Design of Shelf Angles for Masonry Veneers

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Objectives
Present a Brief Overview of:
• Masonry Veneer Wall systems and their vertical supports.
• How these systems behave under vertical loads.
• How the vertical support systems can be designed.
• Present a few examples.

Introduction
In general, masonry veneer (stud backed) must be supported at very floor over 30 ft in height (except at gables). Also typically done for CMU backed veneers (differential movements).

This usually requires that shelf angles be placed at each floor above 30 ft and designed to support the weight of veneer above.

Masonry Veneer

Movement joint below shelf angle must accommodate:
Thermal and moisture expansion of brick and elastic and creep shorting of support elements.

What’s wrong with this detail?
The angle is awful thin and where’s the Continuous Insulation (CI)?
More “realistic detail” – Note the angle thickness and expansion joint height.

Design - typically ties spaced to resist out-of-plane loads

Veneer weight – vertical load

Shelf angle must be designed to resist vertical veneer weight load

Shelf angle span between anchors

Common shelf angle design is to assume a uniform dead load from the veneer and design the angle to span as a beam between anchors OR

Shelf Angle Frame Design Model

Assuming the angle legs act as a bolted frame with a vertical dead load applied to the end of the horizontal leg

Question how much of the angle length is effective?

Can use finite element models of veneer, angles, spandrel supports.

Harbor Courts Complex Baltimore

Office/Condominium

8-Story Hotel

Parking D

Lots of shelf angles

8-Story Hotel with Plaza Deck

28-Story Office/Condominium Tower

7-Story Parking Deck
Investigation of Problems

Localized Cracking and Distress of Brick

Mortar Blockage in Horizontal Expansion Joints Below Shelf Angle

Inadequate Bearing of Brick on Shelf Angle

Horizontal Expansion Joints

Problems

Popped out – no ties
Cracked away

To solve these problems (mostly shelf angle related) you get to use FE to save money and lawyers are paying.
These analysis showed that the stiff brick (vertically) spans between the less flexible sections of the angle with little stress in the brick (Dead load).

Based on finite element analyses and field testing, a number of observations about the shelf angle veneer interaction can be made:

1. The veneer is very stiff relative to its supports.
2. Shelf angles are poor in torsion and do not really act as beams between anchors.
3. The angle rotates away from veneer and provides little support to the veneer away from anchor.
4. The brick can span a significant distance.

Suggested Design Method Based on Observed Behavior:
1. Assume that the veneer will act as a beam spanning in-plane horizontally between anchors.
2. Design brick to ensure that the brick flexural stresses are low enough to be resisted by the veneer.
3. Determine the vertical veneer reactions at assumed support spacing.
4. Design shelf angle to transfer support reaction to slab or spandrel beams.

Veneer Span Design:

Limit Net flexural Tensile Stress
TMS 402 ASD Procedures for URM – Table 8.2.4.2 - F_t limits
But does not really have limits that apply to this type of loading
You could may an argument that Stress are parallel to the Bed joints. For this loading and solid units the F_t varies from 40 to 106 psi.
For Normal to Bed joints (OOP) – F_t varies from 20 to 53 psi

Veneer Span Design:

<table>
<thead>
<tr>
<th>Veneer Thickness (in)</th>
<th>F_t (psi)</th>
<th>Veneer Height (ft)</th>
<th>Span (ft)</th>
<th>Weight (psf)</th>
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<td>18.65</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 1 Maximum Veneer Spans for Select Heights and F_t
Angle Design: Example 1
Support a 10 ft height of 4" clay brick veneer

Previous Table would suggest the brick could span at least 17 ft. and as little as 1 ft height of veneer could span at least 5.4 ft.
Shear OK
The brick capacity will not often govern anchor spacing.
Try an anchor spacing of 6 ft. – The Veneer can span this distance for heights over 1.5 ft (Table 1)

Angle Design: Example 1

Veneer Span

Veneer Height

The anchor shear reaction would then be (assuming trib. width distribution):
Reaction from brick = 40 psf x 10' x 6' = 2400 lb.
Adding an additional 10 lb/ft for the angle weight would produce a total vertical reaction of
R total = 2460 lb.

