MASONRY INSIGHTS

Masonry -

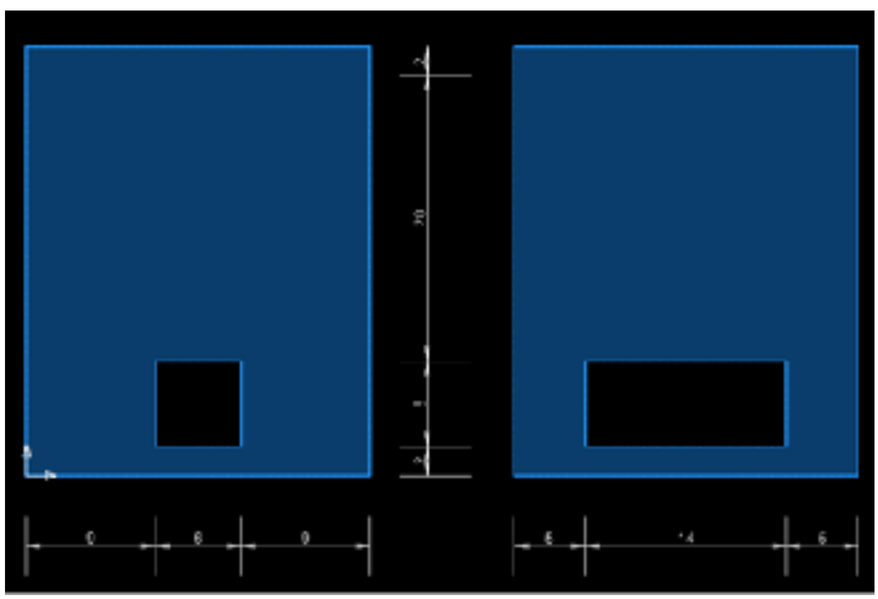
How is an FEA reporting lintel forces?

Finite element analysis is a great tool that sheds new light on the behavior of various building materials especially masonry. When looking at the design of lintels over an opening for instance, the software can visually show the effects of arching action as well as fixity at the ends of the lintel versus the simply supported beam simplification often used for hand calculations. These new insights can lead to more efficient use of masonry as a building material thus increasing the economy of construction as well. However, when using the FEA software, care must be taken to understand the calculations and simplifications that occur behind the scenes within the “black box.” When creating a structural model, read through the software documentation provided to learn what assumptions were used by the software designers. When reviewing the output, it is a good idea to perform a few hand calculations to confirm the software results are in the ballpark of what is expected. With better understanding comes better design and more savings for the building owner.

Post-processing example 2: Masonry wall panel lintel forces

Given:

Two CMU wall panels with geometry as shown in the following diagram. Loading from the roof is near the top of the wall with a parapet above. The openings within each wall panel are different sizes for comparison of load path and internal forces. Each panel is reviewed only for gravity loading.



