDATION STRUCTURE LOADS. Standards for determining earth pressures and foundation structure loads are contained in NAVFAC DM-7.

2. FLUID PRESSURES AND FORCES. Fluid pressures and forces which must be considered in structural design are as follows:

a. Hydrostatic Pressure. Use hydrostatic pressure criteria in American Civil Engineering Practice, Vol. II. (See References.)

b. Wave Forces. Wave force criteria are described in DM-25.1, DM-25.4, DM-25.5, DM-25.6, and DM-26.

c. Current Forces. Current force criteria are contained in DM-25.1, DM-25.4, DM-25.5, DM-25.6 and DM-26.

3. CENTRIFUGAL FORCES. See AASHTO and AREA design standards.

4. TRACTION. See Section 4.

5. THERMAL FORCES. (See, also, Section 10.) Provide for stresses or movements resulting from variations in temperature. On cable structures, consider changes in cable sag and tension. The rises and falls in the temperature shall be determined for the localities in which structures are built. They shall be established from assumed temperatures at times of erection. Consider the lags between air temperatures and interior temperatures of massive concrete members or structures.

a. Temperature Ranges. Except as indicated in the AASHTO design standard, the ranges of temperature for exterior, exposed elements, generally, shall be:

	Climate (^{o}F)	
Structure	Moderate	Cold
Metal	0 to 120	-30 to 120
Concrete:		
Rise	30	35
Fall	-40	-45

The design of framing within enclosed buildings seldom need consider the forces and/or movements resulting from a variation in temperature of more than 30^{o} to 40^{o}F and the effects of such forces and/or movements often are neglected in the design of buildings having plan dimensions of 250 ft. or less, although movements of one-quarter to three-eighths inch can develop and may be important for buildings constructed with long bearing walls, parallel to direction of movement.

b. Piping. To accommodate changes in length due to thermal variations, pipes frequently are held at a single point. In vertical piping in buildings, the loads may be severe and shall be included in the design of supporting framing.

6. FRICTION FORCES.

a. Sliding Plates. Use 10 percent of the dead load reactions for bronze or copper-alloy sliding plates. Consult manufacturer for special systems.

b. Rockers or Rollers. Use 3 percent of the dead load reactions when employing rockers or rollers.

c. Foundations on Earth. Criteria for foundations on earth are contained in NAVFAC DM-7.

d. Other Bearings. Use the Standard Handbook for Mechanical Engineers (see References) for coefficients of friction. Base the forces on dead load reactions plus any applicable longtime live load reactions.

7. SHRINKAGE. (See, also, Section 10.)

a. Stress. Arches and similar structures shall be investigated for stresses induced by shrinkage and rib shortening.

b. Coefficient of Shrinkage. For masonry structures, the minimum linear coefficient of shrinkage shall be assumed as 0.0002, and the theoretical shrinkage displacement shall be computed as the product of the linear coefficient and the length of the member.

8. FOUNDATION DISPLACEMENT AND SETTLEMENT. (See, also, Section 11.) Criteria for foundation displacement and settlement are outlined in NAVFAC DM-7.

9. ICE

a. On Antenna Supports and Transmission Line Structures. See Section 6.

b. On Bridge Piers. See AASHTO Standard and Dynamic Ice Forces on Piers and Piles (see References.)

Section 10. COMBINATIONS OF LOADS

1. GENERAL. The following criteria stipulate combinations of loads (and related load factors or allowable stresses) to be considered in the design of structures and foundations. Members shall have adequate strength (and stiffness) to resist all applicable combinations at applicable stresses or load factors for said combinations.

2. CLASS A STRUCTURES. The provisions of the AASHTO and AREA design standards shall apply.

3. CLASS B STRUCTURES. The provisions of ACI-318 shall apply as follows:

a. Working Stress Design. The provisions relating to increased allowable stresses under para. 4a of Section 10 (Combinations of Loads - Class C Structures) shall apply.

b. Exception for Plastic Design of Steel Frames. The provisions of Part 2 of the AISC design standard shall apply vis-a-vis the corresponding provisions of ACI-318.

c. Clarifications.

(1) The increased load factor of ACI-318 for earthquake vs. wind load is intended to apply in the design of all Class B Structures of all materials.

(2) ϕ Factors - The load and ϕ factors of ACI-318 shall not apply in designs using materials other than concrete (or unit masonry).

(3) The load duration factors for the design of wood members are separate from these provisions relating to load combinations.

(4) Non-concurrence of various loads is specified throughout this Design Manual, and shall be considered in combining loads for purpose of design.

(5) Importance factors: Except in conjunction with earthquake and snow loads, importance factors (or risk factors) are not used in these criteria. However, the designer should keep in mind that the loading criteria given herein provide the minimum level of performance acceptable. Some facilities may require or warrant a higher level of performance. Such requirements usually will be developed before a project reaches the design stage, however, if the requirement has not been identified and the designers believe that is essential, guidance from NAVFACHQ should be sought.

