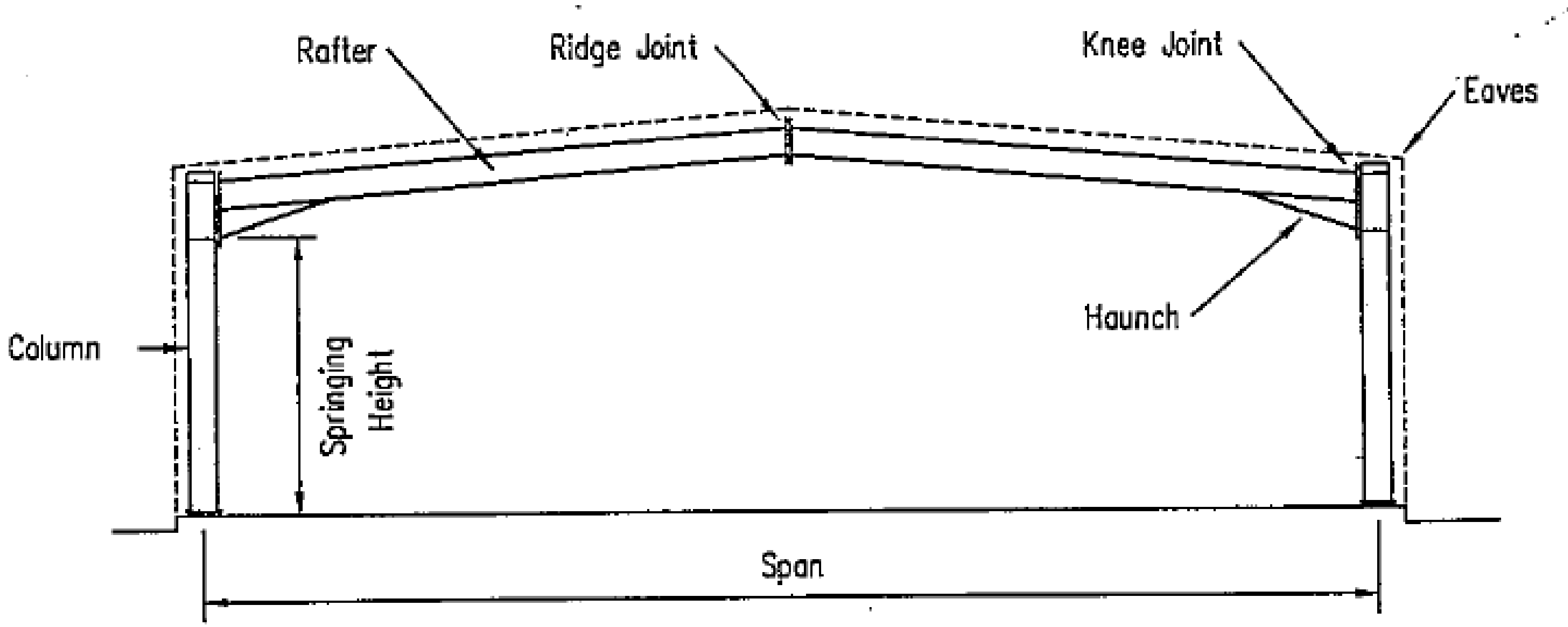
Portal frames



Portal frames

A factory in a wind Region B industrial estate

Building size:

Length = 72 m (frame centers)

Width = 25 m (column centers)

Height = 7.5 m (floor to centerline at knee)

Frame:

Steel portal = single span across 25 m width

Spacing = 9 m

Pitch = 3°

Portal frames

Floor:

Reinforced concrete to carry 4.5 tonne forklift with unlimited passes

Roof and walls

Trimdek 0.42 BMT (Base Metal Thickness) sheeting

Doors:

4×roller shutter doors each 4 m × 3.6 m high

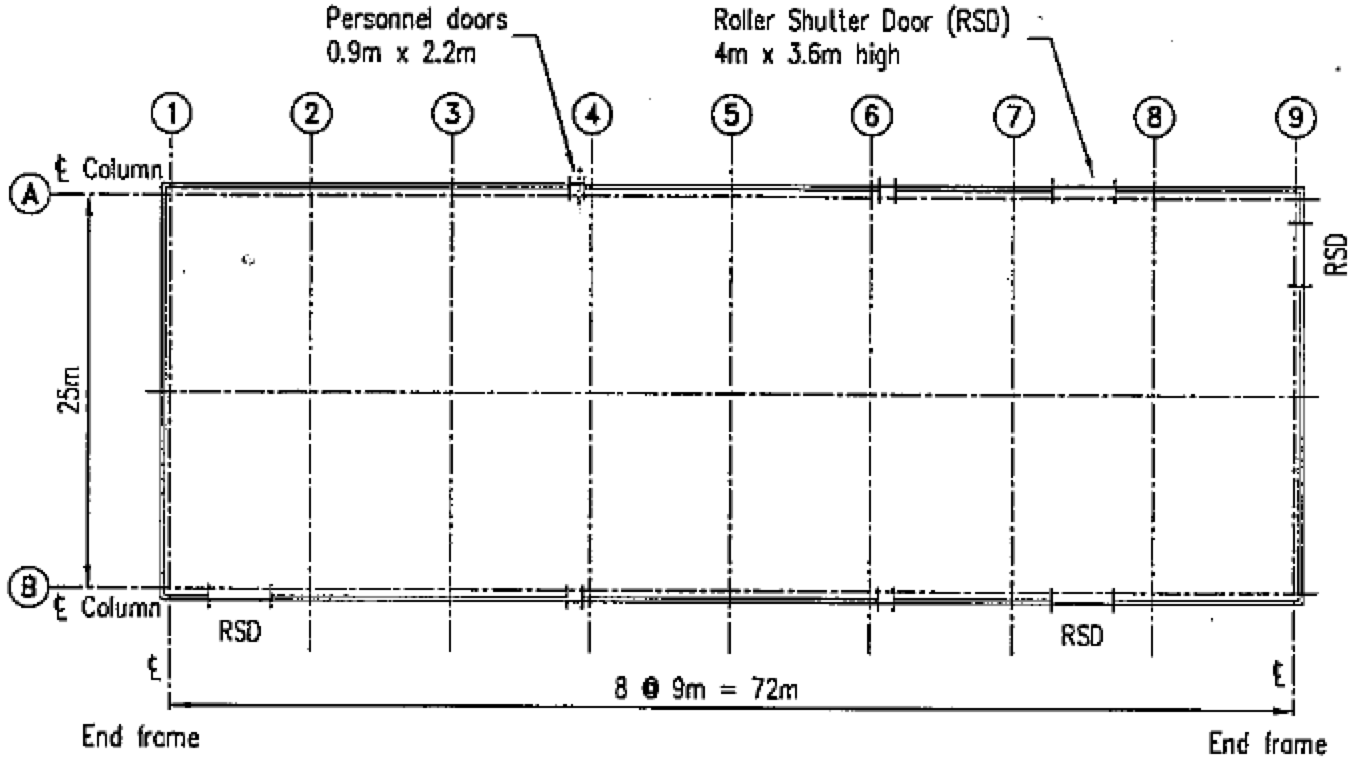
4×personnel doors each 0.9 m × 2.2 m high