1. Graphically compare the axial forces within the two panels.

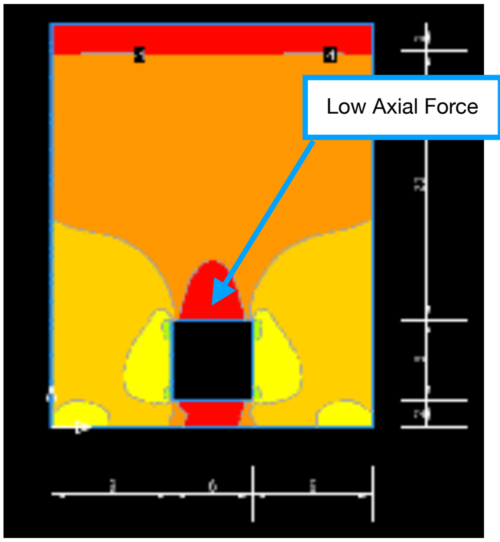


Figure 2a

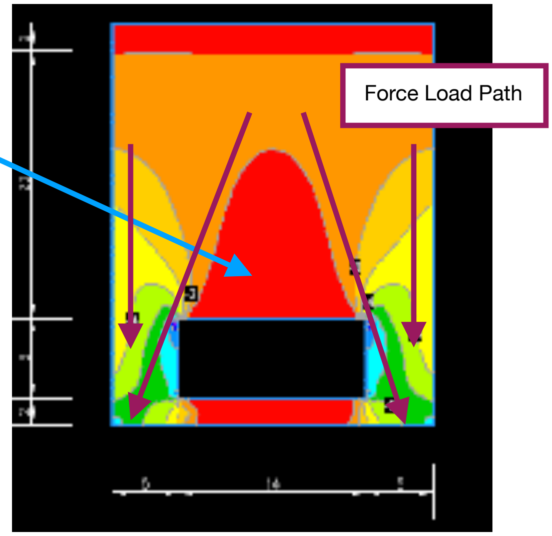


Figure 2b

a. Refer to figures 2a and 2b. Starting at the top of the wall above the roof line, there is an area of red in both panels. This area does not have any external load thus the red indicates an area of low axial force from only the self weight of the masonry. Below both openings is another area of red as would be expected since the opening does not pass any load through it. Note that just above each opening is yet another area of red. The shape is slightly curved at the top and looks roughly like an arch. These results demonstrate arching action showing that the axial loads from the wall and roof above transfer to each side of the opening thus the lintel will only need to support the small area just above the opening that is mostly self weight of masonry.

b. The loads above the opening distribute to each side of the opening. The left wall has sufficient space for the load to spread out with only a small increase in axial loading. The right wall has significantly less space thus the load concentration is much higher as demonstrated by the green areas.

c. The images in figures 3a and 3b below show cut lines at various locations to see how the magnitudes vary at multiple locations within each wall panel.

