LESSON 5 - LATERAL LOADS:

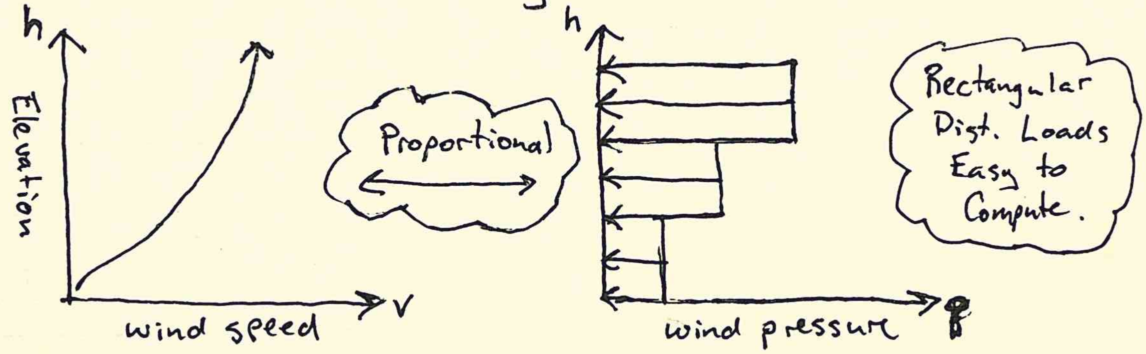
A. PRIMARY TYPES OF LATERAL LOADS:

1.) WIND LOADS
2.) SEISMIC LOADS

- CONSIDERED SEPARATELY:
  - Do not design for simultaneous 50 yr. wind storm concurrent with the 50 yr. earthquake
  - Larger of the two controls

B. Wind Loads:

- Resultant forces caused by wind pressure on structure



- IN DESIGN, WIND IS REPRESENTED AS A STATIC PRESSURE

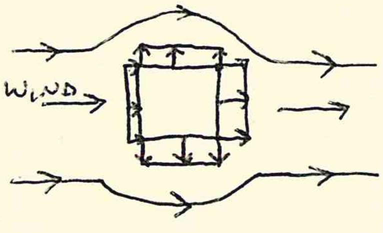
BASIC PRESSURE: $$p_s = \frac{mV^2}{2}$$

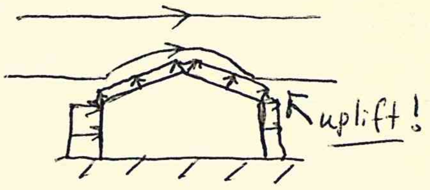
m = mass density of air

V = Wind velocity

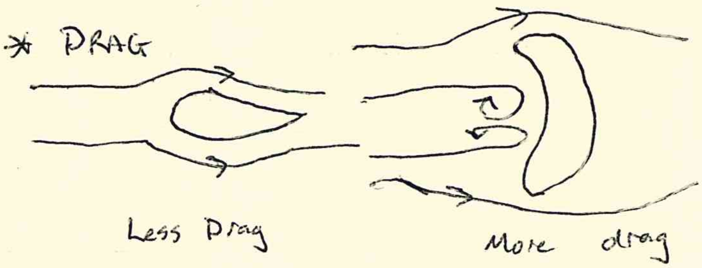
- FACTORS AFFECTING WIND PRESSURE:
  1.) Wind Velocity
  2.) Air Pressure
  3.) Ground Roughness
  4.) Shape of Structure

* BERNOULLI'S PRINCIPLE





* DRAG



TERMINOLOGY IN WIND DESIGN

MWFRS - Main Wind Force Resisting System
Structural System designed to resist lateral Load from wind.