Soil Condition:

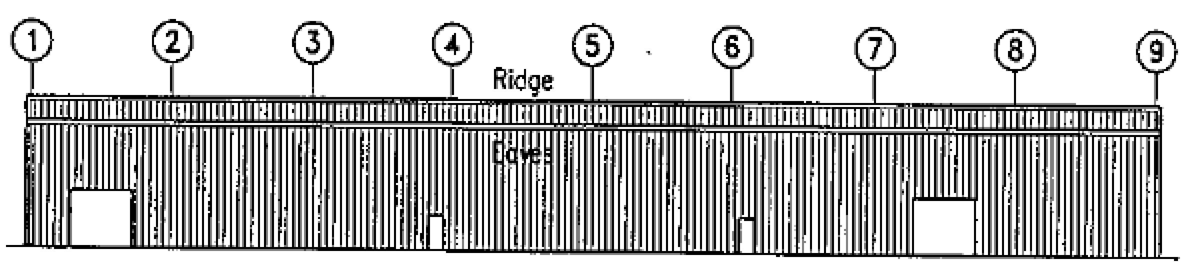
Stiff clay with C_u=50 kPa

Footings:

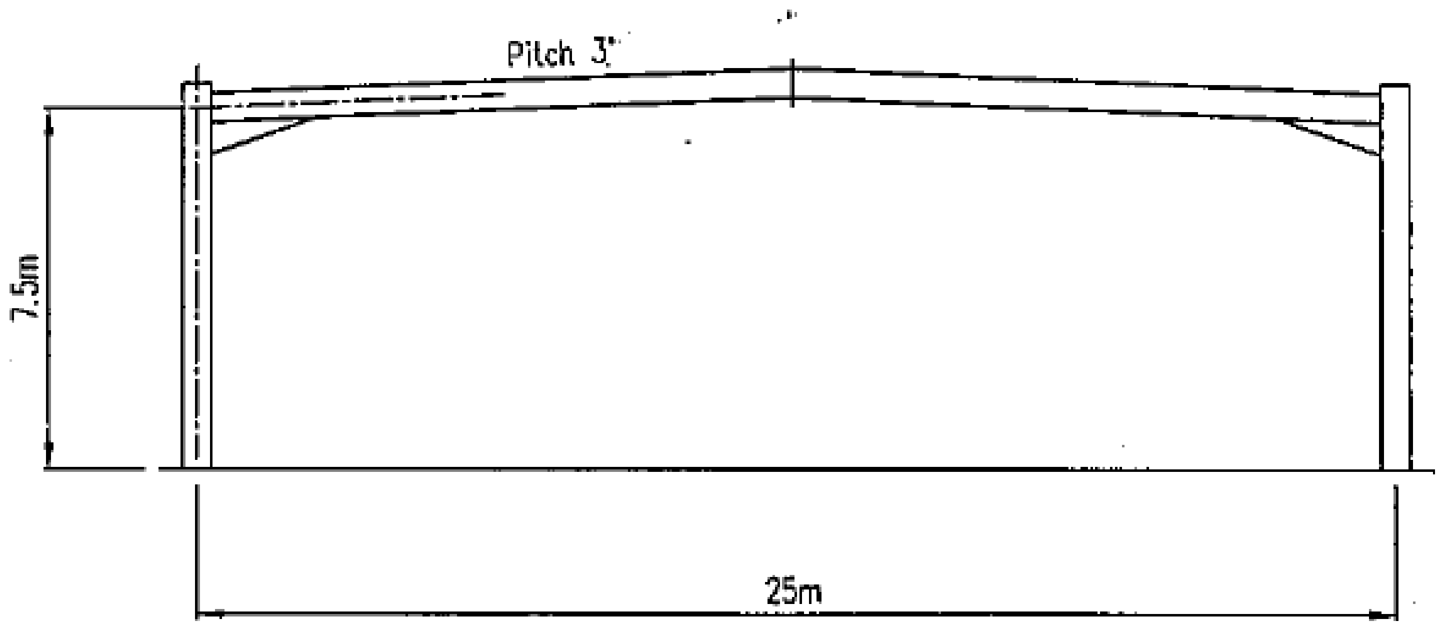
Bored piers or pad footings



Floor Plan



Elevation



Typical Section

Dead Loads

- Dead loads acting on a portal-framed industrial building arise from its weight including finishes, and from any other permanent construction or equipment.
- The dead load will vary during construction, but will remain constant thereafter, unless significant modifications are made to the structure or its permanent equipment.
- For preliminary analysis, a dead load of 0.1 kPa can be allowed for the roof sheeting and purlins. The weight of the rafter should be included, but the weight of roof bracing, cleats and connections is not usually considered as being significant.

