XIII. RECOMMENDATIONS FOR HURRICANE RESISTANT DESIGN AND CONSTRUCTION: STRUCTURAL DESIGN CONSIDERATIONS

A. Stress and safety factors

377. Working stresses for construction materials usually depend on the design standard for the material being used, that is, steel, concrete, timber etc. These standards incorporate safety factors. For instance, much structural steel design is on the basis of about a 1.65 safety factor against yield; if the allowable working stress is increased by 1.33 for wind, this means the safety factor is reduced to about 1.24 for wind load.

378. Specific safety factors, for example, for aluminium structural design, are as follows, using United States of America aluminium standards for structural design:

Tension members

Factor of safety on tensile strength	1.95
Factor of safety on yield strength	1.65

Columns

Factor of safety on buckling strength	1.95
Factor of safety on yield strength for short columns	1.65

Beams

Factor of safety on tensile strength	1.95
Factor of safety on tensile yield strength	1.65
Factor of safety on buckling strength	1.65
Factor of safety on shear buckling of webs	1.20

379. If the allowable working stresses for aluminium are increased by 1.33 for wind loads, safety factors above are decreased by 1/1.33.

380. For reinforced concrete design, the new United States design standard, ACI 318-71, for ultimate design, calls for an ultimate strength load factor of $U = 1.4D + 1.7L$. This is the basic load factor for ultimate structural design in concrete. For wind loading, an ultimate load factor of $U = 0.9D + 1.3W$ is used, with the provision that the strength of the member cannot be less than the basic load factor. Obviously, with a load factor at the ultimate of $0.9D + 1.3W$, there is very little safety factor for wind, except that already provided by the basic load factor. If local climatology calls for a 160 kmph design wind, a 190 kmph wind will increase equivalent static loadings to 1.44 times the static loading for a 160 kmph wind, exceeding the load factor coefficient for wind design for concrete.

381. However, actual collapse loads may be greater and a complex statically indeterminate structure probably would not fail if overloaded, especially since portions of the entire structure may not simultaneously undergo the same wind loadings.

382. In considering safety factors, failures can very well occur in smaller components such as cladding, windows, roof anchors, light gauge girts and purlins etc. In these smaller components, the safety factors used in design standards for concrete, structural steel, structural aluminium, timber etc., may be not be sufficient. Safety factors for smaller components must be realistic.

B. General height-width ratios

383. Under many building codes, a building with a height to width ratio of about 2:1 generally does not require analysis for wind loadings. For hurricanes, however - since these cause extraordinarily high wind loads - all buildings should be analysed for wind, or at least checked by comparison or by inspection against known standards for wind loadings. This is especially true for prefabricated buildings and construction materials such as cement-asbestos panels and glass panels.

C. Provisions for high water during hurricanes

384. For resisting high water or high tidal surges, embankments raised to sufficiently high elevations above sea-level will be the first means of protection. Other means of protecting structures against high water are to design pole-type structures with timber piles or poles, or concrete piles or columns embedded into the ground, and with the first floor of the structure at a sufficiently high elevation to be above high water.

D. Specific recommendations for various materials

385. Specific detailed recommendations are given, by engineering construction details, in figures 70 through 76, for hurricane-resistant design and construction. These show important details for concrete block structures with wood roof trusses, steel joists, and timber structures. Tie down details in these figures are of the utmost importance. Sizes of beams and footings should be varied to fit specific designs. Tie beam action and diaphragm action of floors and roofs are important to resist racking loads on the exterior walls.