Components & Cladding - Other structural & non-structural elements exposed to wind, not part of MWFRS

WIND LOAD SELECTION METHOD:

METHOD 1 - SIMPLIFIED PROCEEDURE
LIMITED TO LOW-RISE BUILDINGS

METHOD 2 - ANALYTICAL PROCEEDURE
ALLOWABLE FOR ALL HEIGHTS

METHOD 3 - WIND TUNNEL PROCEEDURE
SPECIAL DESIGNS

LOW-RISE BUILDING: MEAN ROOF HEIGHT $\leq$ 60ft

CE3202: METHOD 2 - MWFRS

– COMPUTING DESIGN WIND LOADS – ANALYTICAL METHOD

$$q_s = \frac{MV^2}{Z} \xrightarrow{ASCE7} q_s = 0.00256V^2$$

- MUST ACCOUNT FOR OTHER FACTORS:

$$q_z = q_s K_z K_{zt} K_d$$ "VELOCITY PRESSURE"

$$\hookrightarrow q_z = 0.00256V^2 K_z K_{zt} K_d$$

* K_z: VELOCITY PRESSURE EXPOSURE COEFFICIENT

→ INCLUDES 2 EFFECTS

1.) HEIGHT ABOVE GROUND

2.) EXPOSURE:

B – Urban, Suburban, Forest
C – Open Terrain, Some Obstructions
D – Near Water, Unobstructed

(see Handout, Table 27.3-1)

* K_{zt}: Topographical Factor (Hills):

$K_{zt} = 1$ on flat ground
$K_{zt} > 1$ if structure on hill

(see Handout, Fig. 26.8-1)

* K_d: DIRECTIONALITY FACTOR

Reduces load due to low probability of full pressure development.

Often $K_d = 0.85$ for buildings

(see Handout, Table 26.6-1)

- What pressure do we apply to external surfaces?

$$p = q(GC_p) - q_i(GC_{pi})$$

Ignore in CE3202 For simplicity (MWFRS)

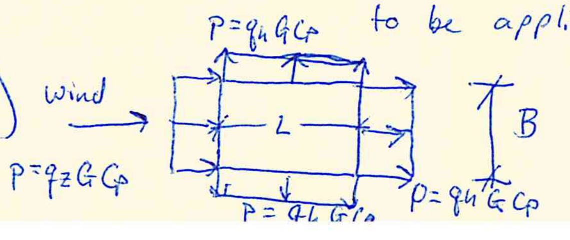
$q = q_z$ for windward wall
$q = q_h$ for leeward wall

* $G = 0.85$ for rigid structures

* C_p = External pressure Coefficient

Establishes fraction of velocity pressure, q, to be applied to each surface of structure

(HANDOUT: Fig. 27.4-1)



internal pressure (Not in your textbook)

$q_i = q_h$ for enclosed buildings (positive & negative internal pressure)

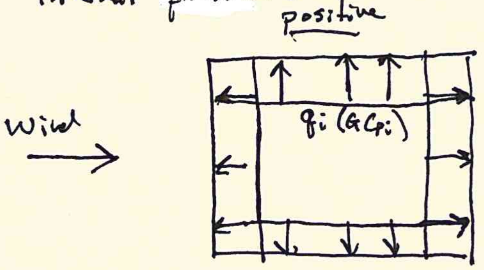
(GC_{pi}) = internal pressure coefficient : Figure 6-5 (handout)

