Architecture 504
Masonry Structures

Infill Walls and Partitions

Definitions
Behavior
Reinforcement

Examples of Masonry Vaulting

Venice Biennale, Foster + Partners

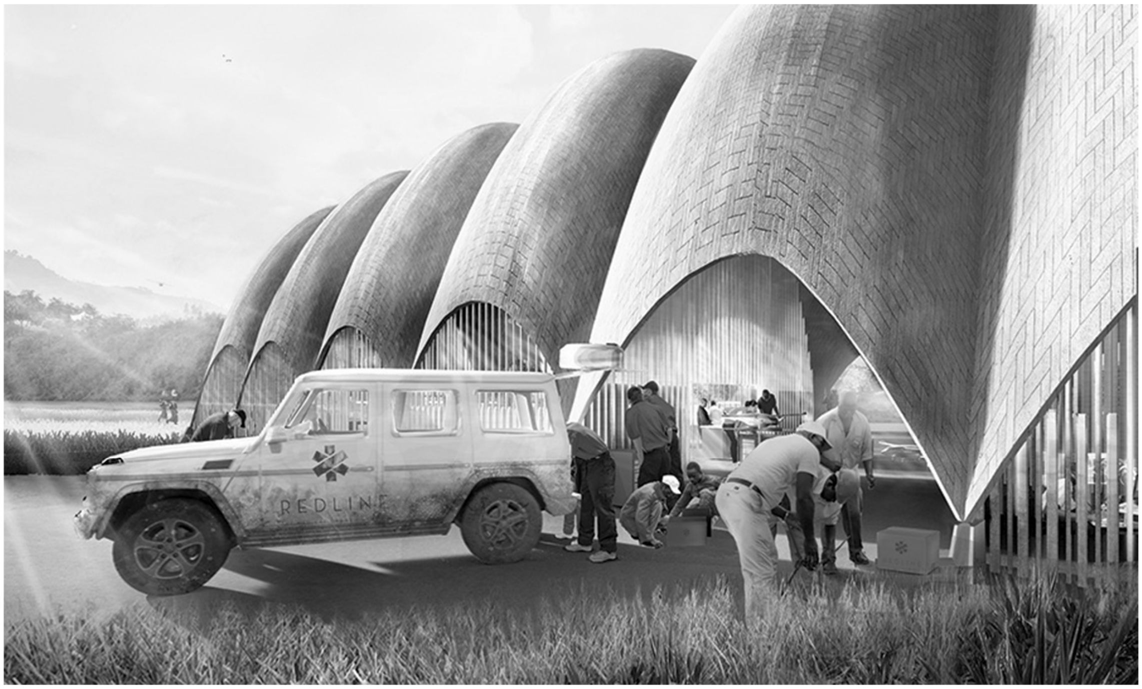
Examples of Masonry Vaulting

Venice Biennale, Foster + Partners

Examples of Masonry Vaulting

Rwanda Droneport, Foster + Partners

Examples of Masonry Vaulting



Rwanda Droneport, Foster + Partners

Twisted Brick Shell Concept Library

HCCH Studio

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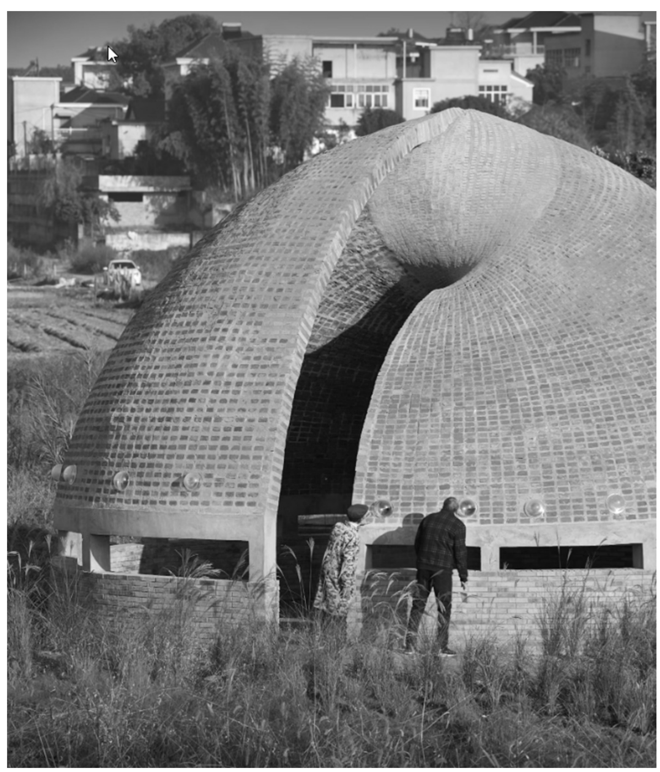