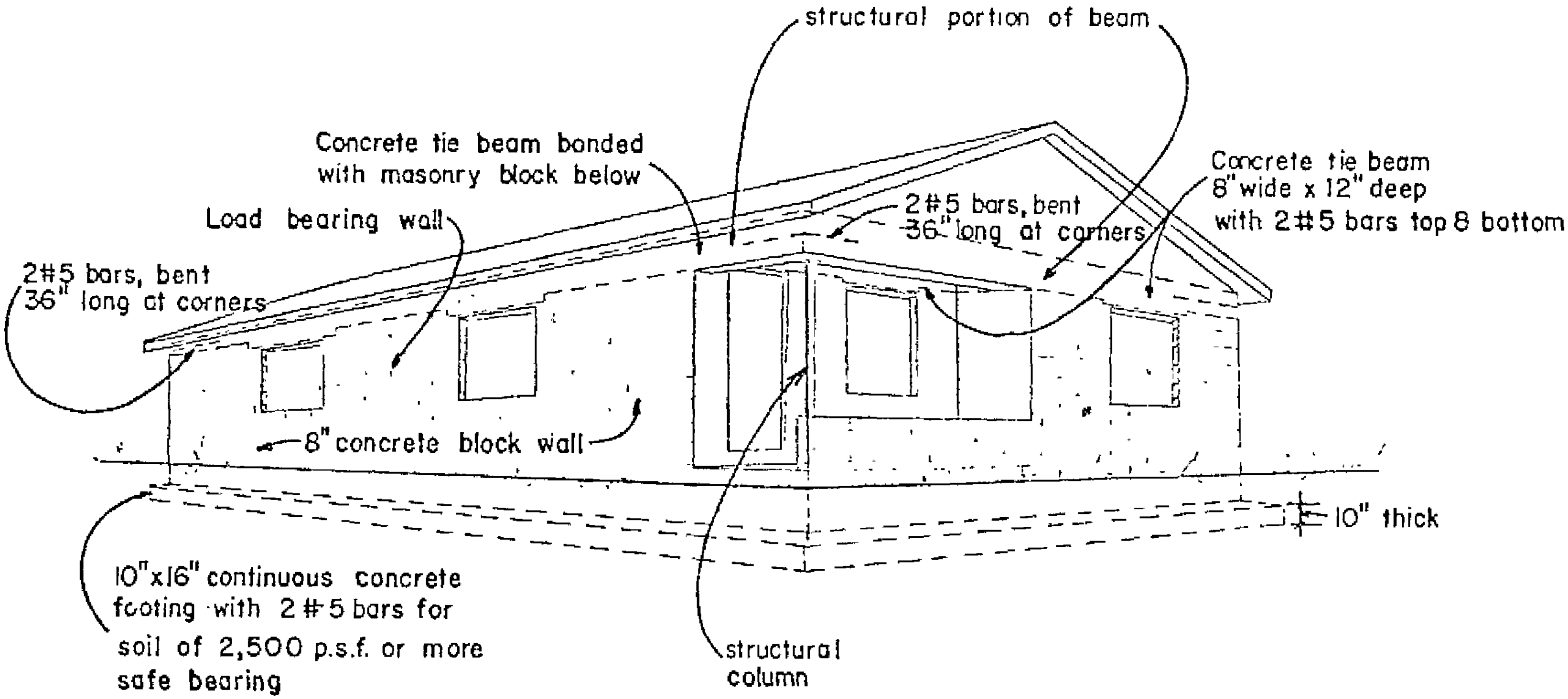


Fig. 70. Construction details of a one-storey house

Note: Equivalent metric measurements:

1" = 2.54 cm.
1 p.s.f. = 4.8 8 kgs/sq. m.
#5 bar = 16 mm bar

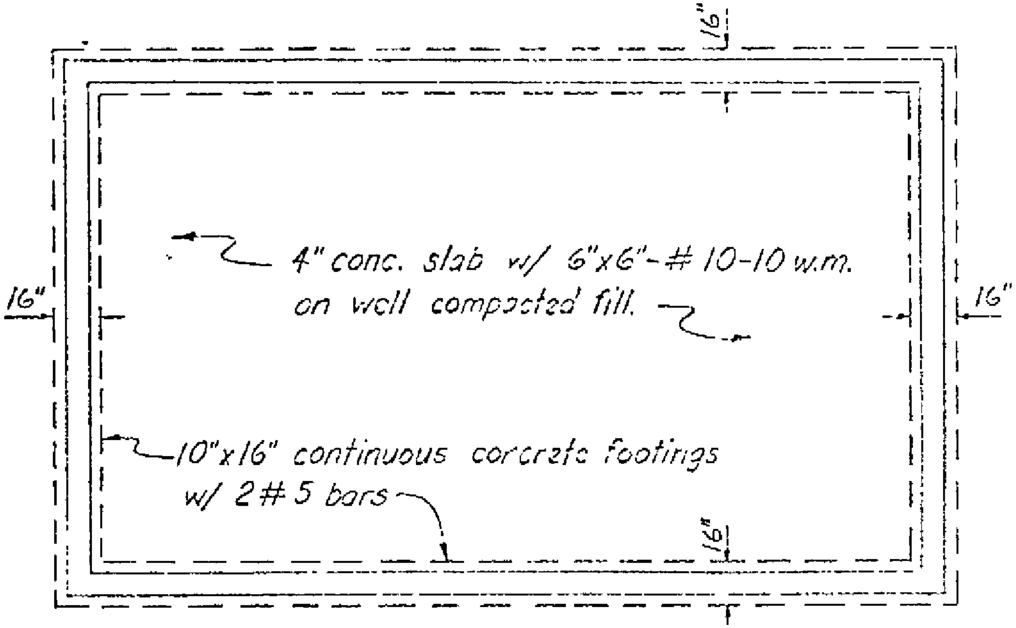


Fig. 71. Foundation plan for a one-storey house

Note: Equivalent metric measurements:

1" = 2.54 cm
#5 bar = 16 mm bar

(1) Roof trusses spaced 18" or 24" anchored to conc. tie beam with 1/8" x 1" strap iron embedded into the conc. a min. of 7" and nailed to the rafter with not less than 16 d. galvanized nails.

(2) Plywood 1/2" min. thickness continuous over two or more spans, staggered with face grain perpendicular to supports, nailed to rafters with 8 d. nails spaced 6" edges and 12" o.c. at intermediate supports.

(3) 30# roofing felt nailed to plywood by 12 gage wire ring-shanked nails applied through tin caps not less than 1 5/8" diameter and not more than 2", not less in thickness than 32 gage sheet metal, spaced 12" o.c.

(4) Coal tar applied in a quantity not less than 25# per square per ply.

(5) 90# roofing felt on top of hot tar (275°-350°F).

(6) Gravel on top of flood coat of tar (150# per square).