Dead Loads

Sheeting: Trimdek 4.3 kg/m^2 = 0.043 kPa
Purlins: Z20019 at 1200mm centres with 15% laps

$$= \frac{1.15 \times 5.68 \times 9.82 \times 10^{-3}}{1.2} = 0.053 \text{ kPa}$$

Total w_G $= 0.043 + 0.053 = 0.096$ kPa say 0.1 kPa
Hence sheeting and purlin load on rafter = $0.10 \times 9 = 0.90$ kN/m (along slope)

Live Loads

- Mainly from maintenance loads where new or old roof sheeting may be stacked in the concentrated areas.
- Roof live loads for cladding, purlins and rafters are specified in AS1170.1.
- Roof cladding must be designed to support a concentrated load of 1.1 kN in any position.
- For purlins and rafters, the code provides for a distributed load of 0.25 kPa when supporting area A is less than or equal to 14 m^2.
- A concentrated load of 4.5 kN at any point.
- Detail calculation for different cases refers to AS1170.1.

Live Loads

- Live load on rafter = $0.25 \times 9 = 2.25$ kN/m (on plan projection)

- The pitch is not steep and so the effect of pitch on the live load is insignificant, ie. Live on lo rafter along slope

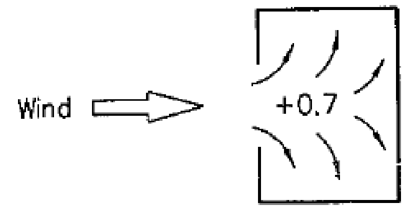
  $= 2.25 \times \cos 3^{\circ} = 2.25$ kN/m

- In addition, a concentrated load of 4.5 kN is applied at the ridge

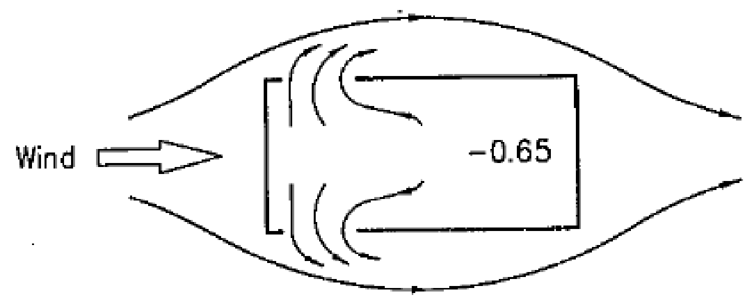
Wind Loads

Wind Loading Parameter	**Region A** Perth Adelaide Melbourne Canberra Sydney	**Region B** Brisbane	**Region C** (cyclonic areas except Region D) Darwin Townsville Cairns
Basic Wind Speed V_u, m/s	50	60	70
Design Gust Wind Speed for $M_{(z,cat)} = 0.80$, $M_s = 0.85$, $M_t = 1.0$ $M_i = 1.0$	34.0	40.8	47.6
Gust Dynamic Wind Pressure q_z (kPa)	0.69	1.00	1.36
Typical Uplift Pressure $p_z = (0.7{+}0.5)q_z$	0.83	1.20	1.63
Typical Dead Load of Sheeting, Purlins & Rafters p_G (kPa)	0.15	0.17	0.20
Design Uplift $= p_z - 0.8p_G$ (kPa)	0.71	1.06	1.47
$\dfrac{\text{Design Uplift}}{\text{Design Uplift for Region A}}$	1.00	1.49	2.07