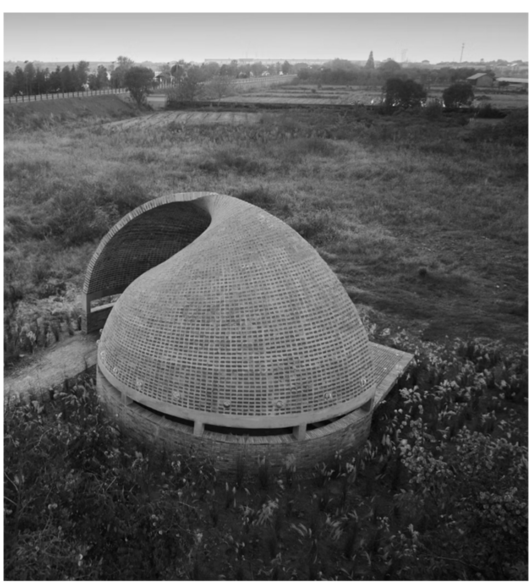

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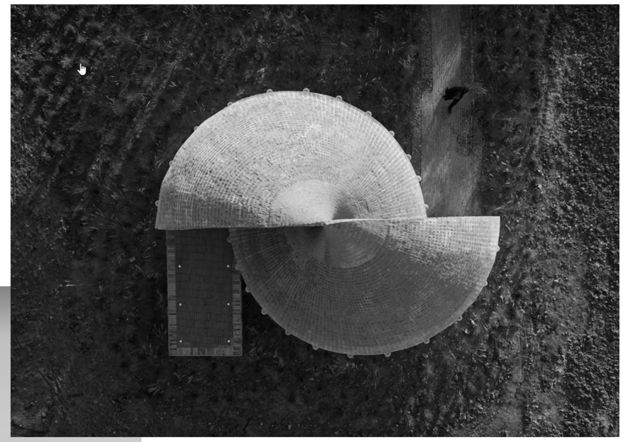

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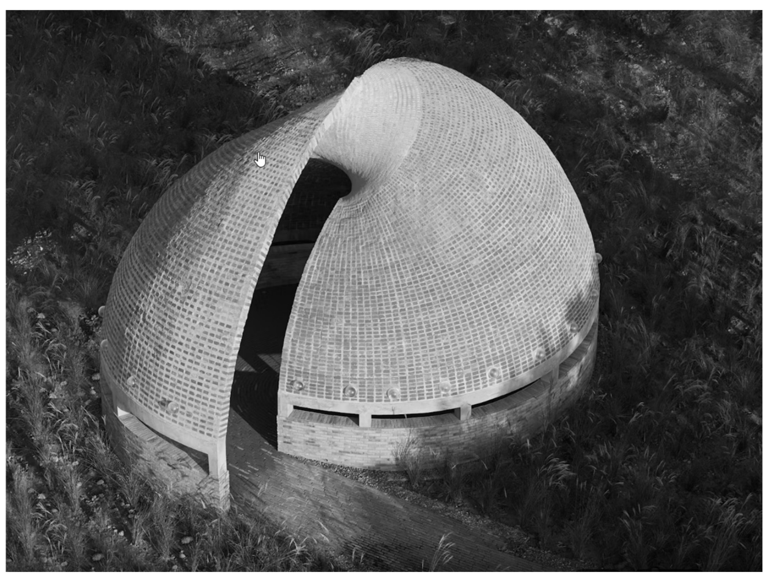