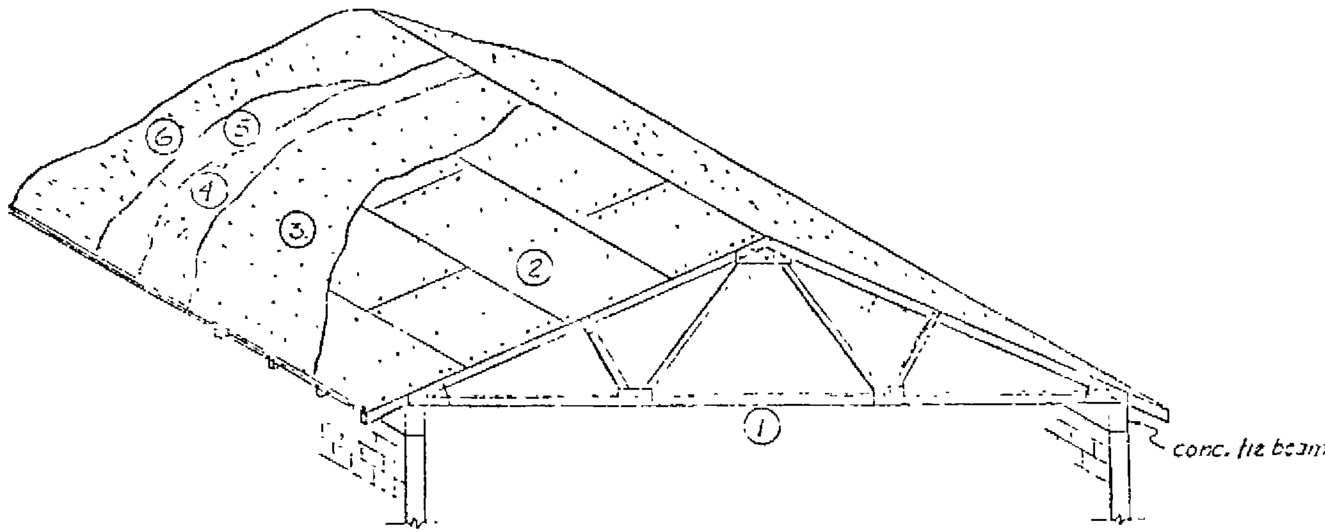


Fig. 72. Roof construction detail

Note: Equivalent metric measurements:

1" = 2.54 cm
1# = .465 kg
275-350 F = 135-176 C

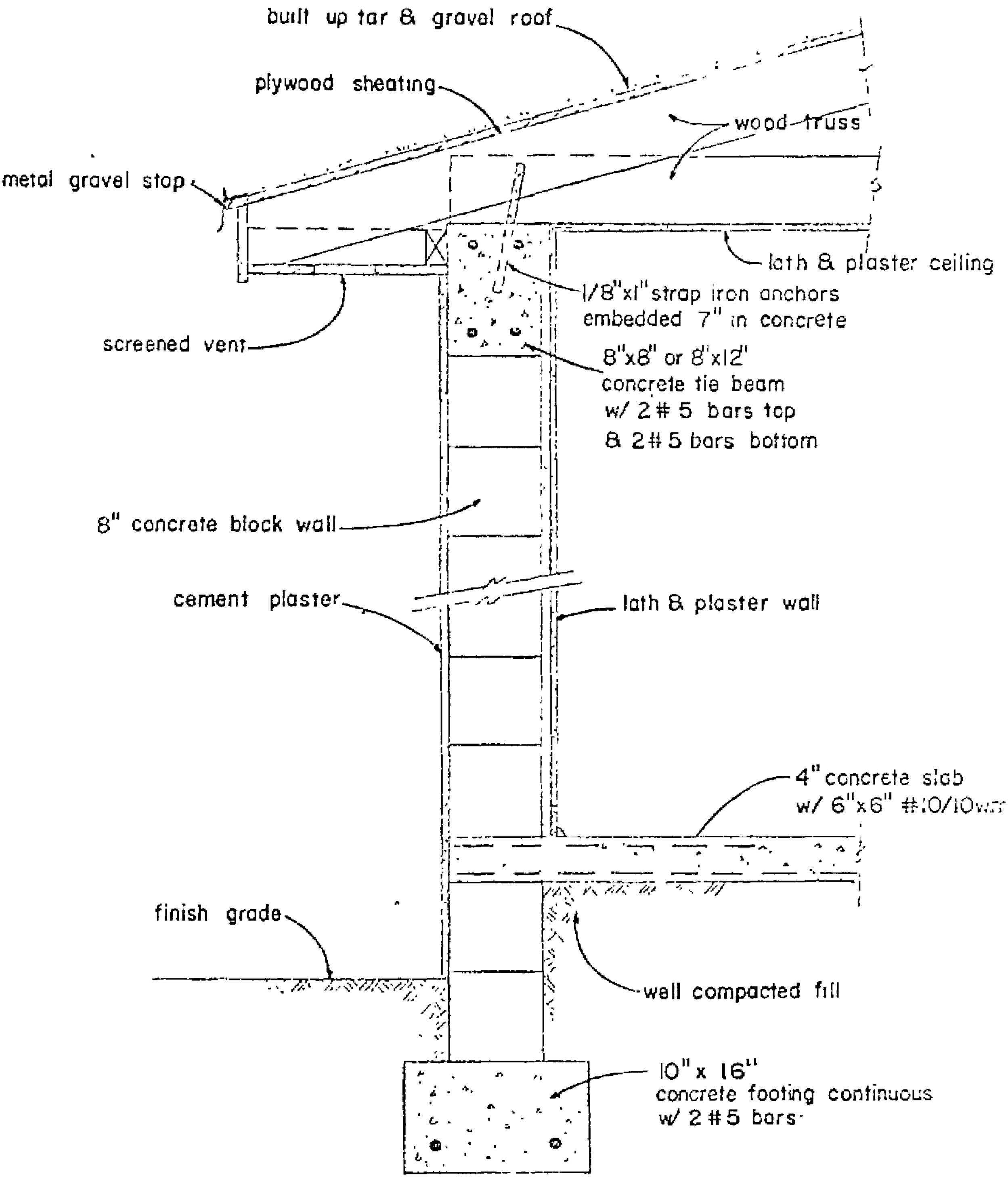


Fig. 73. Typical block wall section - residential structure

Note: 1" = 2.54 cm
#5 bar = 16 mm bar

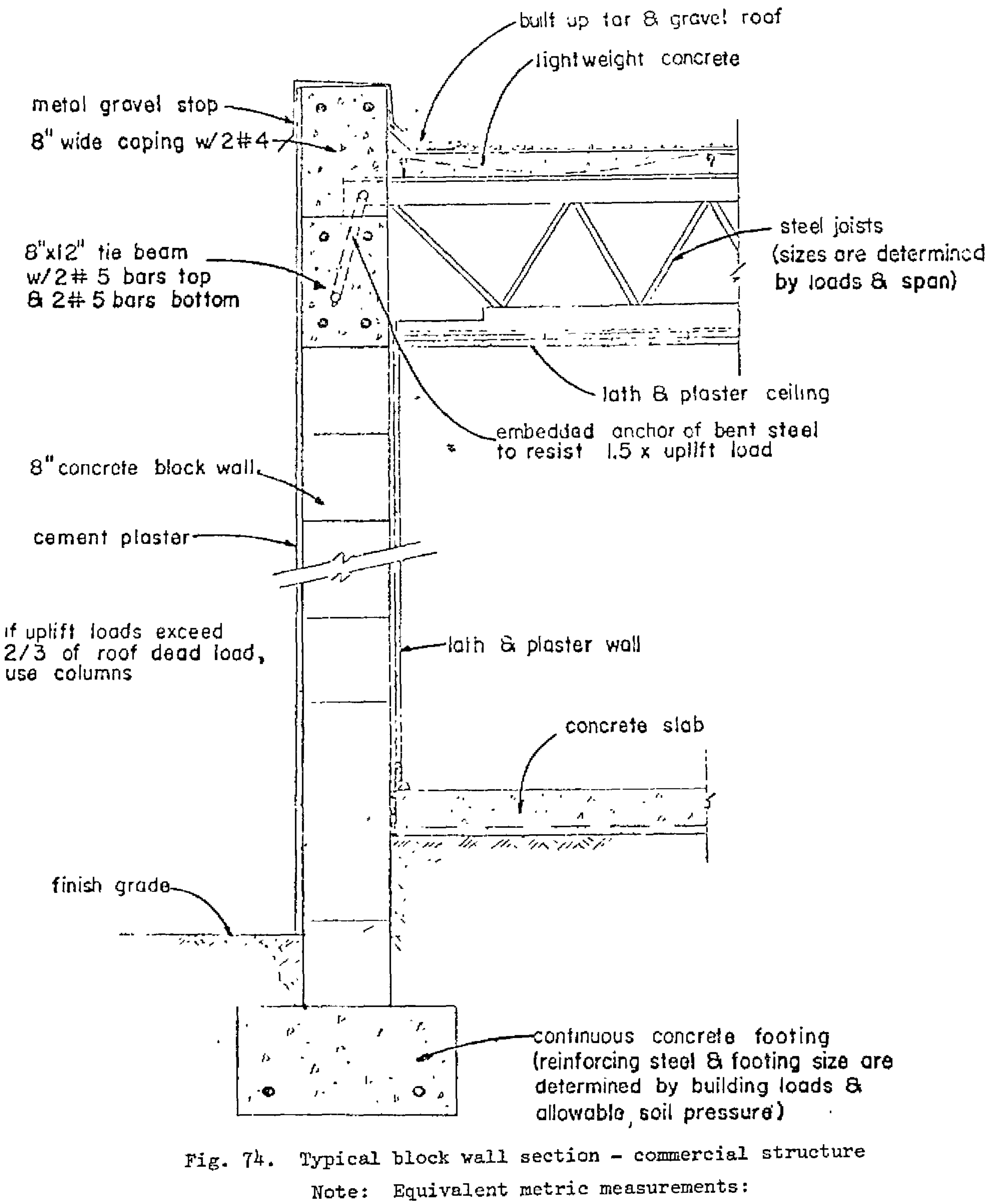
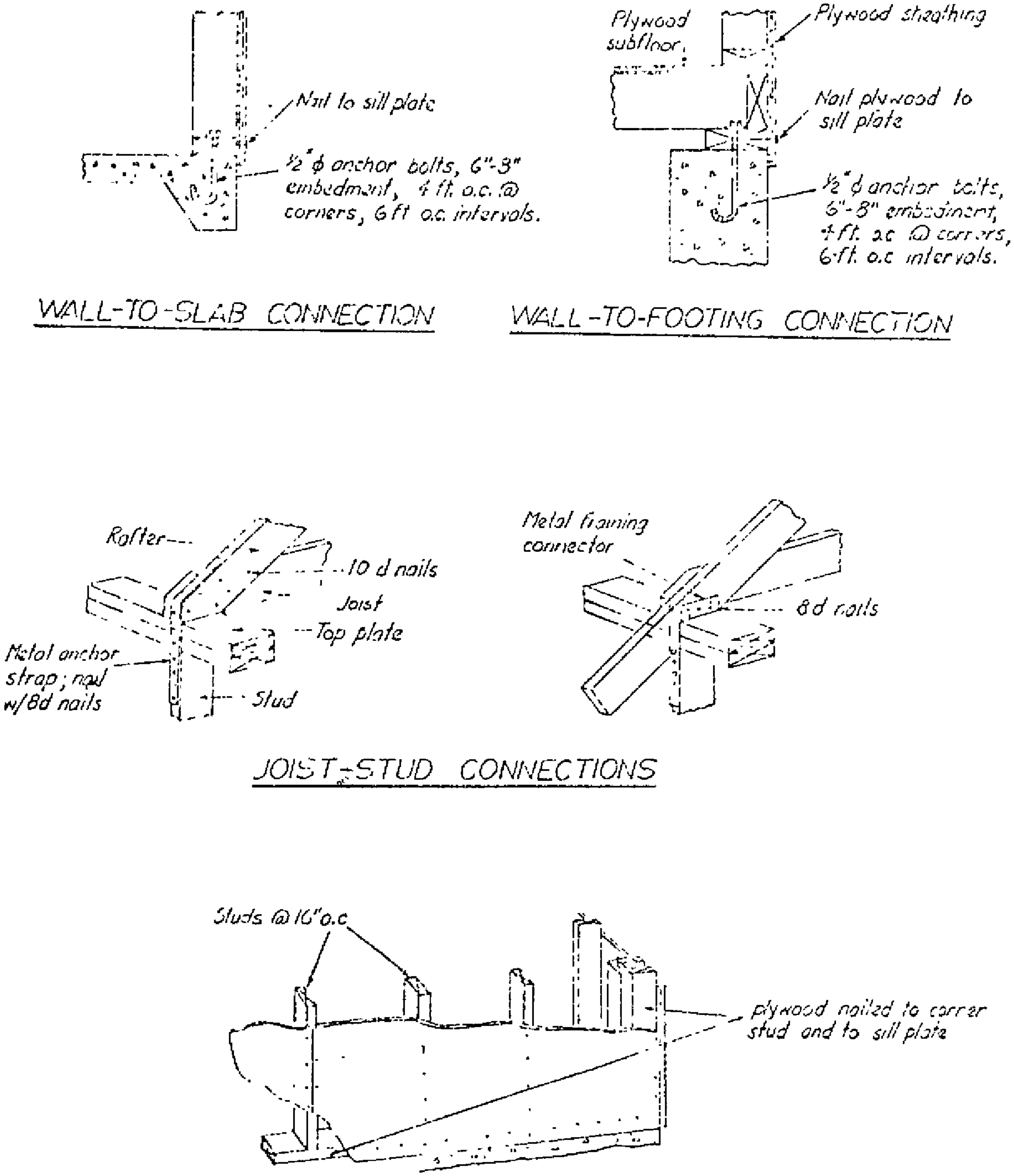


