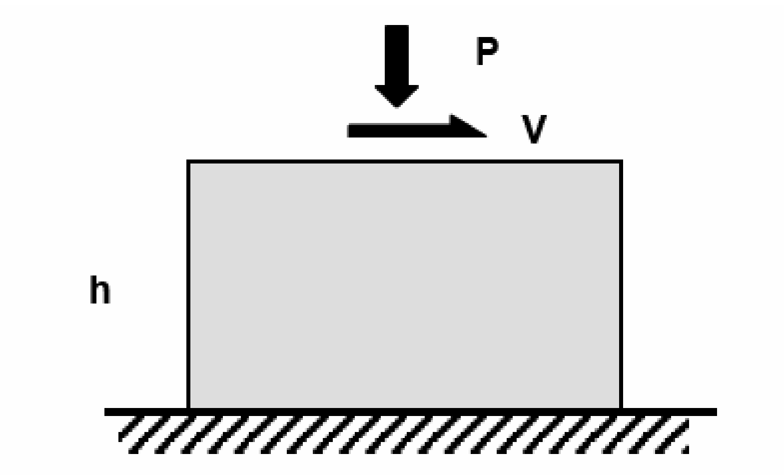
DESIGN OF REINFORCED MASONRY SHEAR WALLS

Introduction

Next, let us consider the behavior and design of reinforced masonry shear walls.

Design Steps

Reinforced masonry shear walls must be designed for the effects of:
1) gravity loads from self-weight, plus gravity loads from overlying roof or floor levels; and
2) moments and shears from in-plane shear loads
Actions are shown below. Either strength or allowable-stress design can be used.



DESIGN OF REINFORCED SHEAR WALLS USING STRENGTH PROCEDURES

Flexural capacity of reinforced shear walls using strength procedures is calculated using moment-axial force interaction diagrams as discussed in the lecture on masonry beam-columns. In contrast to the elements addressed in that lecture, a shear wall is subjected to flexure in its own plane rather than out-of-plane. It therefore usually has multiple layers of flexural reinforcement. Computation of moment-axial force interaction diagrams for shear walls is much easier using a spreadsheet.

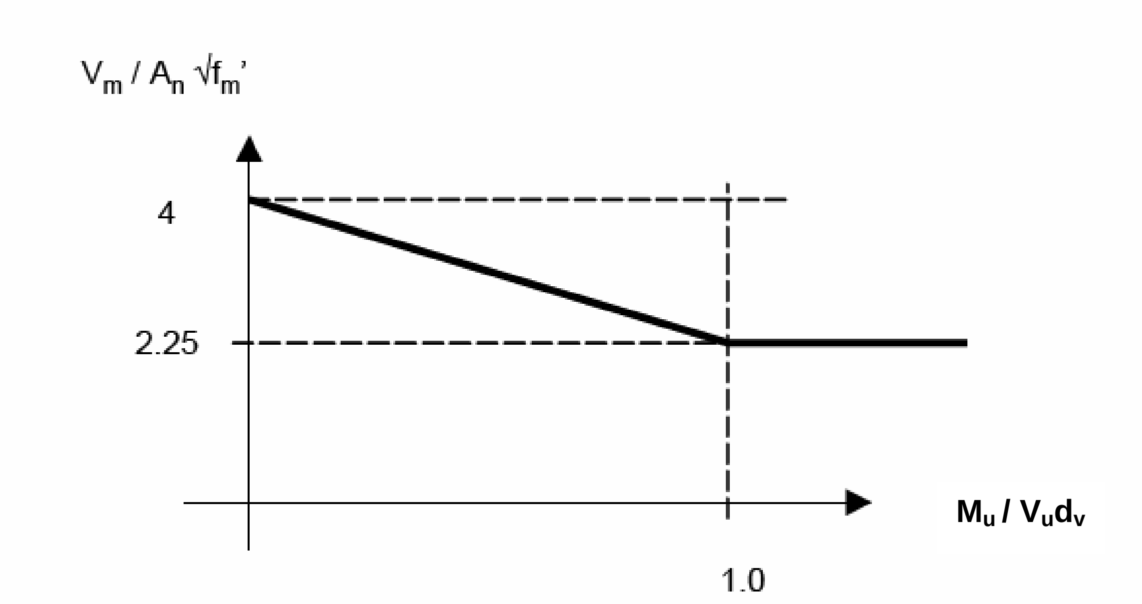
From the 2005 MSJC Code, Section 3.3.4.1.2, nominal shear strength is the summation of shear strength from the masonry and shear strength from the shear reinforcement.