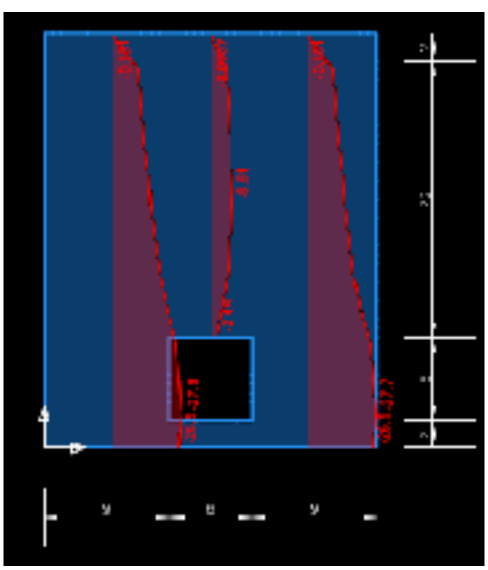


Figure 3a

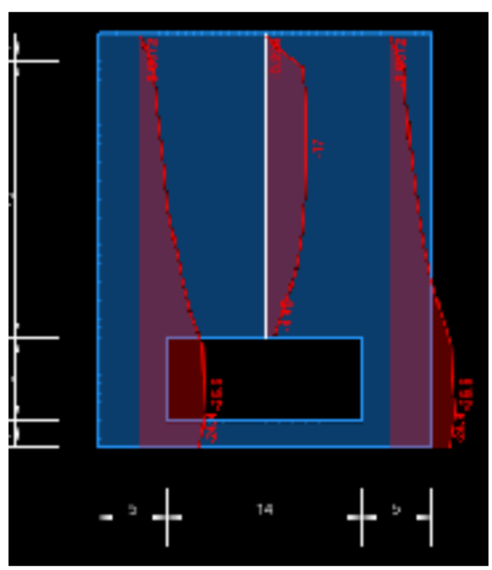


Figure 3b

2. Thrust Forces:

There is one more component to be aware of with arching action. In a typical arch, the compressive forces within the arch develop a horizontal component which are called thrust forces. These thrust forces need to be considered in the strength of the wall. Figures 4a and 4b below demonstrate the horizontal compression thrust loads for for the two different sized openings. In figure 4b, the larger opening has significantly larger thrust loads since the “arch” is wider thus supporting more load from above. Additionally, the larger opening has a smaller width available to resist the load since the overall masonry panel width remains the same. Therefore, the masonry each side of the opening must be reviewed for adequate strength to resist these high thrust loads. If the distance between opening and joint or end of panel is too small, failure is a possibility. To see the magnitude of the thrust forces, vertical cut lines in the masonry wall can be used in a similar fashion to figures 3a and 3b.

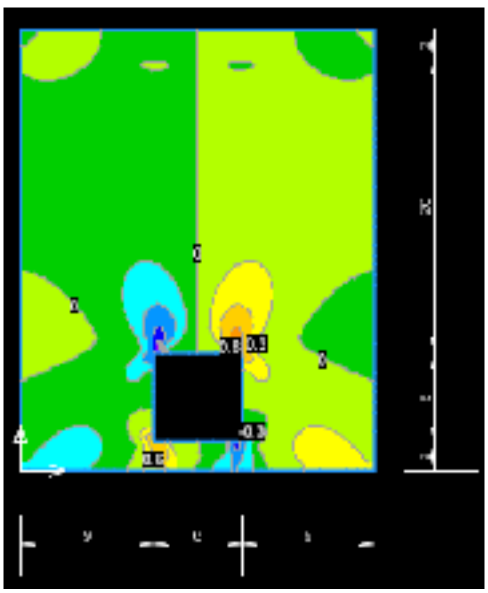


Figure 4a
Thrust

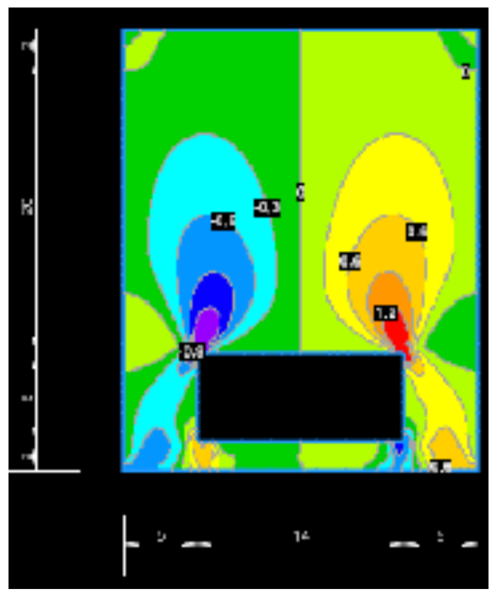


Figure 4b
Thrust

3. Lintel Design:

In part 1 above, it was mentioned that the lintel will only need to support the self weight of masonry above the opening. This is partly true based on traditional masonry design but it doesn’t quite explain the whole story as the depth of the lintel matters when extracting the loading information from the FEA program results. Refer to figures 5a and 5b. Both figures show the vertical shear force within the lintel, however, the only difference is that the lintel in 5b is modeled as a deeper section and has a higher shear load than in 5a. The reason for this difference is that the core mechanic behind finite element analysis. In FEA for this example, the wall is split into many small roughly square elements to analyze the internal forces within the wall.