Fig. 74. Typical block wall section - commercial structure

Note: Equivalent metric measurements:

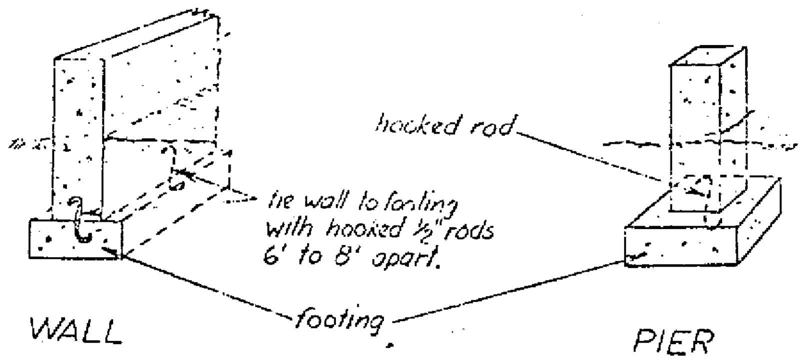
1" = 2.54 cm
#4 bar = 12 mm bar
#5 bar = 16 mm bar



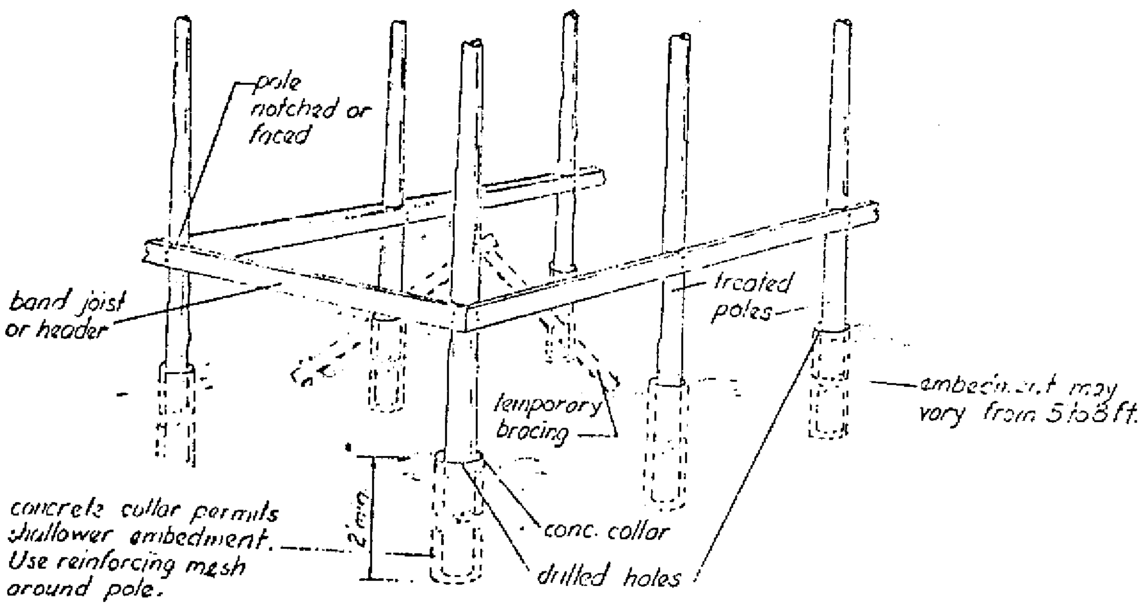
Corner detail

Fig. 75. Details for structural connexion of members

Note: 1" = 2.54 cm
1 foot = 30.48 cm



Anchoring footings to concrete wall or pier on solid ground



Foundation detail for pole type structure

Fig. 76. Details of foundations

Note: 1" = 2.54 cm
1' = 1 ft. = 30.48 cm

SUMMARY OF RECOMMENDATIONS FOR WIND LOADINGS AND STRUCTURAL DESIGN CONSIDERATIONS

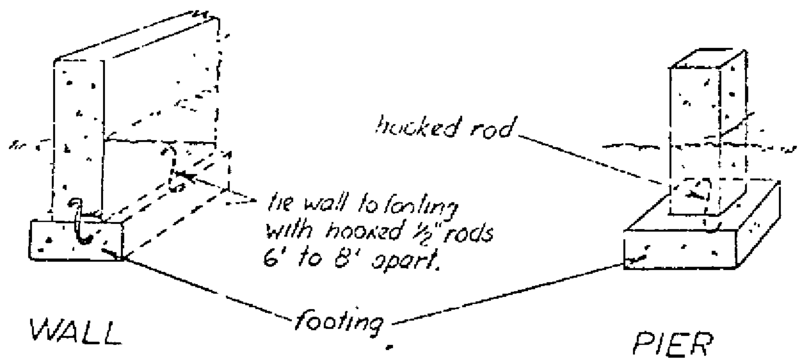
386. The [illegible] rules and recommendations in summary form are furnished:

(a) Ba[illegible] past climatology of the area, adopt a design storm, taking into account prob[illegible]es of recurrence over a period of years and the type of structures a[illegible]pancies being considered.

