

Commentary on Multi-Story Tilt-Up Panel Design Using ACI 551.2R-15

The ACI 551 design guide states that tilt-up concrete walls can be analyzed using the provisions of Chapter 14 of the ACI 318-11. Most walls, and especially slender walls, are widely evaluated using provisions from the “Alternative design of slender walls” in Section 14.8. The same provisions are presented in ACI 318-14 but reorganized in different chapters with slightly revised terminology. The provisions (or method) is applicable when the following conditions are met:

- The cross section shall be constant over the height of the wall *ACI 318-11 (14.8.2.2)*
- The wall can be designed as simply supported *ACI 318-11 (14.8.2.1)*
- The maximum moments and deflections occurring at midspan *ACI 318-11 (14.8.2.1)*
- The wall must be axially loaded *ACI 318-11 (14.8.2.1)*
- The wall must be subjected to an out-of-plane uniform lateral load *ACI 318-11 (14.8.2.1)*
- The wall shall be tension-controlled *ACI 318-11 (14.8.2.3)*
- The reinforcement shall provide design strength greater than cracking strength *ACI 318-11 (14.8.2.4)*

For multi-story panels, ACI 551 utilized the alternative design method even though some of the conditions above are not met. An investigation of Example B.5 solution in ACI 551 was compared with a detailed FEA model using the engineering software program [spWall](#). The results of the comparison identified two important issues summarized in this article along with [StructurePoint’s](#) observations and recommendations.

1. Issue: **Proper calculation of moment magnification**

Using the same moment magnification factor (magnifier) for the maximum negative moment section based on the properties of the maximum positive moment section within the same span is not valid. In some cases, this will underestimate the second order design moment at the negative section.

Recommendation: Calculate the moment magnification factor separately for positive and negative moments and repeat for each wall segment or conservatively use the highest magnification factor. This procedure should be repeated for all load combinations under consideration.

Illustration: In Example B.5, this issue is illustrated in Figures 1 and 2 for Load Combination 1 (1.2D + 1.6Lr + 0.5W) where:

ACI 551 (presented) $M_{u,negative} = -9.07$ kip-ft (Using positive moment magnification factor from span 3).

ACI 551 (corrected) $M_{u,negative} = -12.83$ kip-ft (Using the correct negative moment magnification factor from span 1 where the max negative moment occurs).

2. Issue: **Proper location of maximum design moments**

For multi-story tilt-up panels such as example B.5, the location of maximum positive and negative moment can vary between first and second order analyses. Thus, magnifying the maximum moment based on first order analysis to estimate the maximum second order moment may be incorrect for some cases. This can lead to underestimating maximum moments and deflections as shown in Figure 2.

Recommendation: Perform the ACI 551 procedure for each wall span individually and evaluate maximum positive and negative design moment values separately after considering moment magnification due to second order effects.

Example B.5: In Example B.5 this issue is illustrated for Load Combination 1 (1.2D + 1.6Lr + 0.5W) where in table 1 the maximum positive design moment moved to Span 1 after second order analysis while the maximum negative design moment remained in span 1.

Table 1 - Comparison of Design Moments						
Method	Maximum Positive (issue 2)			Maximum Negative (issue 1)		
	M_{ua} kip-ft	M_u kip-ft	Location	M_{ua} kip-ft	M_u kip-ft	Location
Current	+5.90	+6.62	Span 3	-8.10	-9.07	Span 1
Recommended	+5.00	+8.50	Span 1	-8.10	-12.83	Span 1