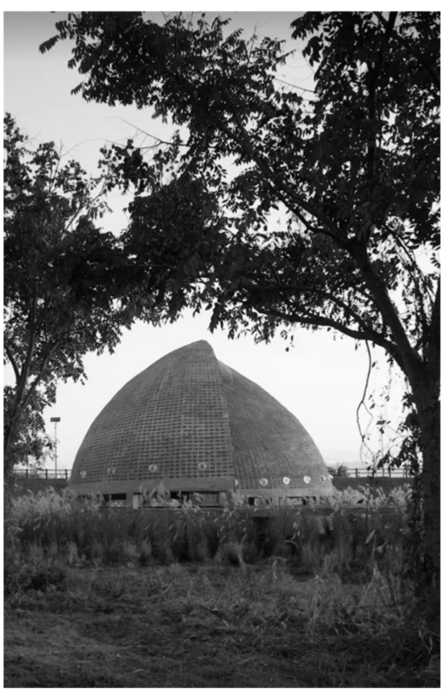

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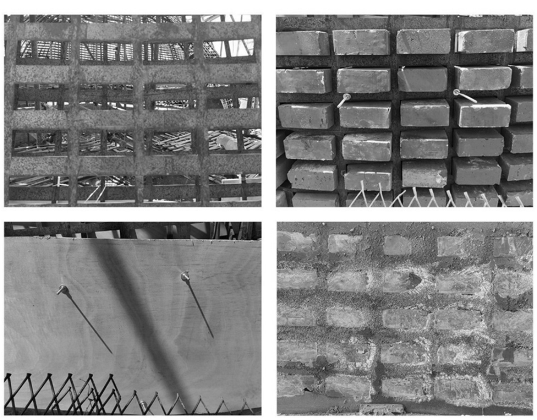
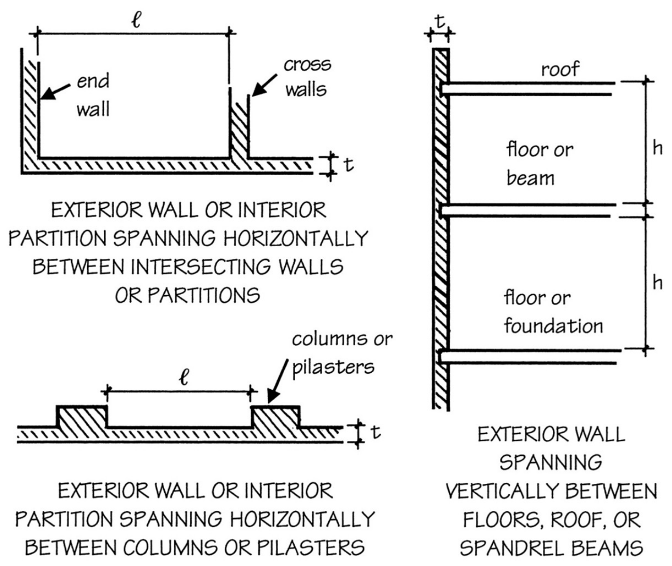


Types of Infill Walls

Infill Walls
- Interior partitions
- Exterior non-supporting walls
- Barriers to fire or sound
- Screen walls
- Non-loadbearing
- Empirical design
- Single story
- Usually empirically designed
- h/t of 36

Infill Walls

h/t ratios



Empirical Span-to-Thickness Ratios for Lateral Support of Masonry Walls

Wall or Element	Maximum Unsupported Height or Length to Nominal Thickness (ℓ/t or h/t)
Non-bearing walls	
Exterior walls	18
Interior partitions	36

(*Based on requirements of the MSJC* Building Code Requirements for Masonry Structures ACI 530/ASCE 5/TMS 402, *and* International Building Code 2003)