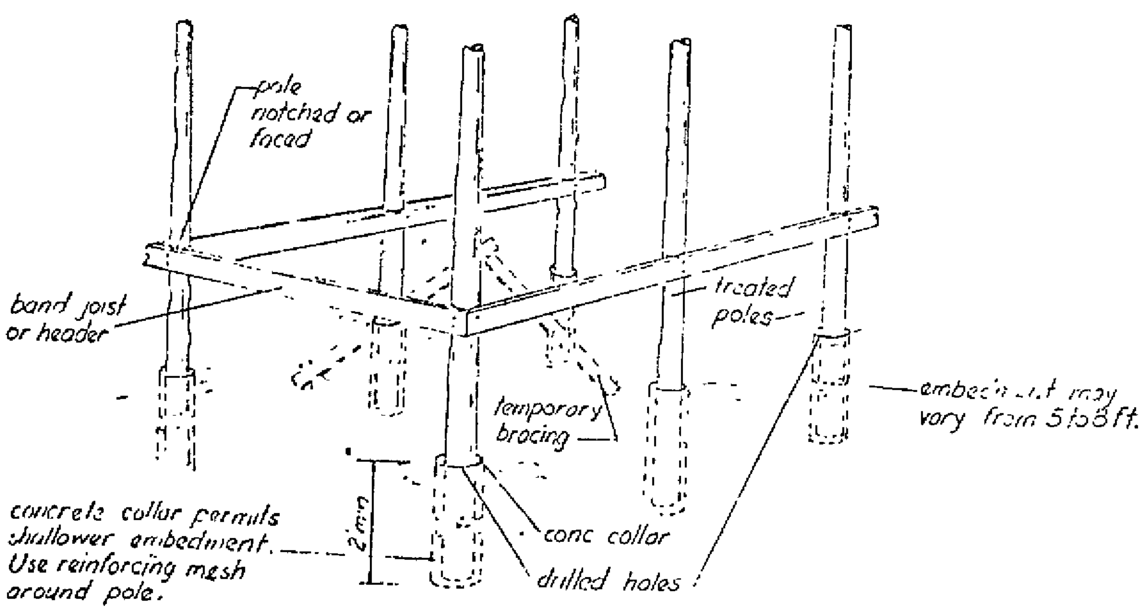
(b) A[illegible]uilding code or set of standards that incorporate high velocity wind loadin[illegible] specifically for hurricane winds or typhoon winds. If the code in for[illegible] not consider hurricane winds, either adopt a new code or modify the existin[illegible]n conformance with detailed requirements given here.

(c) [illegible]l areas, based on past experience or estimates, establish a map showing p[illegible]rricane tidal surges for several design storm periods (50 years, [illegible], 200 years etc.). For construction in these areas subject to tidal su[illegible]tional consideration or safeguards must be provided (dikes, levees, esc[illegible], fill, pole-type construction etc.).

387. These [illegible]eral rules will cover hurricane-resistant design and constructi[illegible]led recommendations, of course, will depend on the variable factors [illegible] such as the type and usage of building, whether it will be used for a [illegible]racy of climatological data etc., always bearing in mind that probabili[illegible]enerally estimates, and may be exceeded.



Anchoring footings to concrete wall or pier on solid ground



Foundation detail for pole type structure

Fig. 76. Details of foundations

Note: 1" = 2.54 cm
1' = 1 ft. = 30.48 cm

SUMMARY OF RECOMMENDATIONS FOR WIND LOADINGS AND STRUCTURAL DESIGN CONSIDERATIONS

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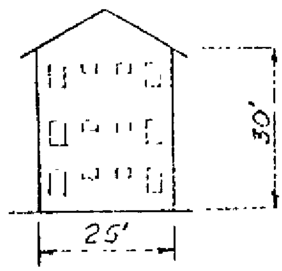
TYPICAL EXAMPLE NO. 1

A multiple dwelling as shown:



In this case, h = 30' b = 25' L = 60'

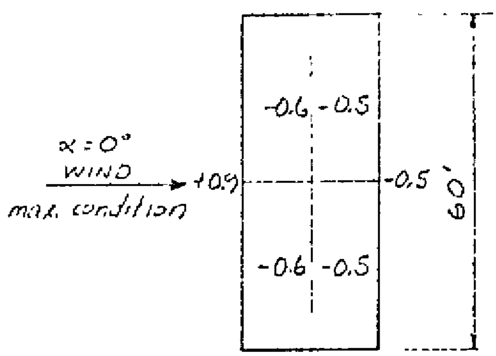
Figure 65 meets the dimensions
h:b:L = 2.5:2:5

Assume the building is at the coast, therefore use table 7

Use 100 mph as design velocity and gust factor = 1.00, therefore from table 4, velocity pressure p = 26 p.s.f.

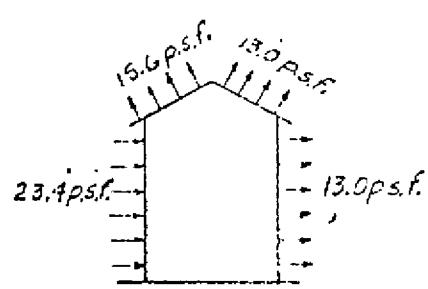
From figure 65 shape factors are obtained

Openings are uniformly distributed
Use ± 0.2 for Cpi (internal pressure coefficient)



For overall stability, using velocity pressure of 26 p.s.f.

26 p.s.f. × (0.9 + 0.5) = 36.4 psf. (23.4 + 13.0)
26 p.s.f. × (0.6) = 15.6 p.s.f.
26 p.s.f. × (0.5) = 13.0 p.s.f.