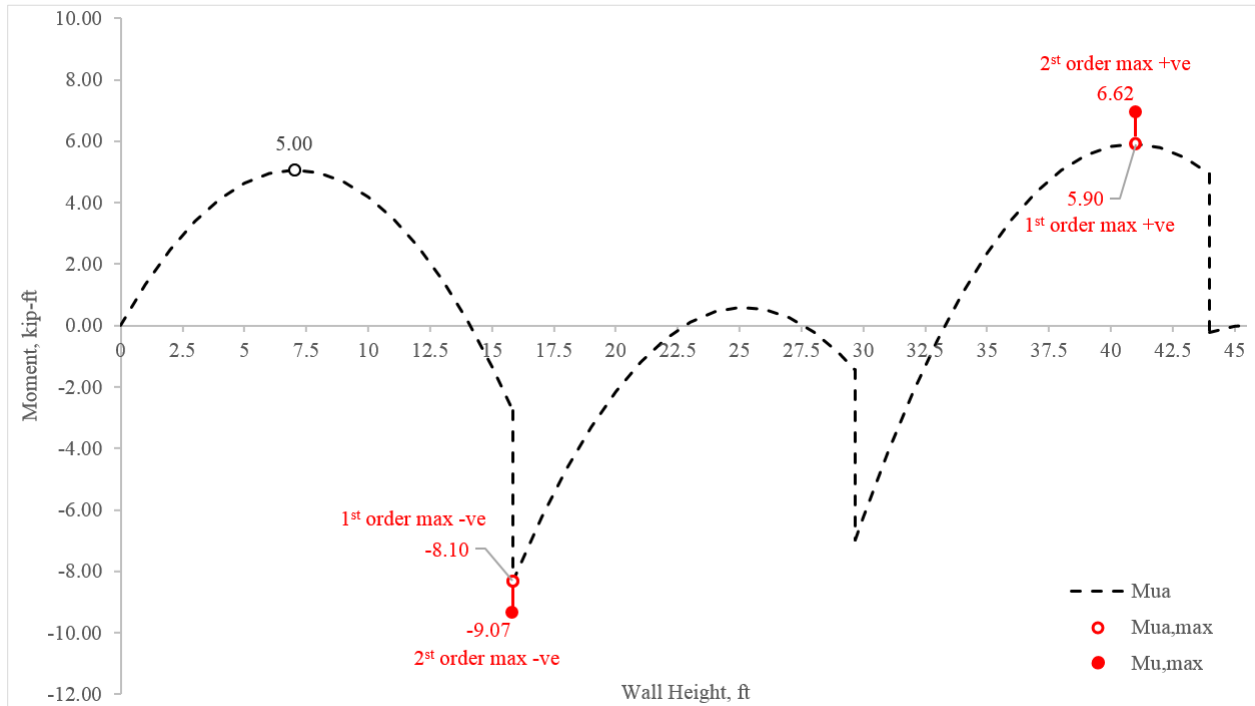


Figure 1 – First Order Moment Diagram and Second Order Maximum Moments (ACI 551 Procedure)