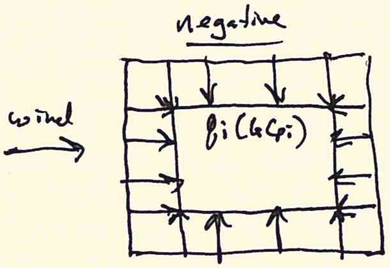
$= \pm 0.18$ Enclosed Buildings

$+$ = toward wall

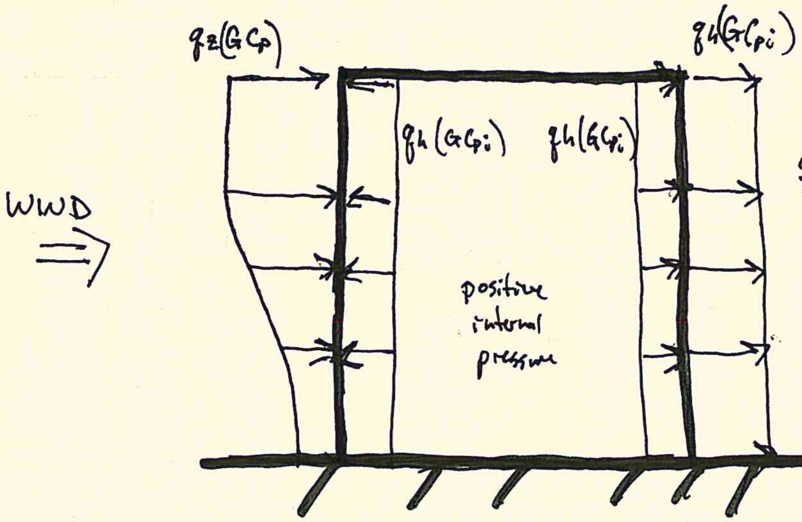
$-$ = away from wall.

internal pressure loads





Combined Internal + External (windward and leeward walls)



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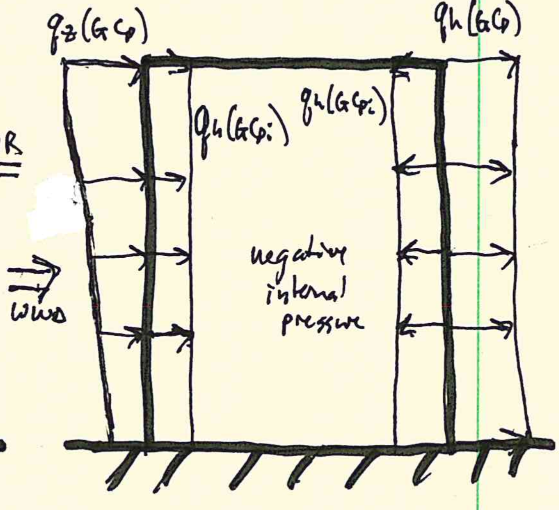
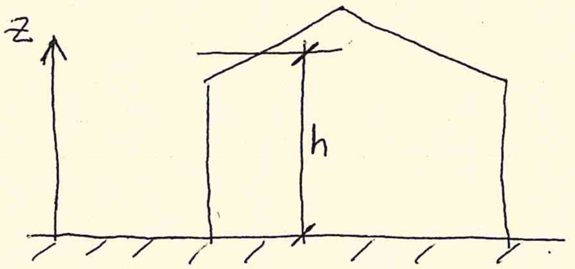