$$V_n = V_m + V_s$$

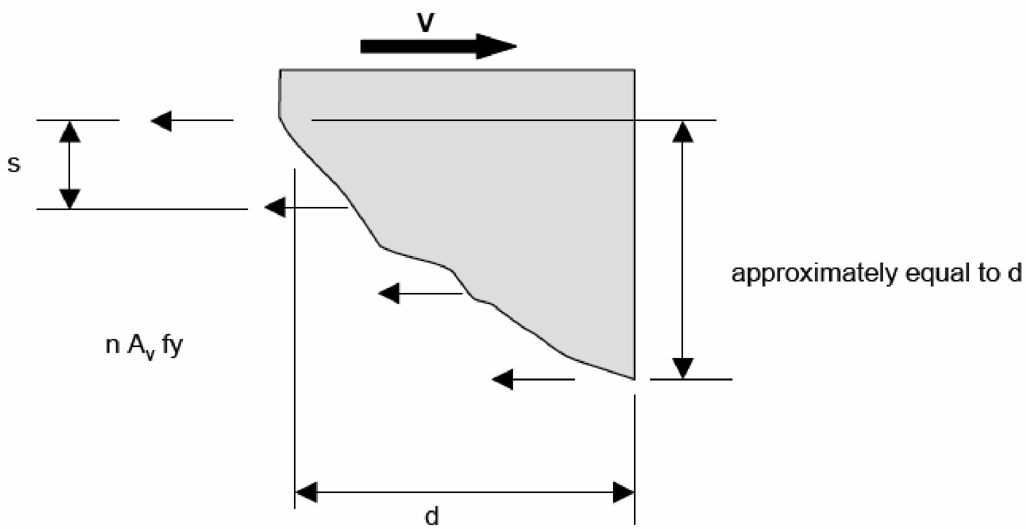
From the 2005 MSJC Code, Section 3.3.4.1.2.1,

$$V_m = \left[4.0 - 1.75\left(\frac{M_u}{V_u d_v}\right)\right] A_n \sqrt{f'_m} + 0.25P_u$$

As *($M_u/V_u d_v$)* increases, V_m decreases. Because *($M_u/V_u d_v$)* need not be taken greater than 1.0 (2005 MSJC Code, Section 3.3.4.1.2.1), the most conservative (lowest) value of V_m is obtained with *($M_u/V_u d_v$)* equal to 1.0.



Just as in reinforced concrete design, this model assumes that shear is resisted by reinforcement crossing a hypothetical failure surface oriented at 45 degrees:



The nominal resistance from reinforcement is taken as the area associated with each set of shear reinforcement, multiplied by the number of sets of shear reinforcement crossing the hypothetical failure surface. Because the hypothetical failure surface is assumed to be inclined at 45 degrees, its projection along the length of the member is approximately equal to *d*, and number of sets of shear reinforcement crossing the potential failure crack can be approximated as (d/s).

$$V_s = A_v f_y n$$

$$V_s = A_v f_y \left(\frac{d}{s} \right)$$

The actual failure surface may be inclined at a larger angle with respect to the axis of the wall, however. Also, all reinforcement crossing the failure surface may not yield. For both these reasons, the assumed resistance is decreased by an efficiency factor of 0.5. From the 2005 MSJC Code, Section 3.3.4.1.2.3,

$$V_s = 0.5 \left(\frac{A_v}{s} \right) f_y d_v$$

Finally, because shear resistance really comes from a truss mechanism in which horizontal reinforcement is in tension, and diagonal struts in the masonry are in compression, crushing of the diagonal compressive struts is controlled by limiting the total shear resistance V_n, regardless of the amount of shear reinforcement:

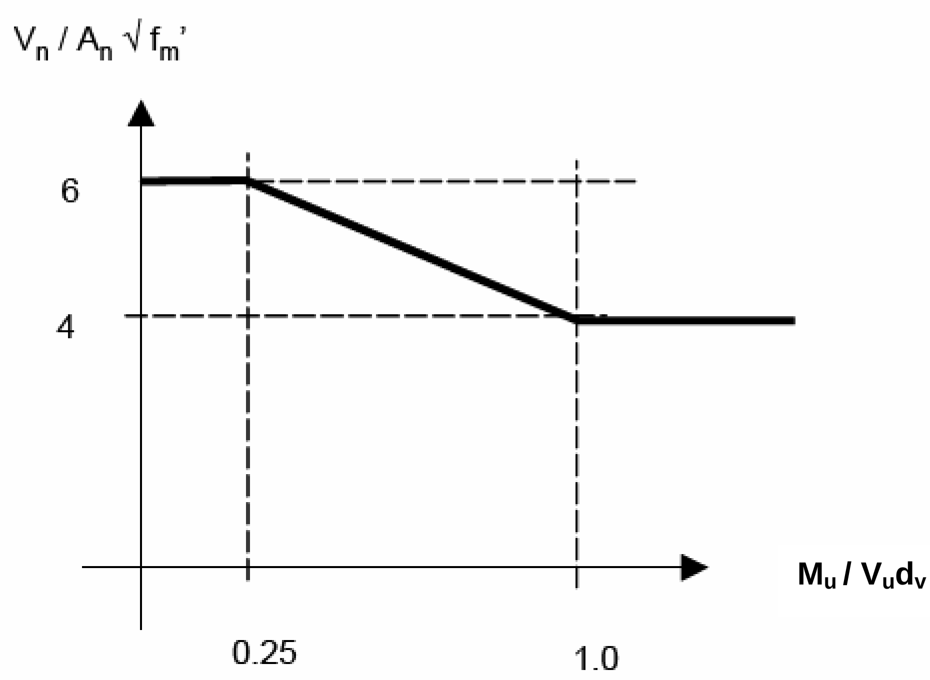
For $(M_u/V_u d_v) \leq 0.25$

$$V_n = 6A_n\sqrt{f_m'} \quad ;$$

and for $(M_u/V_u d_v) > 1.00$,

$$V_n = 4A_n\sqrt{f_m'} \quad .$$

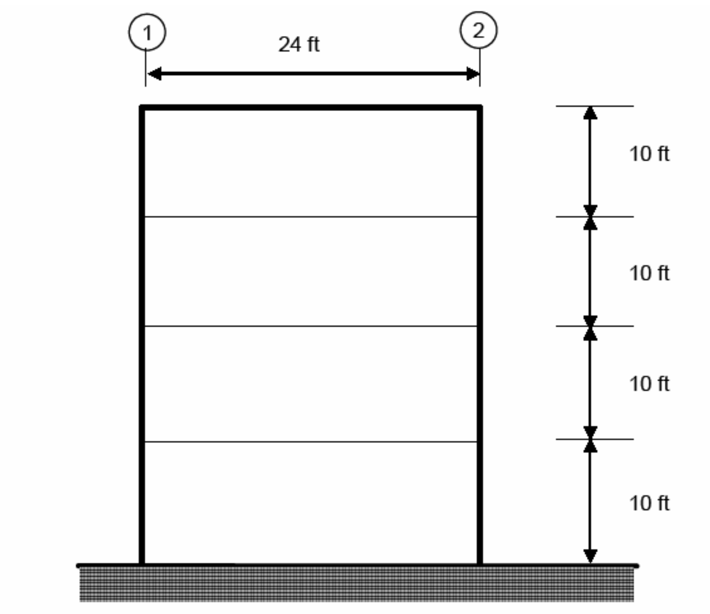
Interpolation is permitted between these limits.



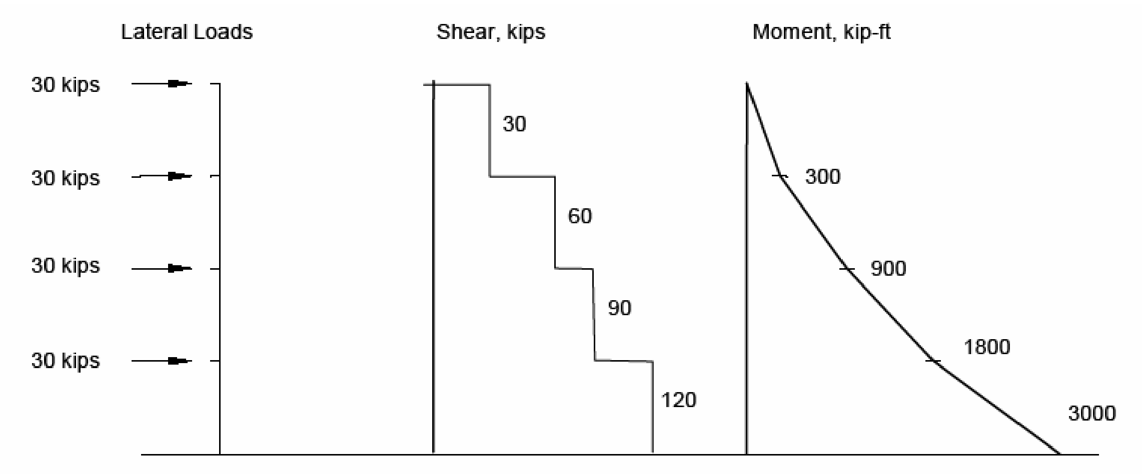
If these upper limits on V_n are not satisfied, the cross-sectional area of the section must be increased.

Example: Strength Design of Reinforced Clay Masonry Shear Wall

Consider the masonry shear wall shown below:



Design the wall. Unfactored in-plane lateral loads at each floor level are due to earthquake, and are shown below, along with the corresponding shear and moment diagrams.