Angle Design: Example 1

Floor Slab
Eccentricity of veneer weight

Brick
Air gap and insulation
Shelf Angle
Anchor Reactions
Anchor spacing

At limit the brick reaction will be applied at the toe of the angle - However it is unlikely that the reaction will ever be applied at this location as the deflection of angle will actually move the reaction back from the toe.

Thus a reasonable design condition is to assume that the Vertical Brick load is applied at the center of the veneer.
If there is a 1" air gap, 1" of insulation and a 1/2 in. angle thickness the eccentricity to the center of the angle thickness can be determined (see next slide):

Eccentricity of veneer weight
= 1 + 1 + ¼ + 3.625/2 = 4.06 in
The moment at the base of the angle toe =
= 4.06 x 2400 = 9750 lb.in
Note there is also a moment due to the angle self weight but this is very small and can be ignored.

How much of the angle is resisting this moment?
At the limit, ½ the length of the angle on each side of anchor will resist the moment, however analysis shows the angle rotation will reduce the amount of angle effective in resisting the moment for longer anchor spacing.
How much angle resist the load depends on thickness of the angle, veneer stiffness and anchor spacing.
Angle Design: Example 1

10 ft height of 4" clay brick veneer

The moment at the base of the angle toe = 9750 lb.in

In the past, the effective length of masonry wall resisting a concentrated load was 4x masonry wall thickness.

The range of analyses showed that this could be used as a conservative rule of thumb for the effective length of the angle.

Use 4 x veneer thickness ≤ anchor spacing

Effective length of angle = 4 x 4 = 16 inches

Note that this can be quite conservative and is less than the 72 inch anchor spacing.

Using AISC LRFD provisions and a φMy limit assuming Fy = 36 ksi. Limit deformation.

\[ S_x \text{ required} \geq \frac{9750 (1.2)}{0.9 (36,000 \text{ psi})} = 0.361 \text{ in}^3 \]

A 3/8" angle with 16 in. width - \( S = 0.375 \text{ in}^3 \) (\( S = bd^2/6 \))

You could also make an argument to use \( \phi M_y = \phi Z_x F_y \)

And \( Z_x = bd^2/6 \)

Angle Design: Example 2 – 5 inch Cavity

10 ft height of 4" clay brick veneer

But now assume that there is 4" of backing wall (cavity) insulation.

The distance between the interface of the veneer and support wall is 1 + 4 = 5 in.

The anchor shear reaction would then be (assuming trib. width distribution):

Reaction from brick = 40 psf x 10' x 4' = 1600 lb.

Adding an additional 15 lb/ft for the angle weight results in would produce a total vertical reaction of R total = 1640 lb.
Angle Design: Example 2 – 5 inch Cavity

Assume that the vertical brick load is applied at the center of the veneer. Assume a ½ in. angle thickness.

Eccentricity of veneer weight = 5+ ¼+ 3.625/2 = 7.06 in

The moment at the base of the angle toe = 7.06 x 1600 =11,296 lb.in

Note there is also a moment due to the angle self weight but this is very small and can be ignored.

Angle Design: Example 2

Both the vertical leg and the horizontal leg must resist the moment. In addition the vertical leg must resist the tension of 1640 lb.

This produces an axial tension stress of = 1640/16 = 102 psi. This stress is less then 1% of yield and by inspection the combined loading is OK.

Use a 7/16 x 8 x 6 angle – Size anchors to resist combined shear and tension loading – note 7/16 x 8 x 8 may not be available everywhere.

Effective length of angle

Use 4 x veneer thickness ≤ anchor spacing

16 inches is less than 48 so use effective length of angle = 16 inches again.

Summary

•Presented a brief overview of Masonry Veneer Wall systems and their vertical supports
•Discussed how these systems behave
•Presented a method how they can be designed
•Presented few examples for design

Thank you!
Questions?