- External pressures
- Internal pressures



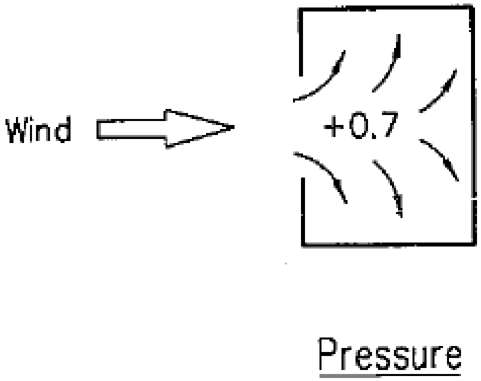
Pressure

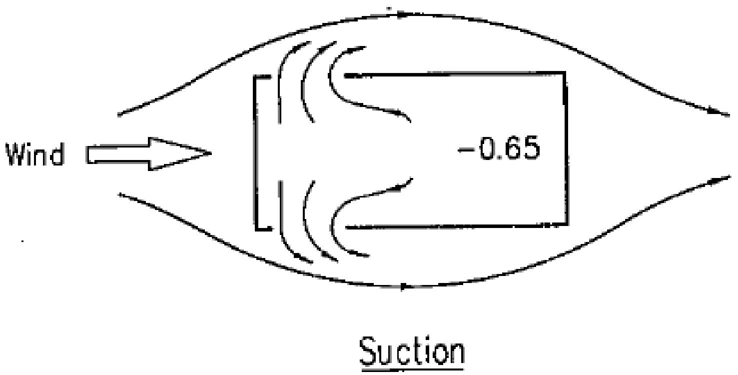


Suction

Wind Loads

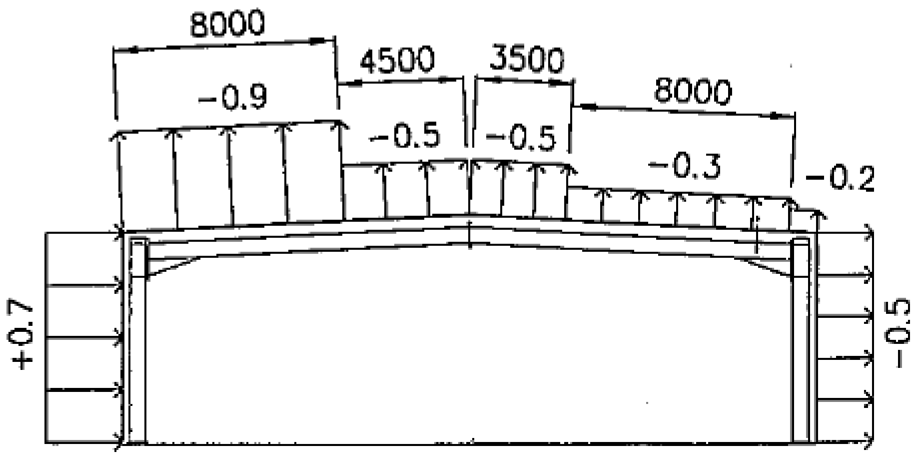
- External pressures
  - ✓ Maximum uplift coefficient, $C_{p,e}$, -0.9, -0.5, -0.3, -0.2
  - ✓ Minimum uplift coefficient, $C_{p,e}$, -0.4, 0, +0.2, +0.3
- Internal pressures



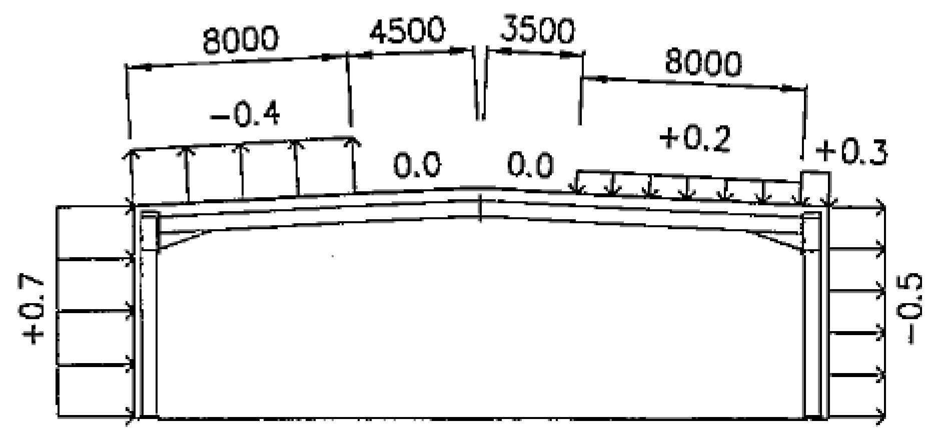


Wind Loads

- External pressures



(a) Maximum Roof Uplift Coefficients

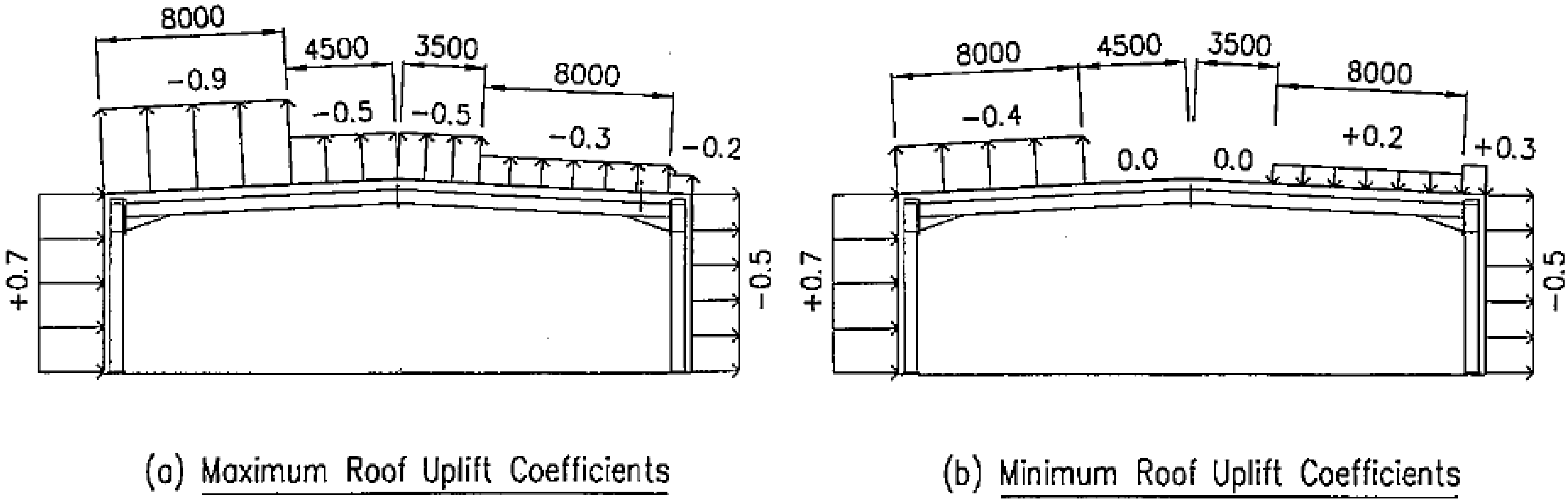


(b) Minimum Roof Uplift Coefficients

External pressure coefficient under cross wind

Wind Loads

- External pressures under cross wind



External pressure coefficient under cross wind

- External pressures under longitudinal wind
  - ✓ Area reduction factor = 0.8

Wind Loads

- Internal pressures under cross wind

Permeability ratio for worst internal *pressure* under cross wind

$$= \frac{2 \times 4 \times 3.6 + 2 \times 0.9 \times 2.2}{15.1} = 2.17$$

Hence $C_{p,i} = 0.5 + \left(\frac{2.17 - 2}{3 - 2}\right) \times (0.6 - 0.5) = +0.52$ *AS1170.2 Table 3.4.7*