(6) For combinations of loads not covered by ACI-318, the provisions which follow relating to load combinations for Class C Structures shall apply.

4. CLASS C STRUCTURES. The categories of "Basic Loads" and "Loads of Infrequent Occurrence" are defined for various types of structures in the several topical design manuals, as applicable. They are to be combined in all combinations which are reasonable for the specific application being considered. Where specific categorization is not presented in the topical design manuals, the following general criteria shall apply:

(1) Dead load, live load, and impact are basic loads.

(2) Wind, earthquake, thermal forces, forces due to shrinkage, forces due to differential settlement, and unbalanced forces due to local failures (such as guy breakage), are loads of infrequent occurrence.

a. Adjustment of Load Factors and Allowable Stresses. Except where specifically indicated otherwise in the topical design manuals, the following shall apply:

(1) For combinations involving basic loads only, the basic allowable stresses (or load factors) shall be used.

(2) For combinations involving basic loads, plus one load of infrequent occurrence, increase allowable stresses by one-third, or multiply overall load factor by 0.75. In no case shall the overall factor be less than 1.10, i.e., a factor of safety of 10% based on ultimate strength.

(3) For combinations involving basic loads, plus two loads of infrequent occurrence, increase allowable stresses by 40% or multiply overall load factor by 0.70. In no case shall the overall factor be less than 1.10, i.e., a factor of safety of 10% based on ultimate strength.

(4) For combinations involving basic loads plus three or more loads of infrequent occurrence, design for an overall load factor of 1.10, i.e. for a factor of safety of 10% based on ultimate strength.

(5) ϕ factors shall be applied in calculating ultimate strength (for concrete members.)

b. Miscellaneous Provisions.

(1) The load duration factors for the design of wood members are separate from these provisions relating to load combinations.

(2) Non-concurrence of various loads is specified variously in this Design Manual and shall be considered in combining loads for purposes of design.

(3) Importance Factors - Refer to Section 10, paragraph 3c.(5).

(4) The following loads shall be considered as of "Infrequent Occurrence."

(a) Impacts of Minor Missiles (small arms ranges, shedding of turbine blade in jet engine test cell, for example).

(b) Explosion of engine or other component during testing.

Section 11. DEFLECTION LIMITATIONS

1. GENERAL. The provisions of the several referenced design standards shall apply.

2. SPECIAL CRITERIA FOR ALLOWABLE DEFLECTION OF ELEVATOR AND ESCALATOR BEAMS AND SUPPORTS. Allowable deflections under static loads (which shall include the static equivalent of the dynamic loads) shall not exceed the following:

a. For overhead machine beams of all alternating-current installations, and for direct-current installations where car speeds exceed 150 feet per minute (fpm) (0.762 meters per second (M/S)) - 1/2000 of the span.

b. For overhead machine beams of direct current installations where car speeds are 150 fpm (0.762 M/S) or less - 1/1666 of the span.

c. For overhead beams supporting machine beams - 1/1666 of the span.

d. For overhead sheave beams - 1/1666 of the span.

3. MACHINERY SUPPORTS (Other than elevators and escalators). Design the beams or girders supporting machines so that the maximum deflection will not exceed 1/50 of the span (impact included), with the span taken as the distance, center-to-center, of the columns and the ends considered as supported without restraint. For criteria regarding deflection limits on supports for centerline guides of turbine generators, see Section 6, para. 5.

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APPENDIX A

METRIC CONVERSION FACTORS

The following metric equivalences were developed in accordance with ASTM E621 and are listed in the sequence as they appear in the text. All equivalences are approximate.

20 psf	=	958 Pa
110 pcf	=	1760 kg/m3
135 pcf	=	2160 kg/m3
1 1/2 in.	=	38 mm
15 psf	=	718 Pa
250 lb.	=	1110 N
24 inch x 24 inch	=	610 mm x 610 mm
12 psf	=	575 Pa
50 plf	=	730 N/m
20 plf	=	292 N/m
800 lb.	=	3560 N
2000 lb.	=	8900 N
200 lb.	=	890 N
4 sq. in.	=	2580 mm^2
3000 lb.	=	13345 N
20 sq. in.	=	12900 mm^2
1500 lb.	=	6670 N
400 sq. ft.	=	36.8 m^2
100 psf	=	4790 Pa
24 plf	=	350 N/m
10 plf	=	146 N/m
1800 rpm	=	188 rad/sec
0.005 in.	=	0.127 mm
80 mph	=	35 m/sec
30 ft.	=	9.1 m
10°	=	0.17 rad
30°F	=	-1.1°C
40°F	=	4.4°C
250 ft.	=	76.2 m
150 ft/mm	=	0.762 m/sec

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