Modern Building Systems' 28'x64' Modular Structure: SAP 2000 Wind Load Analysis

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Outline

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Why Modular Structures?

In 2004… "Prefab housing production in North America as a whole is about 300,000 units per year and valued at $11 billion USD. Consumer acceptance of such products is rising steadily and emphasis is turning towards 'higher end' designs."

-Smith et.al., "High Performance Modular Wood Construction Systems", University of New Brunswick 2007.

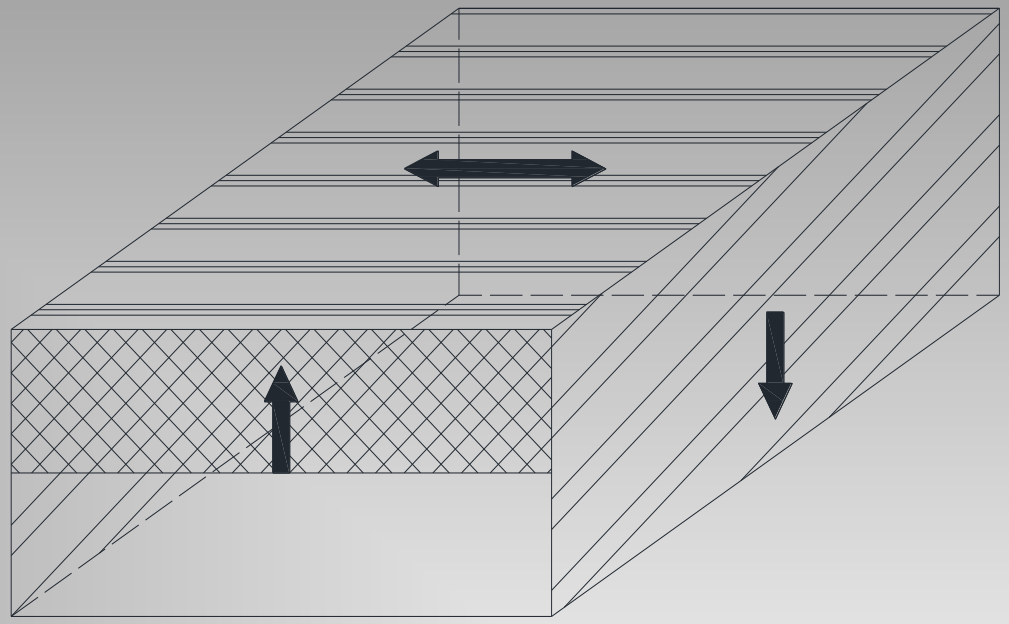
2011 Mcgraw Hill report shows that 25% of architects who utilize BIM (Building Information Modeling) software also incorporated modular components in their plans.

Overall lack of attention to modeling modular structures.

Load Path and Load Sharing

A load path is the path that forces are transferred between the elements of an assembly to safely travel into the foundation.