For the worst internal *suction* under cross wind when dominant openings are on the leeward wall, use the value of $C_{p,i}$ for leeward external wall surface

$C_{p,i} \quad = -0.50$ *AS1170.2 Table 3.4.3.1(B)*

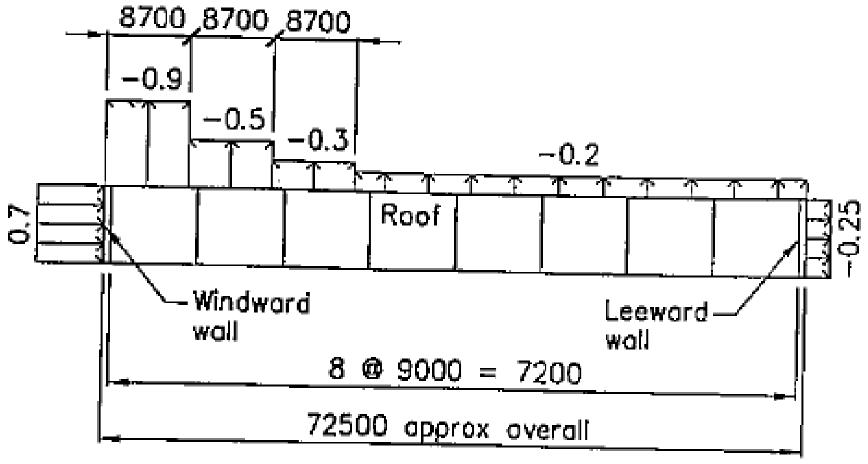
- Internal pressures under longitudinal wind

Permeability ratio for worst internal *pressure* (end wall door open, others closed)

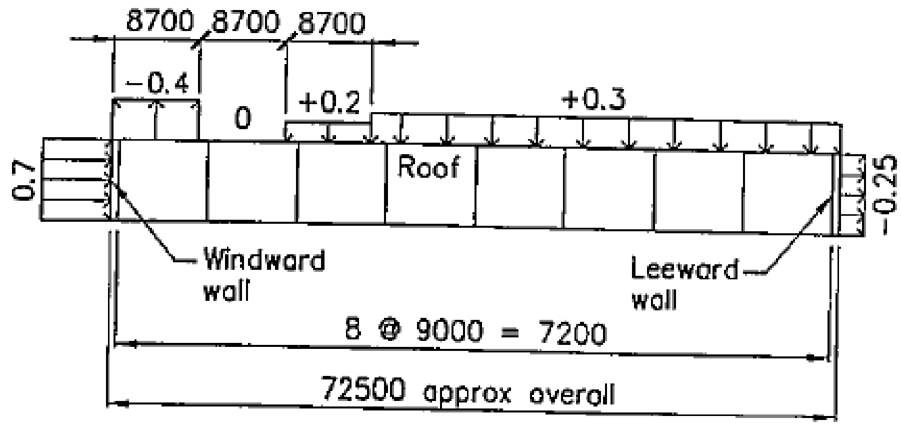
$= \frac{4 \times 3.6}{15.1} = 0.95$ *AS1170.2 Table 3.4.7*

