MASONRY INSIGHTS

Masonry - how to account for partial grouting

Masonry design requires custom material types to be used to account for attributes unique to masonry such as grouting only reinforced cells (partial grouting). Partial grouting will affect the self weight of the material as well as the stiffness of the finite elements. Some finite element analysis programs account for partial grouting but for the rest, modifications must be made to the finite element properties such as altering the thickness of the element. Following is an example of how to adjust the properties within the model to accommodate the partial grouting within a masonry wall.

Given: 8” normal weight CMU wall with #5 rebar at 32” oc supporting a single bay of steel roof bar joists spanning 20’-0” (assume 4” joist bearing thus e = 7.625/2 - 4/2 = 1.81”
wall weight = 51psf per NCMA TEK 14-13B
A_{net} = 46.0 in2/ft S_{net} = 90.1 in3/ft
I_{net} = 343.7 in4/ft r_{avg} = 2.59 in [NCMA TEK 14-1B]
f'_m = 2500psi
Roof height = 20’-0” with a 3’-0” parapet
Wind Load: W_u = 30psf; W_s = 0.6(30) = 18psf

1. Determine equivalent thickness of a partially grouted masonry wall
   $t_{eq} = A_{net}/b = (46.0in^2/ft)/(12in/ft) = 3.83$ in

2. Calculate distance extreme compression fiber to neutral axis, c
   Roof Dead Load: P_f,DL = 15psf (20’/2) = 150plf P_{uf},DL = 1.2 (150plf) = 180plf
   Roof Snow Load: P_f,LL = 35psf (20’/2) = 350plf P_{uf},LL = 1.6 (350plf) = 560plf
   Wall Dead Load: P_w = 51psf (20’/2 + 3’) = 663plf P_{uw} = 1.2 (663) = 796plf

   P_f = 150 + 350 = 500plf P_{uf} = 180 + 560 = 740plf
   $P = P_w + P_f$ = 1163plf $P_u = P_{uw} + P_{uf}$ = 1536plf
   $A_s = 0.31in^2 (12/32) = 0.116in^2/ft$ f_y = 60,000psi
   $c = (A_s f_y + P_u)/(0.64f'_m b) = [(0.116)(60,000) + 1536] / [0.64(2500)(12)] = 0.443”$
   [TMS402-13 Equation 9-35]

3. Calculate moment of inertia for partially grouted masonry wall, I_{eq}
   $Em = 900f'_m = 900 (2500) = 2,250,000$psi
   n = Es/Em = 29,000,000/2,250,000 = 12.9
   d = min(t/2, teq) = 3.81”

   $$Ieq = n(As + Pu/fy)(d-c)^2 + bteq^3/3 =$$
   $I_{eq} = 12.9[0.116 + 1536/60,000)(3.81-0.443)^2+(12)(3.83)^3/3 = 245.4\ in^4/ft$
   [TMS402-13 Equation 9-34]

4. Calculate axial capacity and shear capacity
   With an equivalent thickness of wall, the net area remains the same as the actual wall, however, the value r_{eq} will be different than r_{avg} listed in NCMA TEK 14-1B
   $r_{eq} = (I_{eq}/A_{net})^{0.5} = (245.4/46.0)^{0.5} = 2.31$

h/r_{eq} = 240/2.31 = 103.9
$Pn = 0.8[0.8f'_m(A_n-A_{st}) + f_yA_{st}](70r/h)^2$ =
Pn = 0.8[91,768 + 6,960](0.673)^2 = 35,848#
[TMS402-13 Equation 9-20]

h/r_{avg} = 240/2.59 = 93
$Pn = 0.8[0.8f'_m(A_n-A_{st}) + f_yA_{st}][1-(h/140r)^2]$ =
Pn = 0.8[91768 + 6960](0.56) = 44,230#
[TMS402-13 Equation 9-19]

As demonstrated here, the in-plane axial capacity of the equivalent thickness section is reduced from the value of the full section but is unlikely to have a large impact on the overall wall design.

For the case of In-plane shear strength the capacity of the equivalent thickness section will remain unchanged as the value A_{nv} remains the same thus the model can accurately calculate shear capacity per TMS402-13 Section 9.3.4.1.2.

4. Compare the out-of-plane flexural capacity and deflection

The FEA model will be unable to accurately calculate the flexural capacity of the equivalent thickness wall section because several variable cannot be entered correctly. The first problem is that the eccentricity of the floor/roof load may not be able to be calculated correctly based on the if it is based on the thickness of the wall which would result in an unconservative value for Pdelta effects. Secondly, the depth of reinforcement may be beyond the equivalent wall thickness thus the software will not allow the correct depth to be entered. Finally, the deflection calculations are based partially upon the gross moment of inertia which will be significantly higher than what will be calculated for the equivalent wall thickness. Therefore, it is recommended to calculate the bending capacity and deflection either by hand or with separate software with results then combined by hand.

Pros:

- Allows for the correct masonry wall weight for gravity and seismic loading
- Provides accurate masonry shear wall capacity
- Provides a conservative estimate of the masonry axial capacity which is unlikely to control the design

Cons:

- The flexural capacity of the equivalent thickness section is unreliable and must be calculated separately
- Similarly, the total deflections due to out of plane loads and Pdelta effects will not be reliable and must be calculated separately.
- Separate models and/or hand calculations will be required to complete the design