Different for
- Gravity Loads
- Lateral Loads

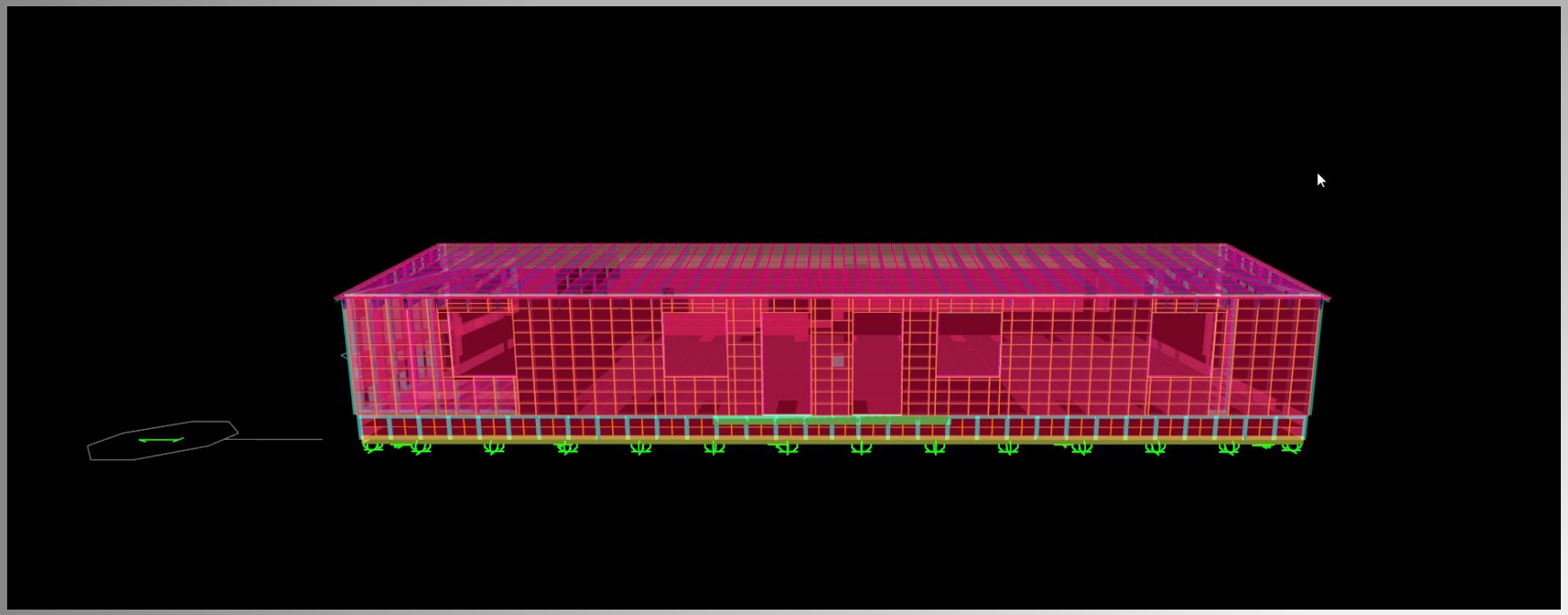


Load Sharing is the ability of individual components to work together to distribute loads that are applied.

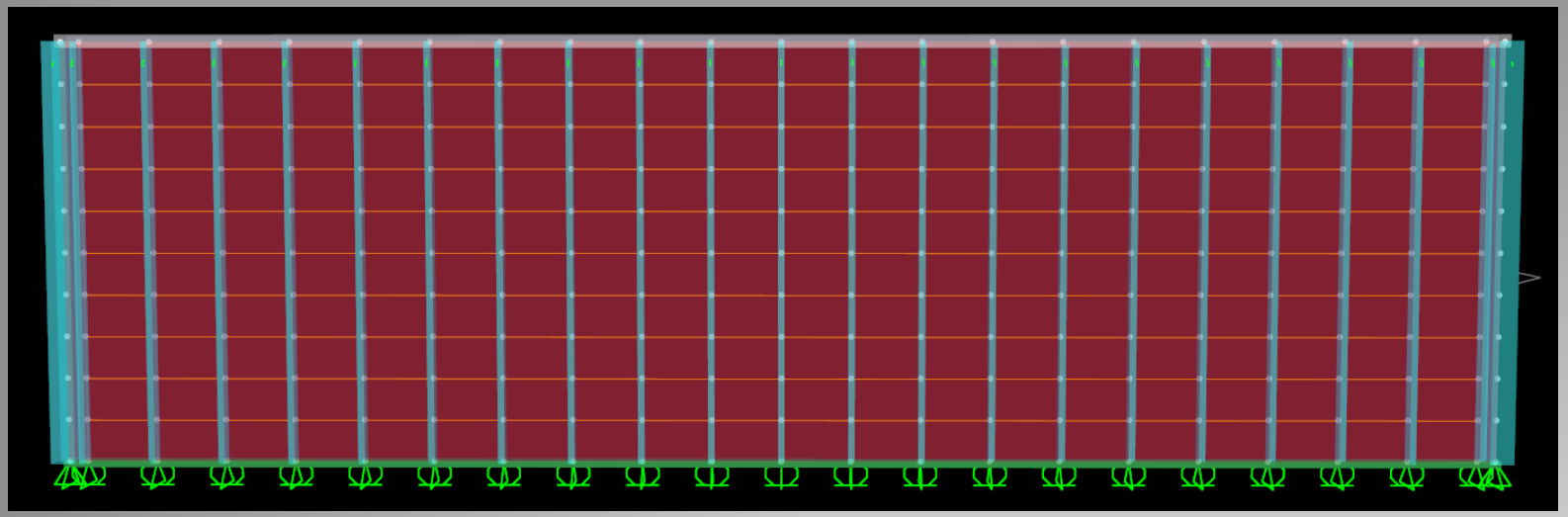
Dependent on the stiffness of the member relative to the stiffness of surrounding elements.