Hence $C_{p,i} = +0.1$ *AS1170.2 Table 3.4.7*

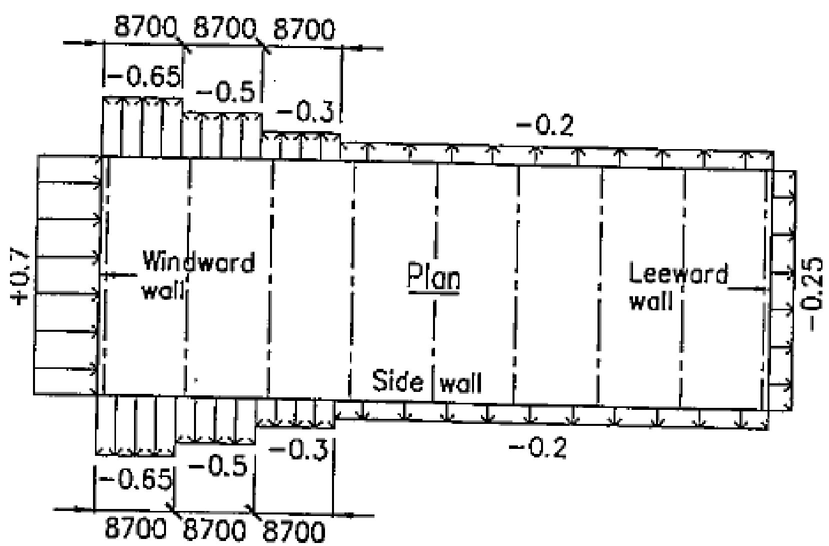
$C_{p,i} = -0.3$



(a) Roof and End Wall Pressure Coefficients Maximum Uplift



(b) Roof and End Wall Pressure Coefficients Minimum Uplift



(c) Wall Pressure Coefficients

External pressure coefficient under longitudinal wind

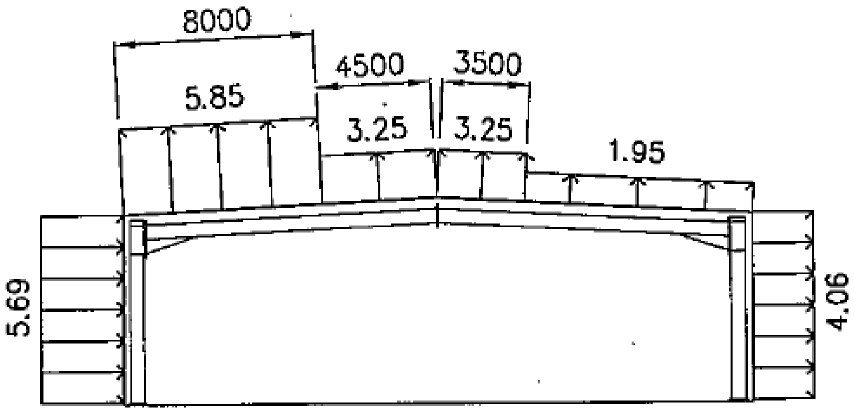
Primary Load Cases

LC1: DL of 0.90 kN/m + frame self weight

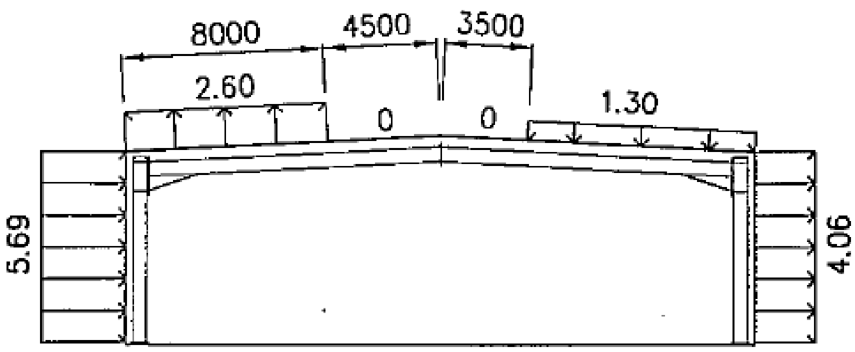
LC2: LL of 2.25 kN/m + 4.5 kN at ridge

LC3: Cross Wind Maximum Uplift

LC4: Cross Wind Minimum Uplift



Cross wind maximum uplift



Cross wind minimum uplift

LC5: Longitudinal Wind First Internal Frame (LW1)
Area reduction factor for roof and walls = 0.8

LC6: Longitudinal Wind with $0.3q_z$ External Roof Pressure and $0.2q_z$ Wall Suction (LW2)

LC7: Internal Pressure Under Cross Wind (IPCW): $C_{p,i} = +0.52$
Area reduction factor does not apply to internal pressures

UDL (rafters and columns) = $0.95^2 \times 0.52 \times 1.00 \times 9.0 = 4.21$ kN/m

LC8: Internal Pressure Under Longitudinal Wind (IPLW): $C_{p,i} = +0.1$
UDL (rafters and columns) = $0.95^2 \times 0.1 \times 1.02 \times 9.0 = 0.83$ kN/m

LC9: Internal Suction Under Cross Wind (ISCW): $C_{p,i} = -0.5$

UDL (rafters and columns) = $\frac{-0.5}{0.52} \times \text{IPCW} = -0.96 \times \text{LC7}$

LC10: Internal Suction Under Longitudinal Wind (ISLW): $C_{p,i} = -0.3$

UDL (rafters and columns) = $\frac{-0.3}{0.1} \times \text{IPLW} = -3.0 \times \text{LC8}$

Live Combinations

- **Strength Limit State**

1. $1.25\ G + 1.5\ Q$
2. $1.25\ G + W_u$
3. $0.8\ G + 1.25\ Q$
4. $0.8\ G + W_u$

- **Serviceability Limit State**

1. W_s
2. $\psi_s Q$
3. $G + W_s$
4. $G + \psi_s Q$

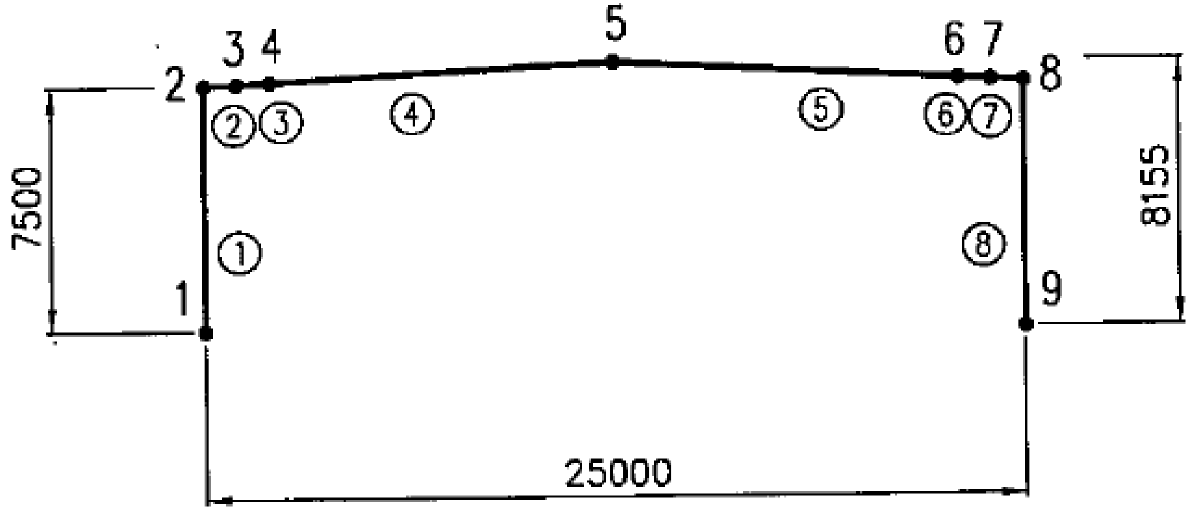
Load Combinations

Load Cases	Factors							
	LC1	*LC2*	*LC3*	*LC4*	*LC5*	*LC6*	*LC7*	*LC8*
LC20	1.25	1.5						
LC21	0.8		1.0				1.0	
LC22	0.8			1.0			1.0	
LC23	1.25			1.0			-0.96	
LC24	0.8				1.0			1.0
LC25	1.25					1.0		-3.0