Use worst case

→ q_z vs. q_h

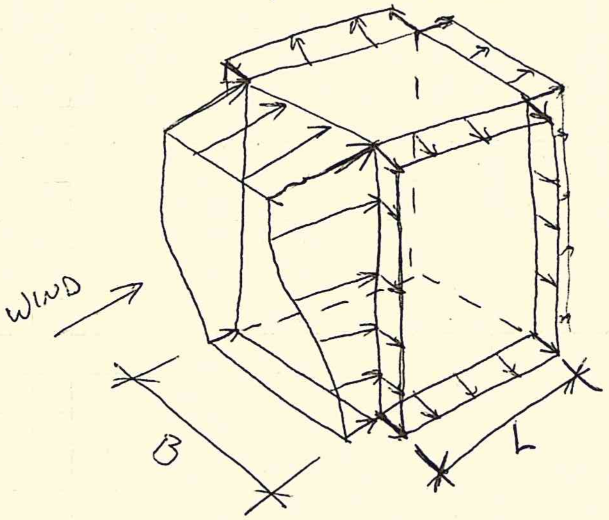


z = height above grade
varies from 0 to
height of structure

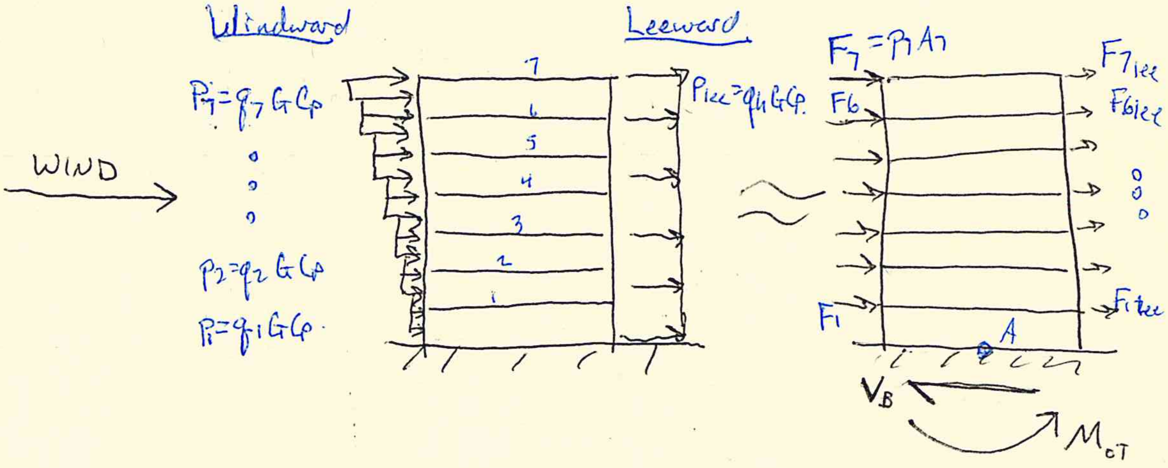
h = value of z equal to
the average roof height

$$q_h = q_z \big|_{z=h}$$

Simplified Procedure only uses h.



SIDE	VARIABILITY	DIRECTION
WINDWARD SIDE,	VARIES OVER HEIGHT	INTO STRUCT.
OTHER SIDES,	SAME OVER HEIGHT	AWAY FROM STRUCT.

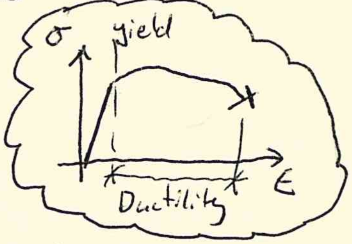


$$V_B = \Sigma F_{windward} + \Sigma F_{leeward}$$

$$M_{OT} = \Sigma M_A$$

C: SEISMIC LOAD

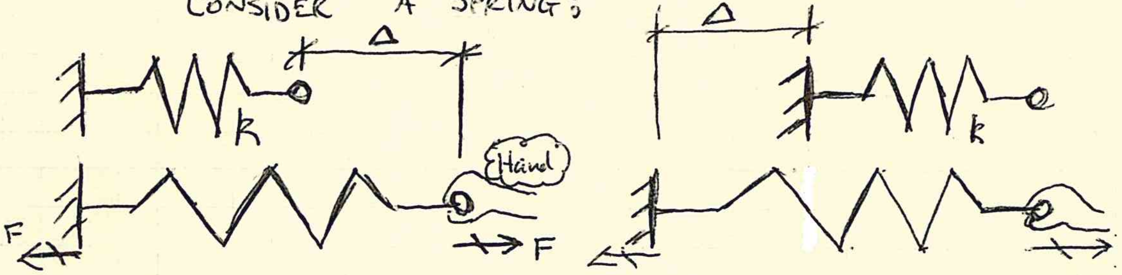
- Effect of ground motion due to earthquakes
- HIGHLY Complex, dynamic load influenced by:
  1.) Seismic Characteristics of site (Seismicity)
  2.) Soil Characteristics of Site
  3.) Mass of structure
  4.) Stiffness of structure
  5.) Ductility of structure