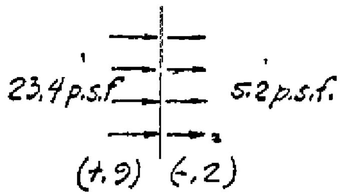
Design pressures

Fig. 77. Structural analysis of a multiple dwelling

Note: 1' = 1 ft. = 30.48 cm
1 p.s.f. = 4.8824 kgs/sq. m

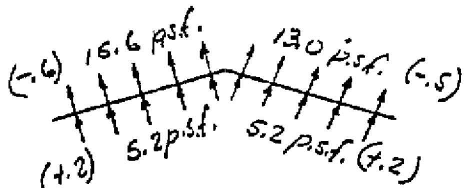
For walls, windows, roof, as components.
Use previous figures with ±0.2 added & 1.00 gust factor.

The <u>front wall</u> governs 23.4 p.s.f.



Total on wall: 23.4 + 5.2 = 28.6 p.s.f.

Roof



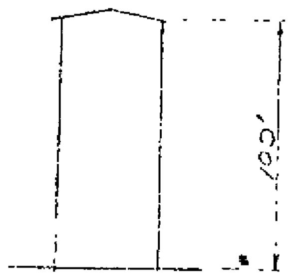
total: 20.8 p.s.f. 18.2 p.s.f.

Fig. 77 (continued)

Note: 1 p.s.f. = 4.8824 kgs/sq. m

TYPICAL EXAMPLE NO. 2

A 100' high power plant tower



In this case h = 100' b = 40' L = 40'

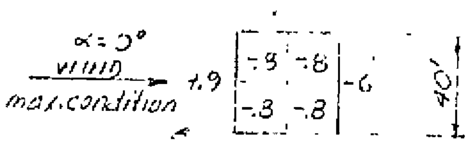
Fig. 10 meets the dimensions

h:b:L = 2:5:1:1

Assume the building is at the coast, therefore use table 7

Use 130 mph as design velocity and gust factor = 1.25, therefore from table 7 velocity pressure p =

30' - 43 p.s.f.
50' - 50 p.s.f.
100' - 61 p.s.f.

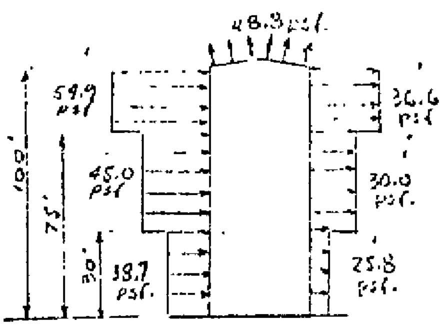


From figure 62 shape factors are obtained

Openings are uniformly distributed
Use ± 0.2 for C_{pi} (internal pressure coefficient)

For over-all stability, using above velocity pressures:

43 p.s.f. x (0.9) + (0.6)= 38.7 + 25.8 p.s.f.
50 p.s.f. x (0.9 + 0.6)= 45.0 + 30.0 p.s.f.
61 p.s.f. x (0.9 + 0.6)= 54.9 + 36.6 p.s.f.
61 p.s.f. x (.8) = 48.8 p.s.f.



Design pressures

Fig. 78. Structural analysis for a 100-foot tower

Note: 1' = 1 ft. = 30.48 cm.
1 p.s.f. = 4.8824 kg/sq. m

TYPICAL EXAMPLE NO. 2

continued

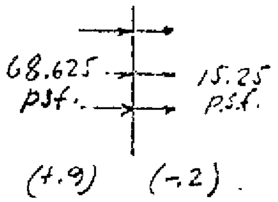
For walls, windows, roof, as components
Use previous figures with ±0.2 added & 1.25 gust factor

The front top wall governs.

61 × 1.25 = 76.25 p.s.f.

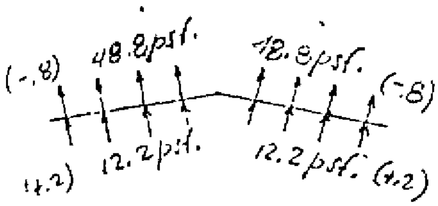
76.25 × .9 = 68.625 psf.

76.25 × .2 = 15.25 psf.



Total on wall: 68.63 + 15.25 = 83.88 p.s.f.

Roof.



(on roof, computed for tributary areas of over 200 sq. ft., gust factor = 1.00)

total: 61 psf.

Above component figures are for height range 75' to 100'. Wall loadings can be reduced at lower heights.

Fig. 78. (continued)

Note: 1 p.s.f. = 4.8824 kg/sq. m

Annex

WIND REQUIREMENTS FOR STRUCTURAL DESIGN IN THE BUILDING CODE IN EFFECT IN SOUTH FLORIDA, UNITED STATES OF AMERICA

Section 2306 on wind requirements and shape factors of the South Florida Building Code is reproduced below.

2306

2306.1 GENERAL: (a) Building and structures and every portion thereof shall be designed and constructed to resist the forces due to wind pressure. The wind velocity shall be taken as not less than 120 MPH at a height of 30 feet above the ground, except as may be otherwise set forth herein.

(b) Such forces shall be applied in any direction, with all possible combinations based on height and shape factors, but in no case shall any roof be designed for less than 30 pounds per square foot live load. The said live load shall not be considered to act simultaneously with the wind load.

(c) Systems shall be designed and constructed to transfer wind forces to the ground.

(d) No allowance shall be made for the shielding effect of buildings or other structures.

(e) The minimum unit wind pressures to be used in design shall be obtained by multiplying the velocity pressures set forth in Table 23-B of Sub-section 2306.2 by the Shape Factors as described in Sub-section 2306.3.

(f) The Building Official may accept a design based on other nationally recognized and accepted data, the validity of which is shown by wind tunnel and/or satisfactory test data, and may require evidence to support the values for wind pressure used in the design of structures not specifically included in this Section.