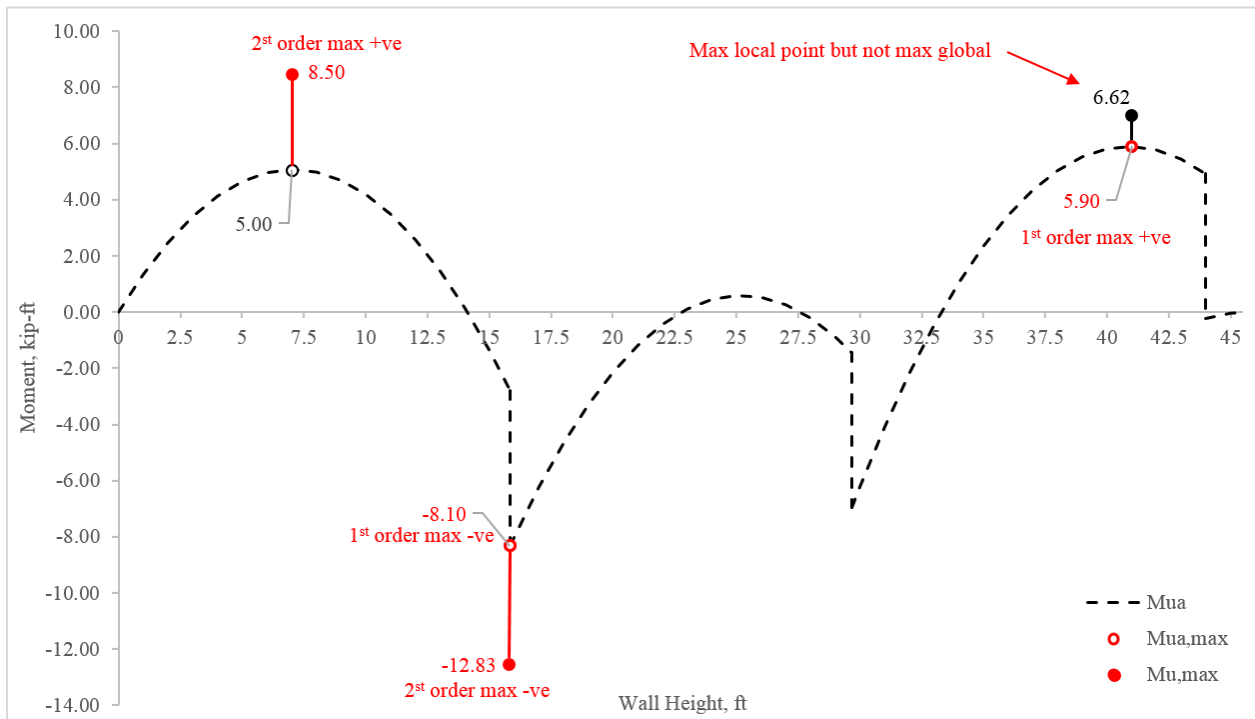


Figure 2 – Recommended Magnified Design Moments

3. Conclusions and Observation

The information presented for first order and recommended second order moments has been verified using an FEA model of the multi-story tilt-up wall panel as shown in the following figure.

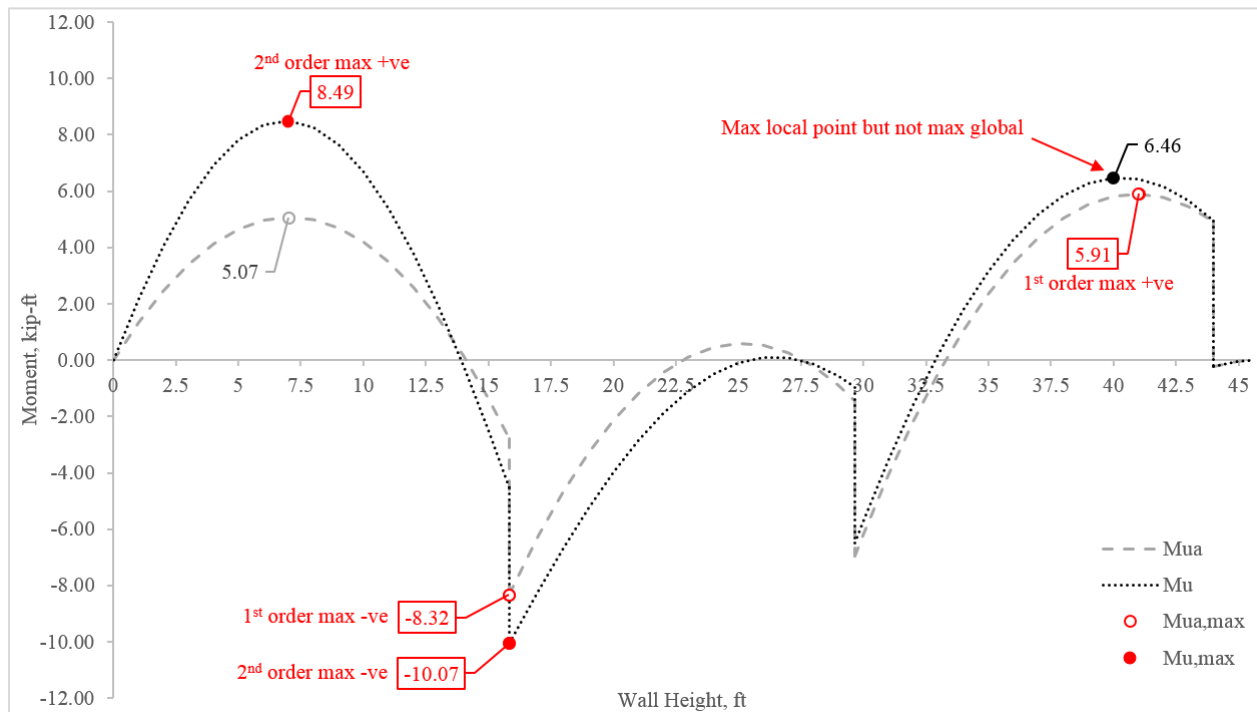


Figure 3 – First and Second Order Moment Diagrams (Using FEA)

The results indicate close agreement with the ACI 551 procedure when the recommended corrections are implemented. It is worth noting that the magnified positive and negative moments are slightly conservative in comparison with the corresponding FEA value as can be seen in the following table.

Method	Maximum Positive				Maximum Negative			
	M_{ua} kip-ft	M_u kip-ft	Magnifier	Location	M_{ua} kip-ft	M_u kip-ft	Magnifier	Location
Recommended	+5.00	+8.50	1.70	Span 1	-8.10	-12.83	1.58	Span 1
FEA	+5.07	+8.49	1.67	Span 1	-8.32	-10.07	1.21	Span 1