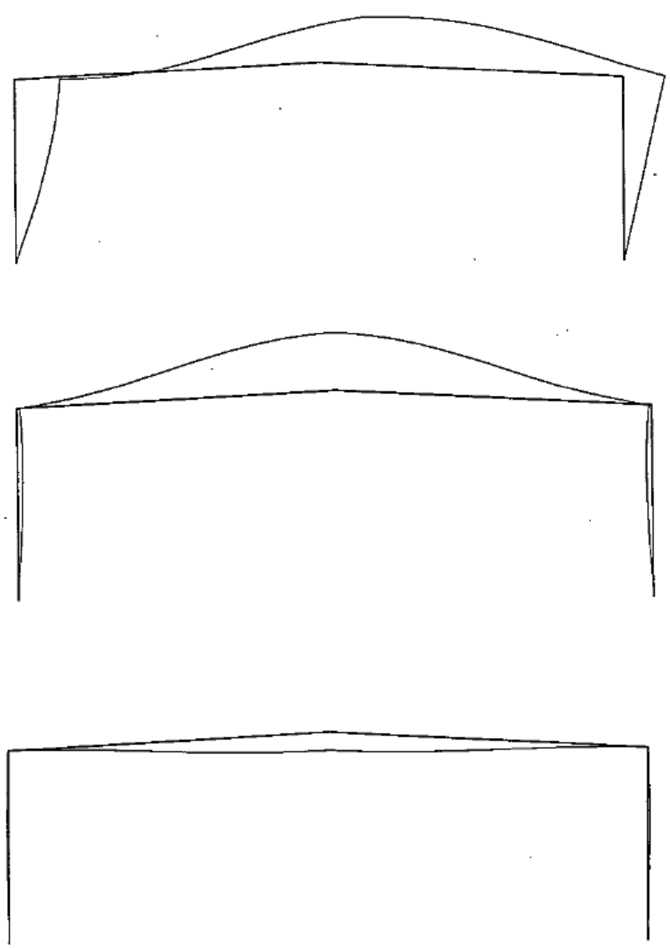
Frame Design

- **Computer analysis**

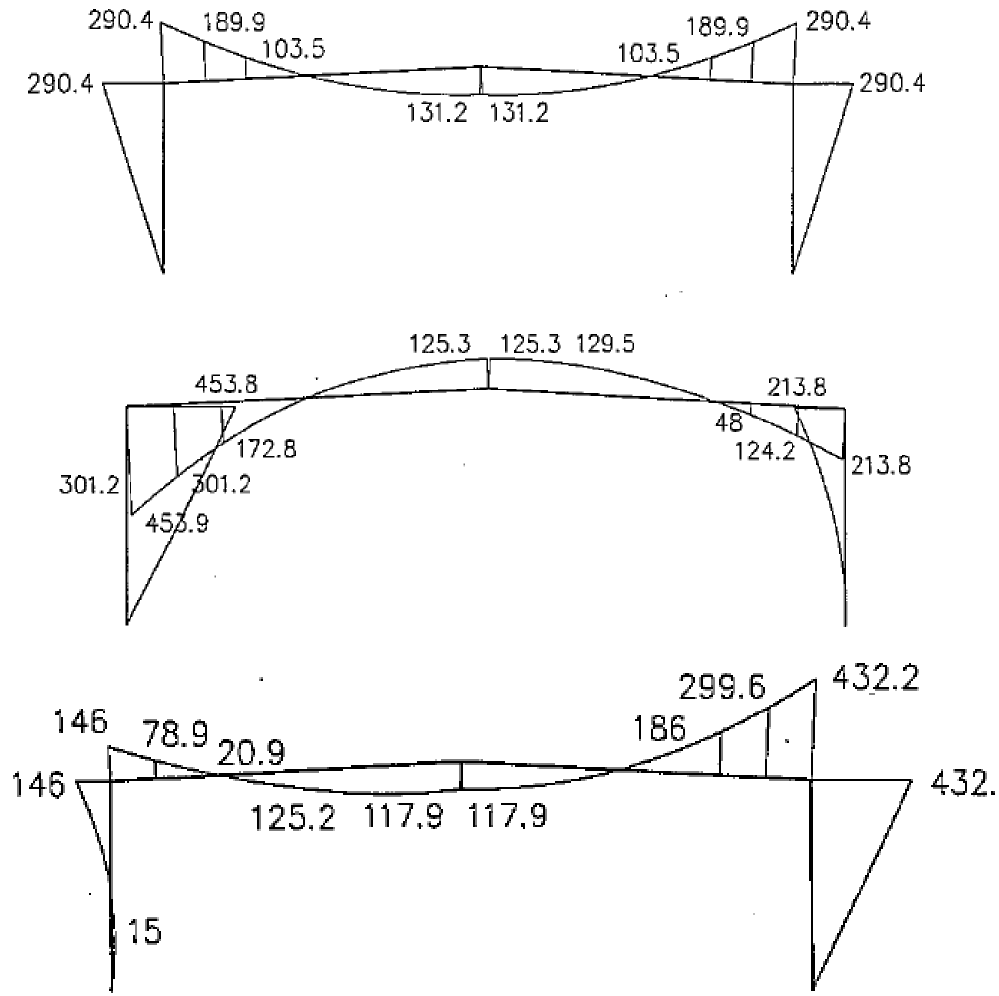
1. Separate load case computer simulations
2. Load combinations
3. First-order elastic analysis
4. Second-order elastic analysis