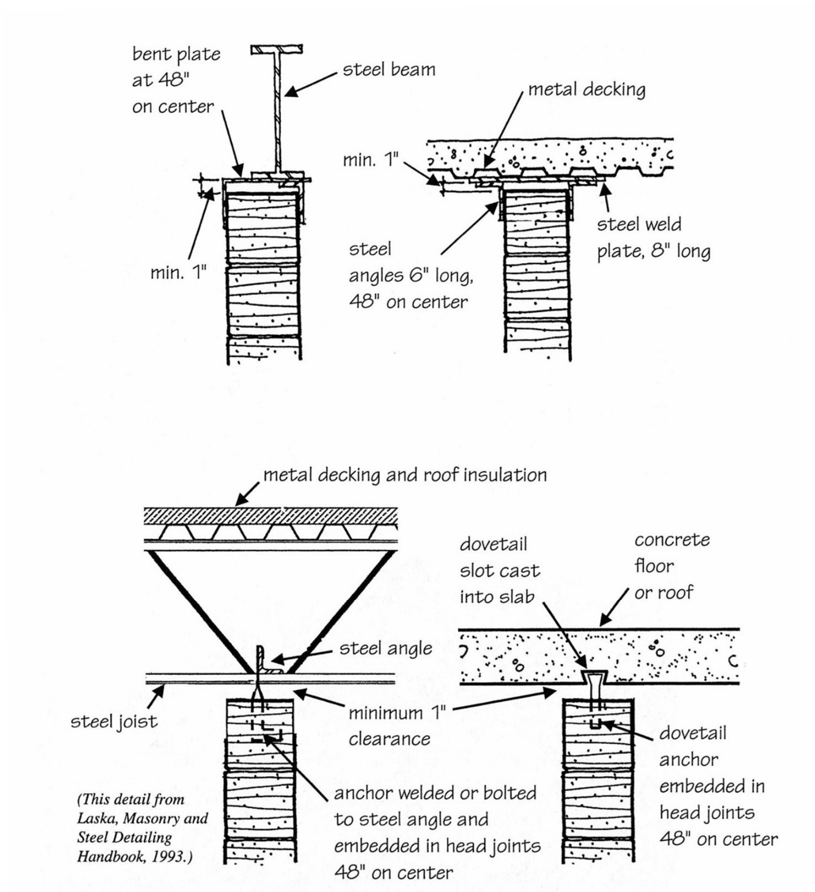
Infill Walls

Must be separated from slabs and columns

Spaces and/or movement joints are used

Spaces must accommodate deflection and story drift

Must be designed to carry out of plane loads – earthquake or wind



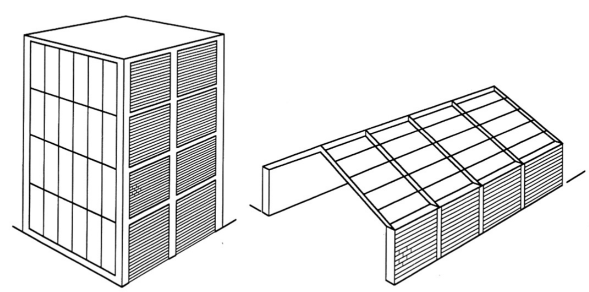
Infill Walls

Can be designed as infill between slabs and columns

Either single or multi-story

When built snuggly against structure they stiffen the frame (carry shear loads from frame). Frame and wall can act as a composite system.

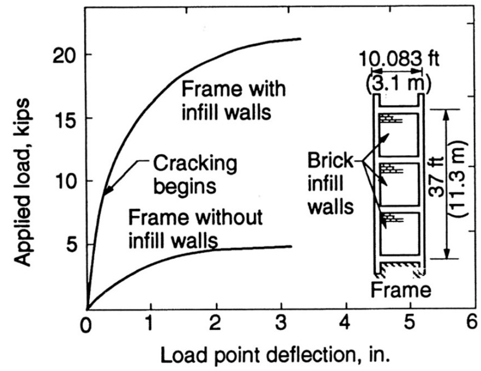
Thermal expansion loads need also be considered.