"stiffness attracts load"
– Dr. Thomas Miller

Structural Model



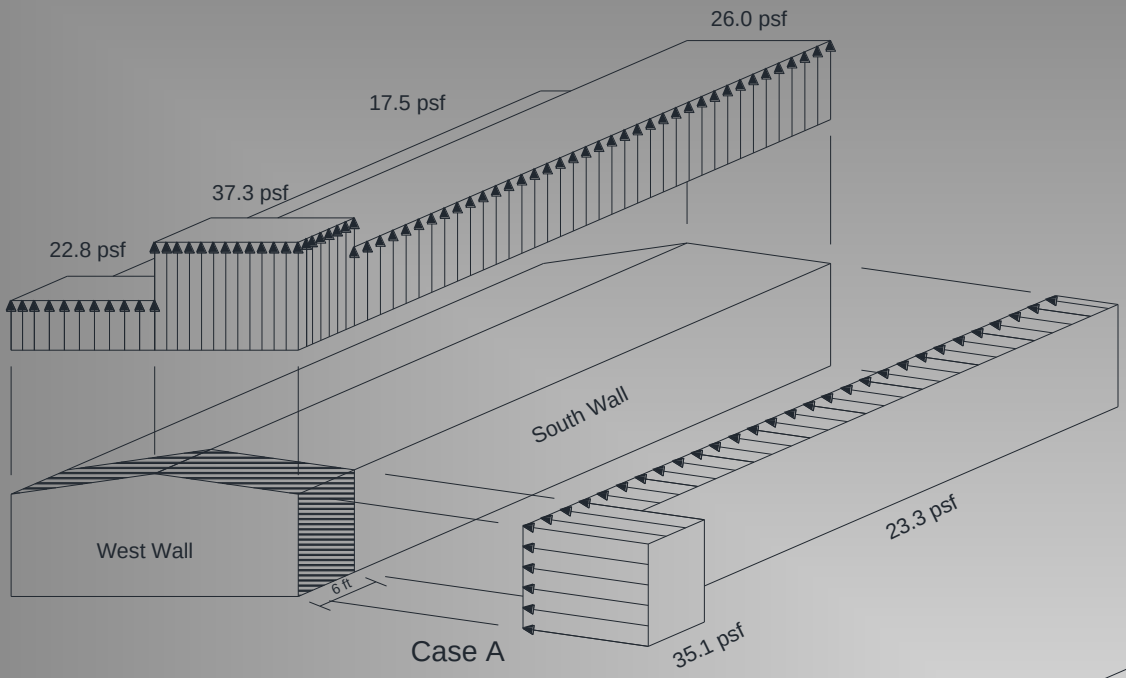
Shear Wall Calibration

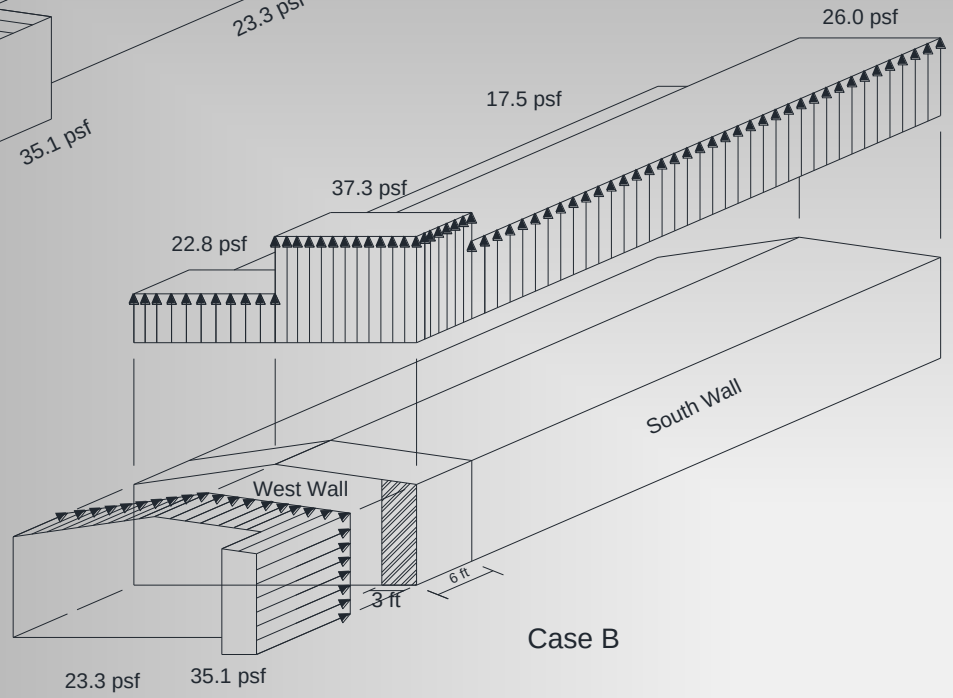


- Same shear wall dimensions as analog but with no openings.
- Spacing of studs changed to remain consistent with no double studs and to create symmetry.
- Calibration performed for both end wall and side walls
- Different layers of sheathing analyzed separately
- Pinned at the ends and out-of-plane deformations restrained
- Moments released at both ends for all frame elements