- Multiple graduate classes on earthquake engineering, is there a simplified method that will work for many structures? YES;

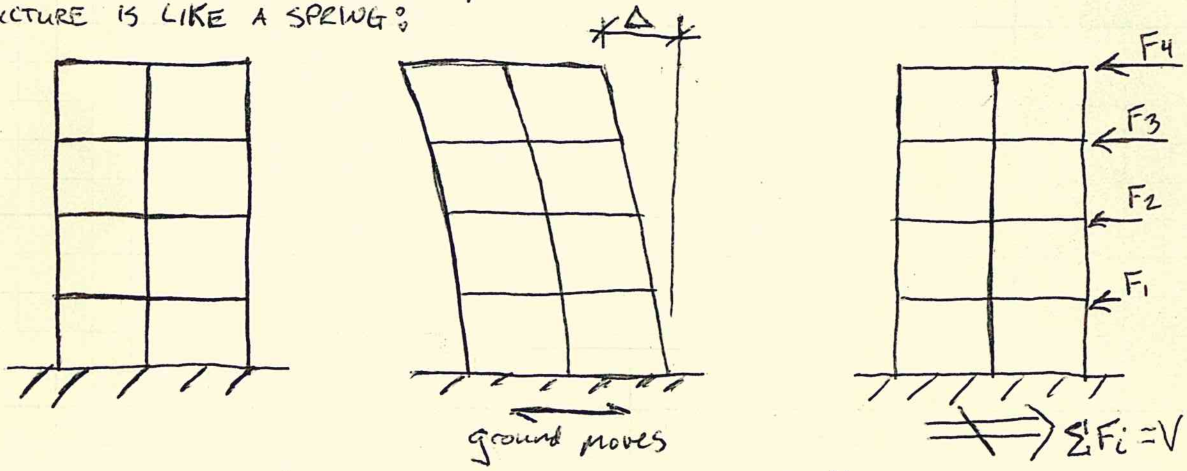
<u>EQUIVALENT LATERAL FORCE PROCEEDURE</u> (ASCE 7)

CONSIDER A SPRING:



$F = \Delta k$ ⟵ Equivalent ⟶ $F = \Delta k$

STRUCTURE IS LIKE A SPRING:



- No giant hand holds the structure, but the <u>inertial forces</u> due to the mass of the floors oppose motion (specifically change in motion)

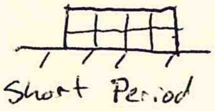
$$F = ma$$

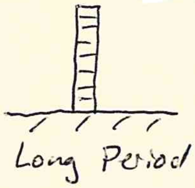
- Offset by structure stiffness
- Sum of these forces resisted by reaction at base, <u>Base Shear</u>, V

Proceedure to determine base shear

1) DETERMINE SPECTRAL RESPONSE ACCELERATION COEFFICIENTS
2) FIND SEISMIC DESIGN CATEGORY
3) Determine Base Shear (maybe)
4) Find Story loads

1.) Spectral Response Acceleration Parameter





Fundamental Natural Period (T) of the structure strongly affects its performance during seismic events.

$T = 1/f_n$, f_n = natural freq.

Spectral: based on freq.

response: building behavior

acceleration: type of response

Tells us: Given a building location, what is the maximum considered earthquake (MCE) for a structure with a given period.

2 Flavors:	Short Period (T=0.2)	One Second (T=1s)
Mapped (MCE) Spectral Response Acceleration Parameter	S_S (Handout, ~~Fig. 1615(1)~~) **Fig. 22-1**	S_1 (Handout ~~Fig 1615(2)~~) **Fig 22-2**
MCE Spectral Response Accel. Parameter	$S_{MS} = F_a S_S$ F_a = Site Coefficient (Handout, Table 11.4-1)	$S_{M1} = F_v S_1$ F_v = Site Coefficient (Handout, Table 11.4-2)
Design Spectral Response Accel. Parameter	$S_{DS} = 2/3\, S_{MS}$	$S_{D1} = 2/3\, S_{M1}$

SITE CLASS: Geological profile of building site.