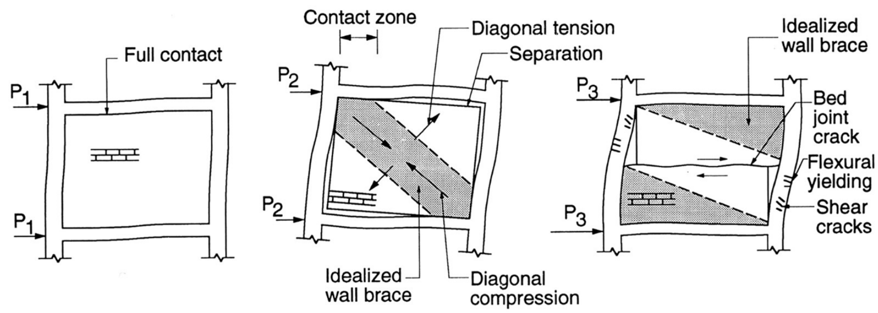


(a) Multistory Building (b) Single-Story Building

Infill Walls

Composite interaction
- Area of contact
- Interfaces
- Level of lateral load
- Degree of bond / anchorage
- Geometric and stiffness characteristics
- Compressive truss (diagonal) action
- Final failure in shear

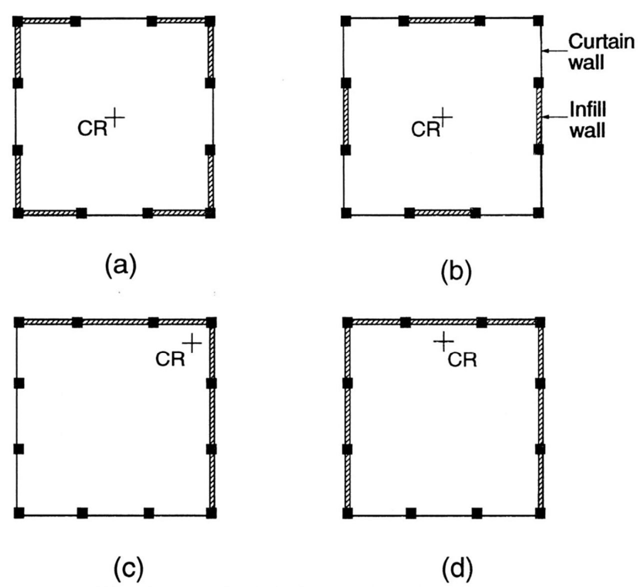




(a) Full Composite Action (b) Compression Strut ($P_2 >> P_1$) (c) Knee brace ($P_1 < P_3 < P_2$)

Infill Walls

The arrangement of infill walls can lead to torsional loads when not symmetrically placed.



CR = Center of rigidity for combined action of walls and frames

Note: Rigid diaphragm action of floors is assumed

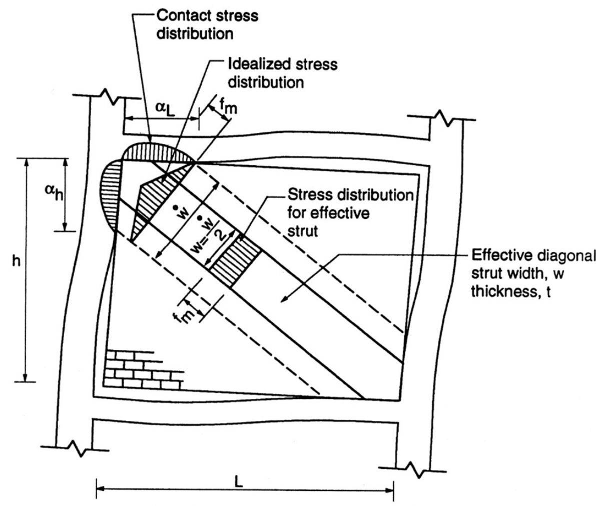
Infill Walls

Diagonal strut action
w ~ L/4 to L/3

Force in strut:

$$\alpha_h = \frac{\pi}{2}\sqrt[4]{\frac{4\,E_f I_c h}{E_m t \sin 2\theta}}$$

$$\alpha_L = \pi\sqrt[4]{\frac{4\,E_f I_b L}{E_m t \sin 2\theta}}$$



where: E_m, E_f = elastic moduli of the masonry wall and frame material, respectively
t, h, L = thickness, height, and length of the infill wall, respectively
I_c, I_b = moments of inertia of the column and the beam of the frame, respectively
$\theta = \tan^{-1}(h/L)$