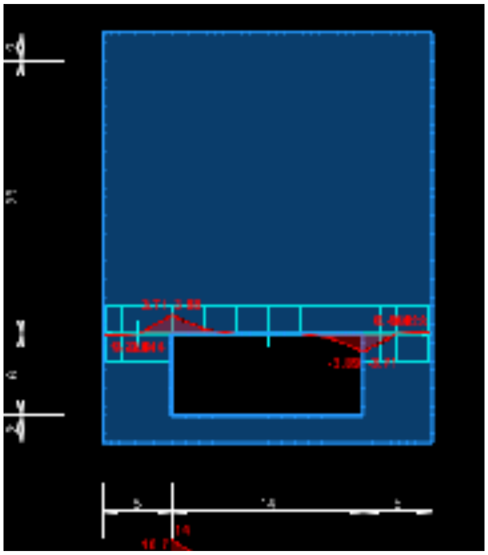


Figure 5a
Lintel Shear

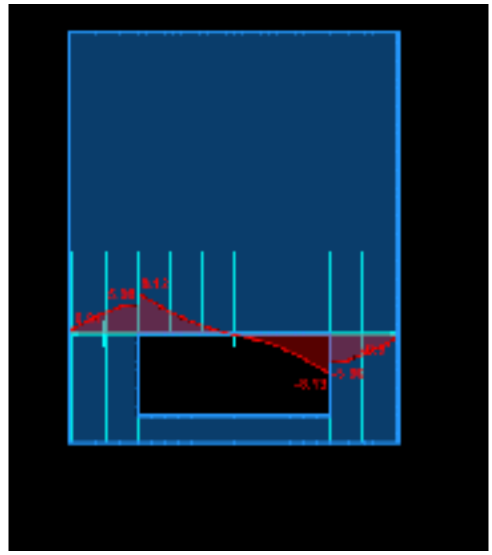


Figure 5b
Lintel Shear

When the depth of lintel is modeled, the analysis program will accumulate the internal forces for every element that is contained within the lintel depth. Therefore, a deeper lintel will have higher forces for both shear and moment. The load from the middle of the lintel will be small since each element has small forces, however, the portions of the lintels at the ends will extend above the arch line visible in figure 2.

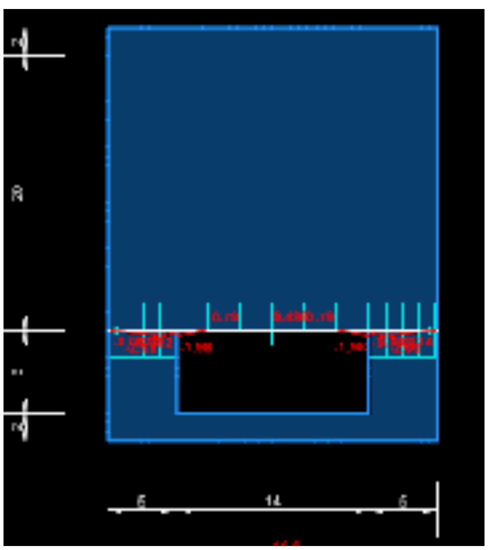


Figure 6a
Lintel Moment

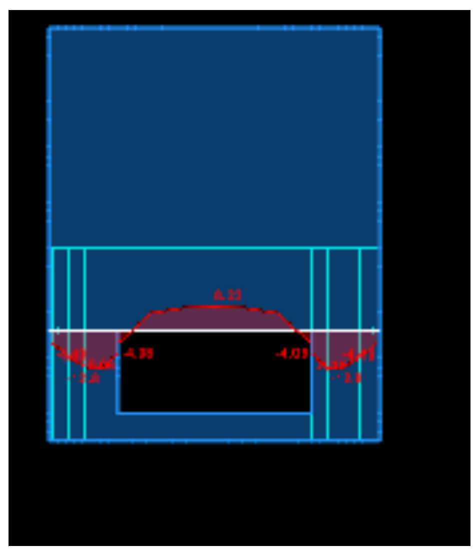


Figure 6b
Lintel Moment

The main takeaway to remember is that the depth and strength capacity of lintel design in FEA is an iterative process. If the original lintel depth does not have adequate capacity, simply increasing the depth of the lintel to compare with the original loads is not the correct path. Once the lintel depth has been increased, the FEA model needs to be run again to see the updated design forces to compare with the capacity of the new lintel size.