A B C D E F

Hard Rock (best case) ⟵ ⟶ Soft/Weak Soil (worst case)

Don't know? Use D, unless you suspect worse.

(Table 11.8-1)

→ SEISMIC DESIGN CATEGORY

Depends on seismic hazard $\left\langle \begin{array}{l} S_{DS} \text{ \& } S_{D1} \\ \text{Occupancy Category} \end{array} \right.$

A B C D E F

$\xleftarrow{\quad}$ Less Severe $\qquad$ $\xrightarrow{\quad}$ More Severe

→ C – F : Require Specilized geotech Reports

→ D – F : Scope of Earthquake Engineering class.

What category to use? See Tables 11.6-1
11.6-2

Use worst case.

→ FLOOR LOADINGS, Seismic Design Category A

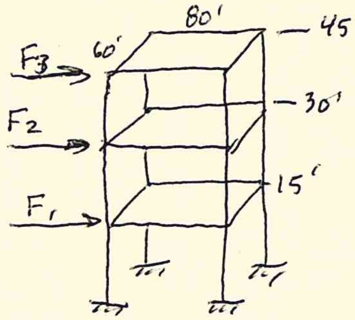
$F_x = 0.010\, w_x$

F_x = Lateral Seismic Load to be applied to floor x

w_x = Dead Load assigned to floor x

All or Total DL! $w_x = \left(\frac{\text{Dead Load}}{\text{Unit Area}}\right)\left(\text{Area of Floor } x\right)$

Example :



DL = 35 psf
Steel Frame
Location: Houghton, MI
Occupancy Category II
Site Class D

$S_S = 0.11g$ Map
$S_1 = 0.02g$ Map

$S_{MS} = F_a S_S$
$F_a = 1.6$ (Table 11.4-1)
$S_{MS} = 1.6(.11) = 0.176g$
$S_{DS} = 2/3\, S_{MS} = 0.117g$
Category A (Table 11.6-1)

$S_{M1} = F_v S_1$
$F_v = 2.4$ (Table 11.4-2)
$S_{M1} = 2.4(.02) = 0.048g$
$S_{D1} = 2/3\, S_{M1} = 0.032g$
Category A (Table 11.6-2)

$F_1 = F_2 = F_3 = 0.010\, w_1$

$w_1 = (35\text{ psf})(60')(80') = 168{,}000\text{ lb}$

$F_1 = 0.010(168000) = \boxed{1680\text{ lb}}$

→ LOADINGS, SEISMIC DESIGN CATEGORIES B & C

1.) Find base shear:

$$V = \frac{S_{D1}\, W}{T(R/I)}$$

V = design base shear

$$V_{max} = \frac{S_{DS}\, W}{R/I}$$

V is overly stringent for short period

$$V_{min} = 0.044\, S_{DS}\, I\, W$$

Minimum

W = Seismic Weight (lb) $\sum_{i=1}^{n} w_i$, n = # floors

T = fundamental period of structure

Estimated by: $T = C_t h_n^x$, h_n = building ht (ft)

Steel frame: $C_t = 0.028$
$x = 0.8$

R/C frame: $C_t = 0.016$
$x = 0.9$

R/C = Reinforced Concrete

Other: $C_t = 0.020$
$x = 0.75$

"other" includes braced frame or shear wall

R = Response Modification factor

gives "bonus points" for ductile structures

Ductile steel or R/C frame, R = 8
ordinary R/C shear wall, R = 4
Ordinary Masonry shear wall, R = 2