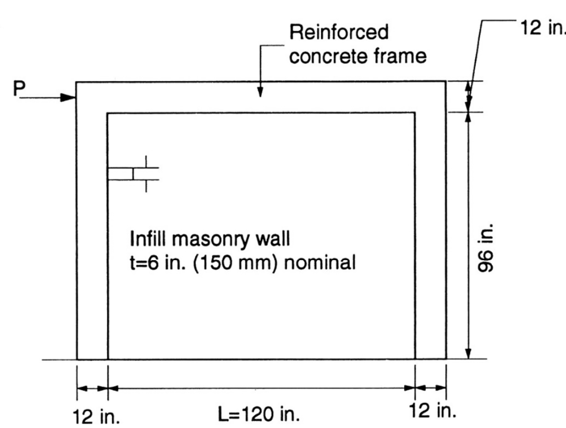
$$w = \tfrac{1}{2}\sqrt{\alpha_h^2 + \alpha_L^2}$$

Infill Walls - example

Determine the increase in stiffness of the frame with the added infill wall

Given:
Infill wall:
Thickness t = 5 5/8”
E_w = 2000 ksi
Frame:
Areas of members: $A_b = A_c = 144$ in^2
Moment of Inertia: $I_b = I_c = 1728$ in^4
Ef = 3000 ksi

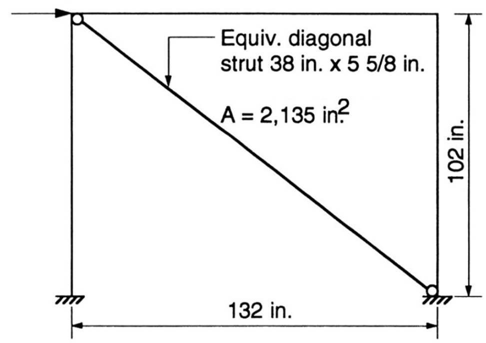
Find:
Width of diagonal strut
Deflection of the frame with and without the wall



(a) Reinforced Concrete Frame and Masonry Infill Wall

Infill Walls - example

Determine the increase in stiffness of the frame with the added infill wall



Equivalent Strut Model

$$\alpha_h = \frac{\pi}{2} \sqrt[4]{\frac{E_f I_c h}{2E_m t \sin 77.3°}} = 32.7 \text{ in.}$$

$$\alpha_L = \pi \sqrt[4]{\frac{E_f I_b L}{E_m t \sin 77.3°}} = 68.5 \text{ in.}$$

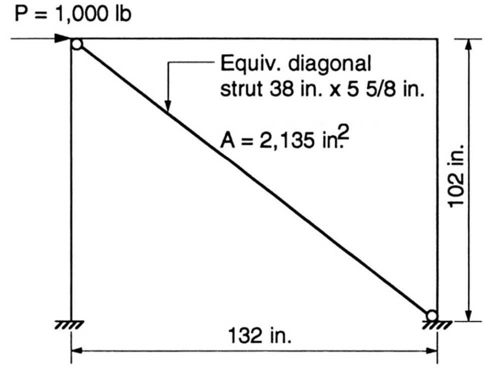
$$w = \tfrac{1}{2}\sqrt{\alpha_h^2 + \alpha_L^2} = 38 \text{ in.*}$$

Area of diagonal strut, $A_d = 38 \times 5.625 = 213.8 \text{ in.}^2$

$$\theta = \tan^{-1}\frac{h}{L} = 38.65°$$

Infill Walls - example

Determine the increase in stiffness of the frame with the added infill wall



Equivalent Strut Model

Deflection of frame without wall:

$$\Delta_{\text{horiz}} = 0.013 \text{ in. (0.33 mm) due to 1000 lb lateral force}$$

$$\therefore \text{stiffness, } k = \frac{P}{\Delta} = \frac{1000}{1.3 \times 10^{-2}} = 77000 \text{ lb/in.} = 77 \text{ kips/in.}$$