(g) Structural members, providing stability for the building or structure, shall be designed to resist the forces set forth in Table 23-B multiplied by the shape factors set forth in Paragraph 2306.3(a).

(h) Building components such as, but not limited to, purlins, girts, wall panels and sheathing, transferring wind loads to the structural frame, shall be designed to resist the forces set forth in Table 23-B multiplied by the shape factors set forth in Paragraph 2306.3(b).

2306.2 VELOCITY PRESSURES: (a) Velocity pressures, in pounds per square foot, based on height above ground, in feet, shall be taken as not less than those in Table 23-B.

TABLE 23-B

HEIGHT ABOVE GROUND (In Feet)	MINIMUM VELOCITY PRESSURE In pounds per square foot
0 to 5	22
5 to 15	27
15 to 25	33
25 to 35	37
35 to 55	41
55 to 75	46
75 to 100	50
100 to 150	55
150 to 250	63
250 to 350	71
350 to 550	80
550 to 750	89
750 to 1000	97
over 1000	100

(b) Velocity pressures are based on the formula

$$P = 0.00256 \times V^2 \times \left(\frac{H}{30}\right)^{2/7} \quad \text{where:}$$

V = 120 MPH; and
H = the height above grade (in feet) of the pressure being computed.

(c) Velocity pressure for heights above 1000 feet may be taken as that for 100 feet.

2306.3 SHAPE FACTORS: (a) Shape factors for the stability of a building or structure shall be taken as ("Plus" signifies pressures inward or downward and "minus" signifies pressures outward or upward).

(1) For Vertical Surfaces:

(aa) Rectangular Prismatic Structures 1.3
(sum of + 0.8 windward and - 0.5 leeward)
(bb) Cylinders 0.7
(cc) Flat surfaces with no appreciable depth such as signs and fences 1.4
(dd) Partially Open Surfaces:

Per cent Solid	Shape Factor (times gross area)
10	0.35
20	0.55
40	0.80
60	1.00
80	1.20
100	1.30

(2) For Horizontal Surfaces (Including Surfaces with less than 10° inclination to the horizontal).

		Windward* 1/3 of surface	Leeward** 2/3 of surface
(aa)	Enclosed Buildings:	-1.0	-0.75
(bb)	Buildings with one ore more sides open	-1.5	-1.25
(cc)	Overhangs and eaves	-1.5 (all cases)	

* The direction from which the wind is coming.

** The direction towards which the wind is going.

(3) FOR INCLINED SURFACES:

Angles from the Horizontal		Normal to Windward Surface	Normal to Leeward Surface
(aa)	Above 70° to 90°	+0.80	-0.50
	Above 60° to 70°	+0.70	-0.50
	Above 50° to 60°	+0.50	-0.50
	Above 40° to 50°	+0.20	-0.50
	Above 30° to 40°	-0.20	-0.50
	Above 20° to 30°	-0.40	-0.50
	10° to 20°	-0.70	-0.50

(bb) Overhangs and Eaves . . . . -1.50 (all cases)

(cc) For buildings with one or more sides open, add -1.0 to the negative factors for inclined surfaces.

(dd) For gable roofs a factor of -0.6 shall be used when the wind is assumed to blow parallel with the roof ridge.

(ee) The wind pressure on a curved roof due to wind blowing at right angles to the axis of the roof shall be computed on the basis that the curved portion is divided into not less than five equal segments. The prèssure on each segment, whether positive or negative, shall be determined by the use of shape factors in Sub-paragraph (aa) above, appropriate to the slope of the chords of the segments.

(ff) In multi-span or saw-tooth roofs where the span heights and slopes are approximately the same and where there is a sheltering effect from the windward span, the external pressures and forces on the intermediate spans may be approximately reduced.

(b) Shape factors for building components transferring wind loads to the structural frame shall be taken as:

(1) VERTICAL SURFACE SHAPE FACTORS

	Pressure Inward	Pressure Outward
(aa) Exterior walls of enclosed buildings, including fixed lites of glass, glazing and all supporting members	+1.1	-1.1
(bb) Operative doors and windows, including all constituent parts	+1.1	-0.55
(cc) Exterior walls of buildings with one or more sides open	+1.1	-1.5

(2) Horizontal Surface Shape Factors as set forth in Paragraph 2306.3(a) (2).

(3) Inclined Surface Shape Factors as set forth in Paragraph 2306.3(a) (3).

2306.4 OVERTURNING MOMENT AND UPLIFT: (a) Computations for overturning and uplift shall be based on the building as a whole using the shape factors set forth in Paragraph 2306.3(a).

(b) Overturning stability of any building or structure taken as a whole shall be provided and shall be not less than 150 percent of wind load overturning moment.

(c) Uplift stability of any building structure or part thereof or isolated component thereof shall be provided and shall be not less than 150 per cent of the wind load uplift thereon.

(d) Stability may be provided by dead loads, anchors, attachments, the weight of earth superimposed over footings or anchors, the withdrawal resistance of piles or the resisting moment of vertical members embedded in the ground.

2306.5 STRESSES: (a) For members carrying wind stresses only, and for combined stresses due to wind and other loads, the allowable stresses and the allowable loads on connexions may be increased 33 1/3 percent from the maximums set forth in this Code for the materials used except as follows:

(1) Such increased stresses shall not apply to foundations except as provided in Section 2310.

(2) Such increased stresses shall not apply to towers, cantilevered projections or metal sheathing where vibrations or fluttering action could be anticipated.

(3) Glass areas shall not be increased from those set forth in Table 35-E.

(4) Such increased stresses shall not apply to glazing materials other than glass.

(b) In no case shall the cross-section properties be less than required for dead load plus live load without wind load.

2306.6 SCREEN ENCLOSURES: The wind loads on screen surfaces shall not be less than set forth in Paragraph 4403.4(c). Design shall be based on such loads applied horizontally inward and outward to the walls with a shape factor of 1.3, and applied vertically upward and downward on the roof with a shape factor of 0.7.