I = Importance factor

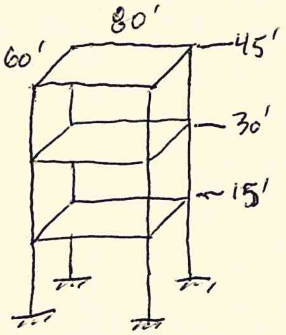
Occupancy Category	
I or II	I = 1.0
III	I = 1.25
IV	I = 1.5

2.) Distribute Loads:

$$F_x = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} V \quad \begin{cases} k = 1 & \text{if } T \le 0.5\text{ s} \\ k = 2 & \text{if } T \ge 2.5\text{ s} \\ \text{otherwise} & k = 1 + \dfrac{T - 0.5}{2} \end{cases}$$

linear interpolation

EXAMPLE



DL = 35 psf
Steel Frame
Location: Kalamazoo, MI
Occupancy Category II
Site Class D

$S_S = 0.12\,g$
$S_1 = 0.05\,g$

$F_a = 1.6$
$F_v = 2.4$

$$S_{MS} = 1.6\,(0.12g) = 0.192g \rightarrow S_{DS} = \tfrac{2}{3} S_{MS} = 0.128g$$
$$S_{M1} = 2.4\,(0.05g) = 0.120g \rightarrow S_{D1} = 2/3\, S_{M1} = 0.08g$$

from S_{DS} and table 11.6-1, design cat. A
from S_{D1} and table 11.6-2, design cat. B ← Controls

$$\rightarrow \quad V = \frac{S_{D1}\,W}{T\,(R/I)}$$

$S_{D1} = 0.08$
$W = (60)(80)(3)(35) = 504000\ lb$
$T = C_t h_n^x = 0.028\,(45)^{0.8} = 0.588$
$R = 8$
$I = 1$

$$V = \frac{504000\,(0.08)}{(0.588)\,(8/1)} = 8570\ lb$$

$$\rightarrow \quad V_{max} = \frac{S_{DS}\,W}{R/I}$$

$$V_{max} = \frac{0.128\,(504000)}{8/1} = 8064\ lb$$ ← controls over V

$$\rightarrow \quad V_{min} = 0.044\,S_{DS}\,I\,W$$
$$= 0.044\,(.128)(1.0)(504000) = 2840\ lb$$ ← does not control

$V = 8064\ lb$ ← use this to assign Force to floors.

$$\rightarrow \quad F_x = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} V$$

$k = 1 + \frac{T - 0.5}{2}$ if $T > 0.5$ & $T < 2.5$
$T = 0.588$

$n = 3$

$$k = 1 + \frac{0.588 - 0.5}{2} = 1.044$$

Example CONTINUED....

$$\sum_{i=1}^{n} w_i h^k = 80(60)(35)(15)^{1.044} + (80)(60)(35)30^{1.044} + (80)(60)(35)45^{1.044}$$

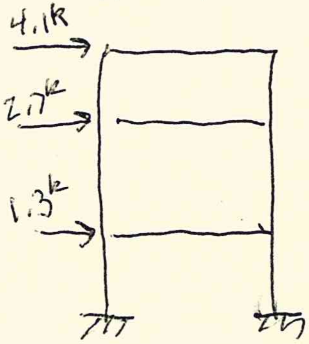
$$= 1.76\cdot10^7$$

$$\therefore F_1 = \frac{80(60)(35)15^{1.044}}{1.76\cdot10^7}V = 0.16(8064) = 1300^{lb}$$

$$F_2 = \frac{80(60)(35)30^{1.044}}{1.76\cdot10}(8064) = 2680^{lb}$$

$$F_3 = \frac{80(60)(35)45^{1.044}}{1.76\cdot10^7}(8064) = 4096^{lb}$$

Loadings



Check, $\sum_{i=1}^{n} F_i \overset{?}{=} V$

$$(4.1 + 2.7 + 1.3) = 8.1^k = 8.1^k = V$$

<u>ok</u>