Deflection of frame with wall:

$$\Delta_{\text{horiz}} = 0.0002 \text{ in. due to 1000 lb lateral force}$$

$$\therefore \text{stiffness, } k = \frac{P}{\Delta} = \frac{1000}{0.0002} = 5 \times 10^6 \text{ lb/in.} = 5000 \text{ kips/in.}$$

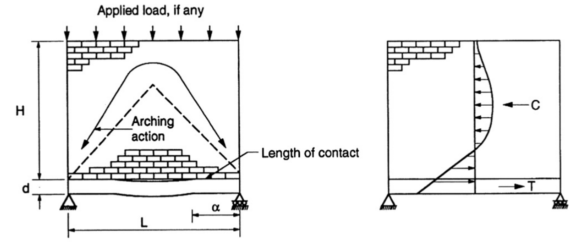
$$\theta = \tan^{-1}\frac{h}{L} = 38.65°$$

Walls Supported on Beams

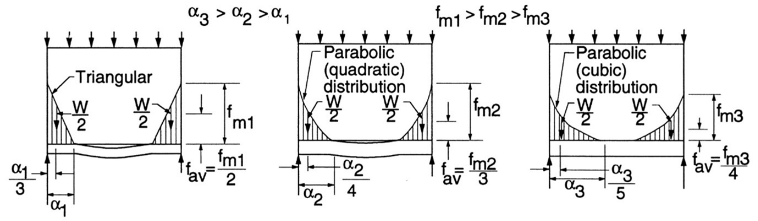
Arching action of wall

Beam-Wall composite

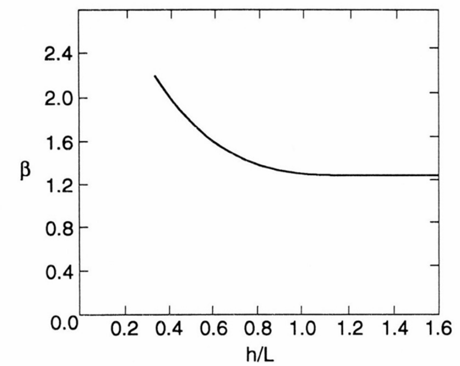
Effect of beam stiffness



(a) Triangular Load Distribution and Arching (b) Stress Distribution at Midspan Due to Deep Beam Behavior



(a) Very Flexible Beam ($K_f > 7$) (b) Flexible Beam ($5 < K_f < 7$) (c) Stiff Beam ($K_f < 5$)



$$K_F = \sqrt[4]{\frac{E_w t h^3}{E_b I_b}} \qquad \alpha = \frac{L}{1 + \beta K_F}$$

Mortar Types

Types M, S, N, O

The following mortar designations took effect in the mid–1950's:

M a **S** o **N** w **O** r **K**

strongest weakest

Table 2-3. Guide to the Selection of Mortar Type*

Location	Building segment	Mortar type: Recommended	Mortar type: Alternative
Exterior, above grade	Load-bearing walls Non-load-bearing walls Parapet walls	N O** N	S or M N or S S
Exterior, at or below grade	Foundation walls, retaining walls, manholes, sewers, pavements, walks, and patios	S†	M or N†
Interior	Load-bearing walls Non-load-bearing partitions	N O	S or M N

*Adapted from ASTM C270. This table does not provide for specialized mortar uses, such as chimney, reinforced masonry, and acid-resistant mortars.
**Type O mortar is recommended for use where the masonry is unlikely to be frozen when saturated or unlikely to be subjected to high winds or other significant lateral loads. Type N or S mortar should be used in other cases.
†Masonry exposed to weather in a nominally horizontal surface is extremely vulnerable to weathering. Mortar for such masonry should be selected with due caution.

Note: For tuckpointing mortar, see "Tuckpointing," Chapter 9.

Portland cement – lime mortars

Relative Parts by Volume

mortar type	Portland cement	lime	sand
M	1	1/4	3 1/2
S	1	1/2	4 1/2
N	1	1	6
O	1	2	9

sum should equal 1/3 of sand volume
(assuming that sand has void ratio of 1 in 3)

Mortar Mixing