Computer Outputs



Deflections



Bending moments

Frame Design

- **Deflection check (lateral deflection limits)**

Type of Building	Limits	Comments
INDUSTRIAL BUILDINGS (a) Steel sheeted walls, no ceilings, no internal partitions against external walls or columns, no gantry cranes	$h/150$ $b/200$	Relative deflection between adjacent frames
(b) As in (a) but with gantry cranes	$h/250$ $b/250$	(i) h may be taken at crane rail level (ii) $h/300$ should be used for heavy cranes
(c) As in 1(a) but with external masonry walls supported by steelwork	$h/250$ $b/200$	
FARM SHEDS	$h/100$ $b/100$	

Frame Design

- **Deflection check (Rafter deflection limits)**

Type of Building and Load	Deflection Limit	Comments
Industrial Buildings		
(a) Dead Load	$L/360$	For roof pitches > 3° (see footnotes)
	$L/500$	For roof pitches < 3° but check for ponding or insufficient roof sheeting slope (see footnotes)
(b) Live Load	$L/240$	Check spread of columns if gantry crane present
(c) Wind Load	$L/150$	If no ceilings
Farm Sheds		
(a) Dead load	$L/240$	Check for ponding if roof pitch < 3°
(b) Live load	$L/180$	
(c) Wind load	$L/100$	

Note: also refer to AS 4100 Appendix B, Table B1 and B2

Frame Design

- **Column design (460 UB 74)**
  - ✓ Column section capacities
    - ❖ Bending capacity
    - ❖ Tension capacity
    - ❖ Compression capacity
  - ✓ Column member capacities
    - ❖ Major axis compression capacity
    - ❖ Minor axis compression capacity
  - ✓ Column combined actions
    - ❖ Section capacity
    - ❖ In-plane member capacity
    - ❖ Out-of-plane member capacity

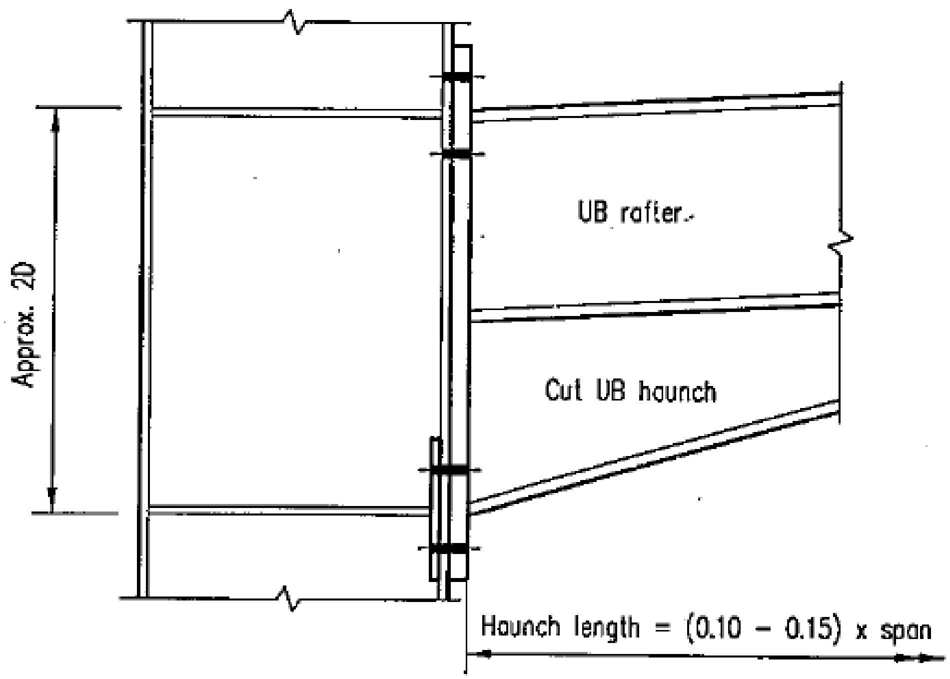
Frame Design

- **Rafter design (360 UB45)**
  - ✓ Rafter section capacities
    - ❖ Bending capacity
    - ❖ Tension capacity

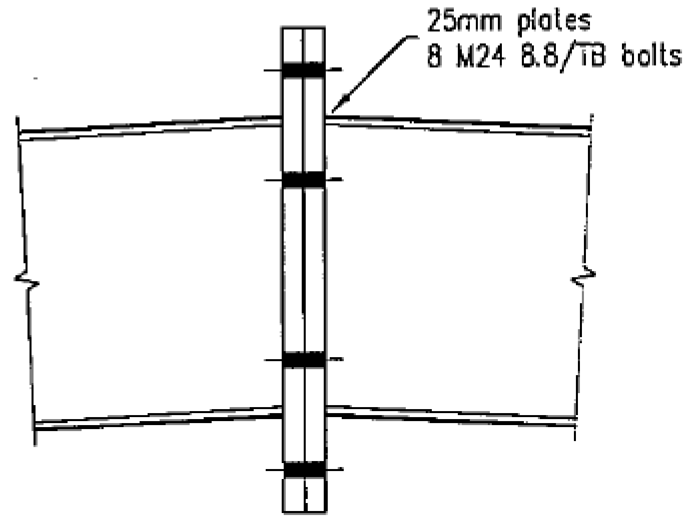
    Note: Include haunched and unhaunched sections
  - ✓ Rafter member capacities
    - ❖ Major axis compression capacity
    - ❖ Minor axis compression capacity
  - ✓ Rafter combined actions
    - ❖ Section capacity
    - ❖ In-plane member capacity
    - ❖ Out-of-plane member capacity

Frame Design

- **Connection Design**



Typical bolted knee joint



Typical bolted ridge joint