Assume an 8-in. nominal clay masonry wall, grouted solid, with Type S PCL mortar. The total plan length of the wall is 24 ft (288 in.), and its thickness is 7.5 in. Assume an effective depth d of 285 in.

	Clay Masonry
Unit Strength	*6,600*
Mortar	*Type S*
f'_m *or* f_g (psi)	*2,500*

Reinforcement = Grade 60; $E_s = 29 \times 10^6$ psi

Unfactored axial loads on the wall are given in the table below.

Level	**DL**	**LL**
(Top of Wall)	(kips)	(kips)
4	90	15
3	180	35
2	270	55
1	360	75

Use ASCE 7-02 Basic Strength Load Combination 7: 0.9*D* + 1.0*E*

Check shear for assumed wall thickness. By Section 3.3.4.1.2 of the 2005 MSJC Code,

$$V_n = V_m + V_s$$

M_u = 1.0(3,000 x 12 x 1,000 in.-lb) = 36.0 x 10^6 in.-lb

V_u = 1.0(120,000 lb) and d_v = *285 in.*

$$M_u / V_u d_v = \frac{36x10^6 \, in. - lb}{120{,}000 lb (285 in.)} = 1.05$$

The 2005 MSJC Code requires that this check be carried using factored loads.

$$V_m = \left[4.0 - 1.75\left(\frac{M_u}{V_u d_v}\right)\right] A_n \sqrt{f'_m} + 0.25P_u$$

$$V_m = [4.0 - 1.75(1.0)]7.5in.x285in.\sqrt{2500\,psi} + (0.9)(0.25)(360{,}000lb)$$

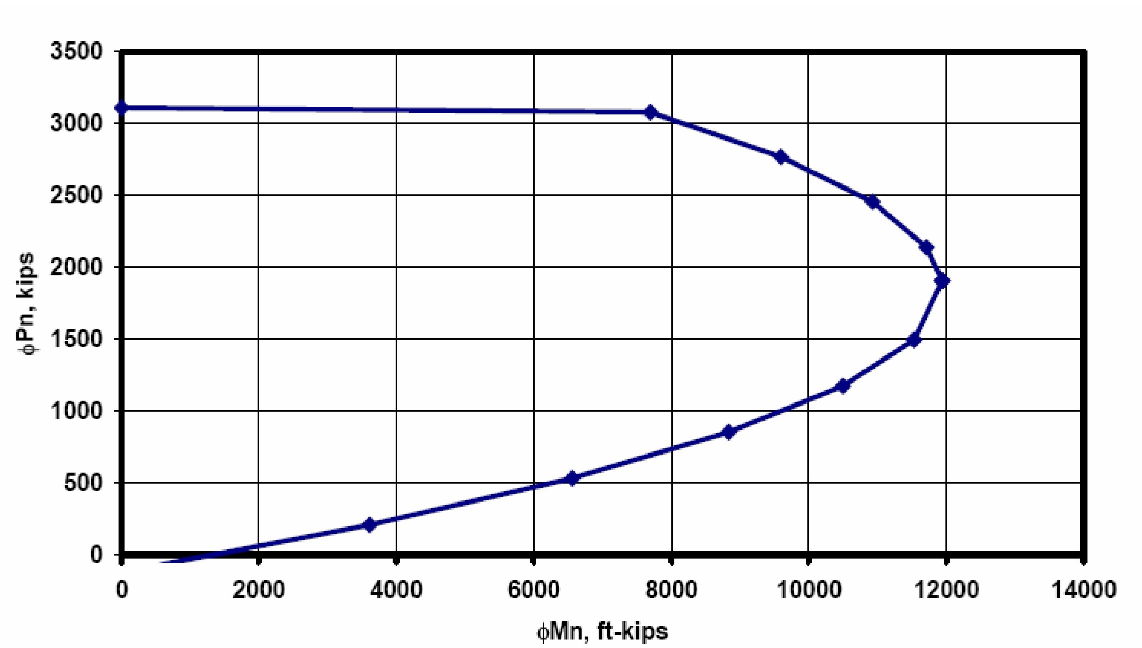
$$V_m = 240.5 + 81.0kips = 321.5kips$$

$\phi V_n > V_u$ where $\phi = 0.8$

$$V_n = V_m = 321.5kips$$

$$0.80(321.5kips) = 257.2kips \geq V_u = 120kips$$

Shear design is satisfactory so far, even without shear reinforcement. Code Section 3.1.3 will be checked later. Now check flexural capacity using a spreadsheet-generated moment-axial force interaction diagram. Try #5 bars @ 4 ft.



At a factored axial load of 0.9D, or 0.9 x 360 kips = 324 kips, the design flexural capacity of this wall is about 4000 ft-kips, and the design is satisfactory for flexure.