Simplified Model of End Wall for Calibration

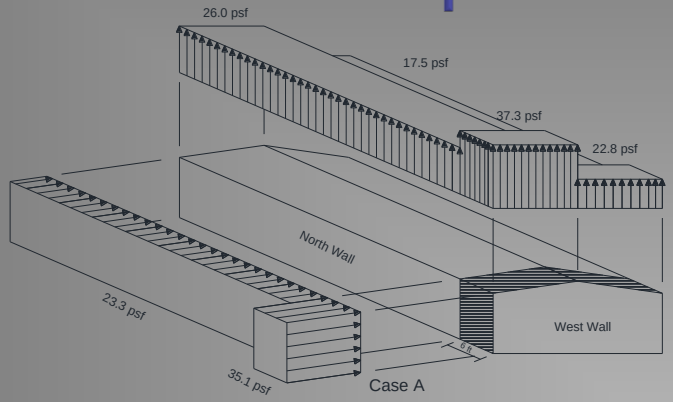
Wind Loads





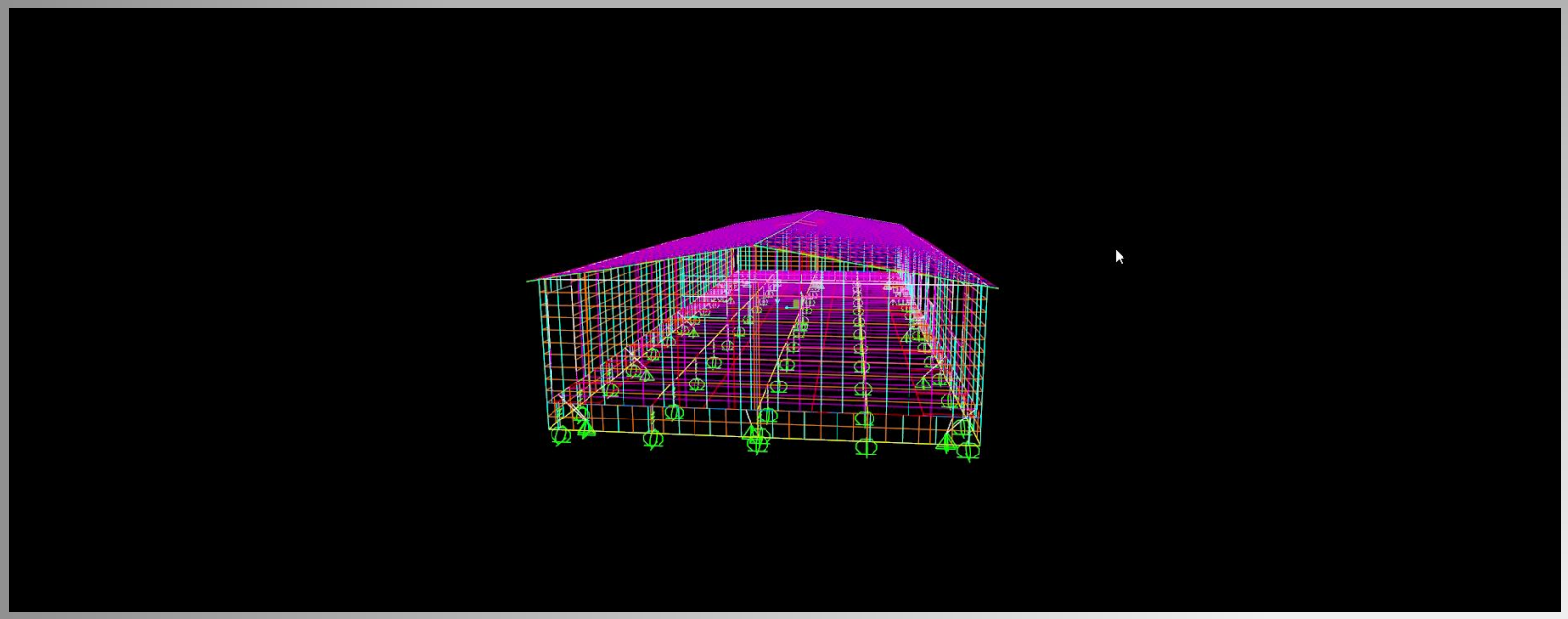
Loading Diagram SW Corner

SAP 2000 Output Verification



0.6D+0.6W NW A

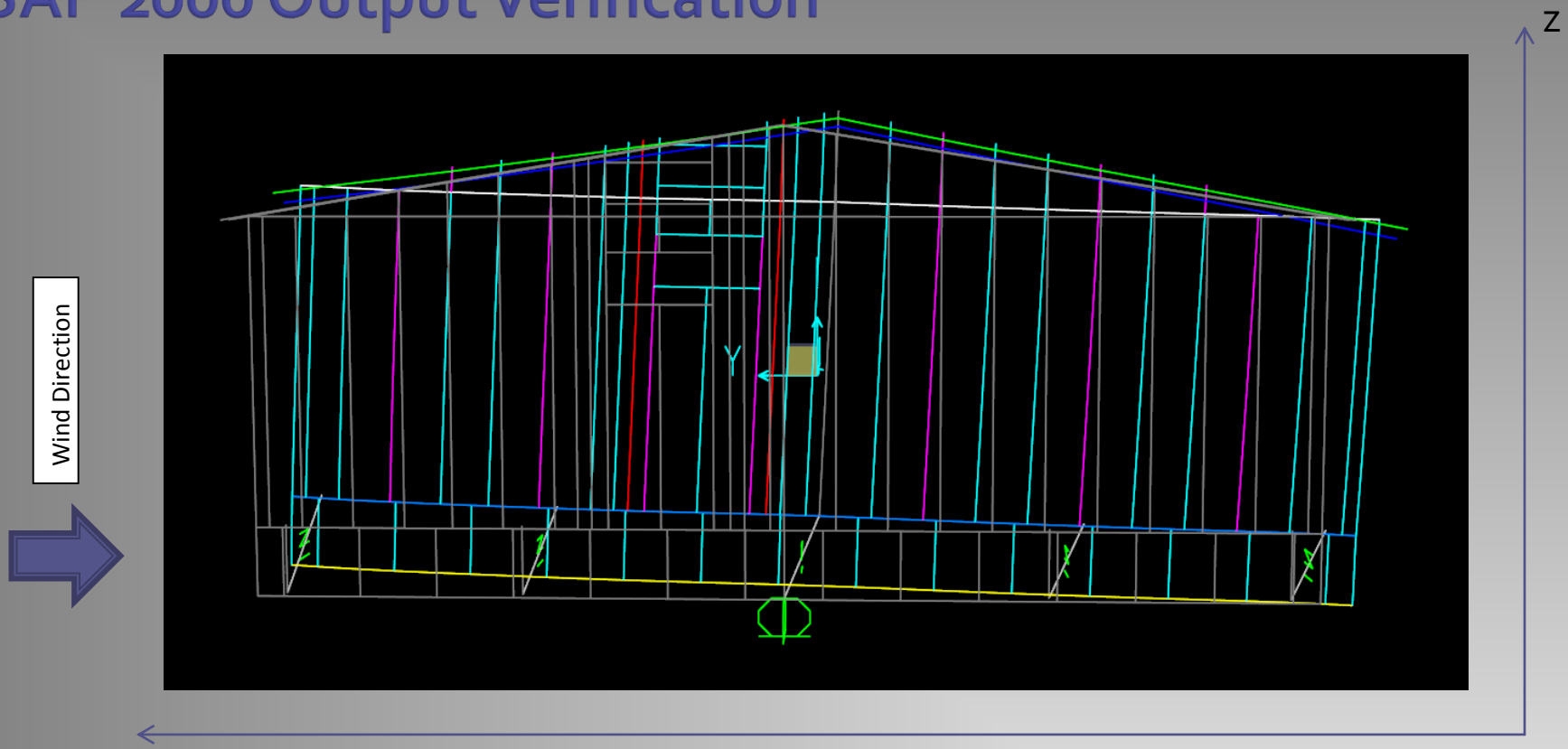
Wind Direction



Load case A on the Northwest Corner.
Deflected shapes are reasonable.
Should expect relatively small deflections in the horizontal direction perpendicular to wind

Qualitative Check

SAP 2000 Output Verification

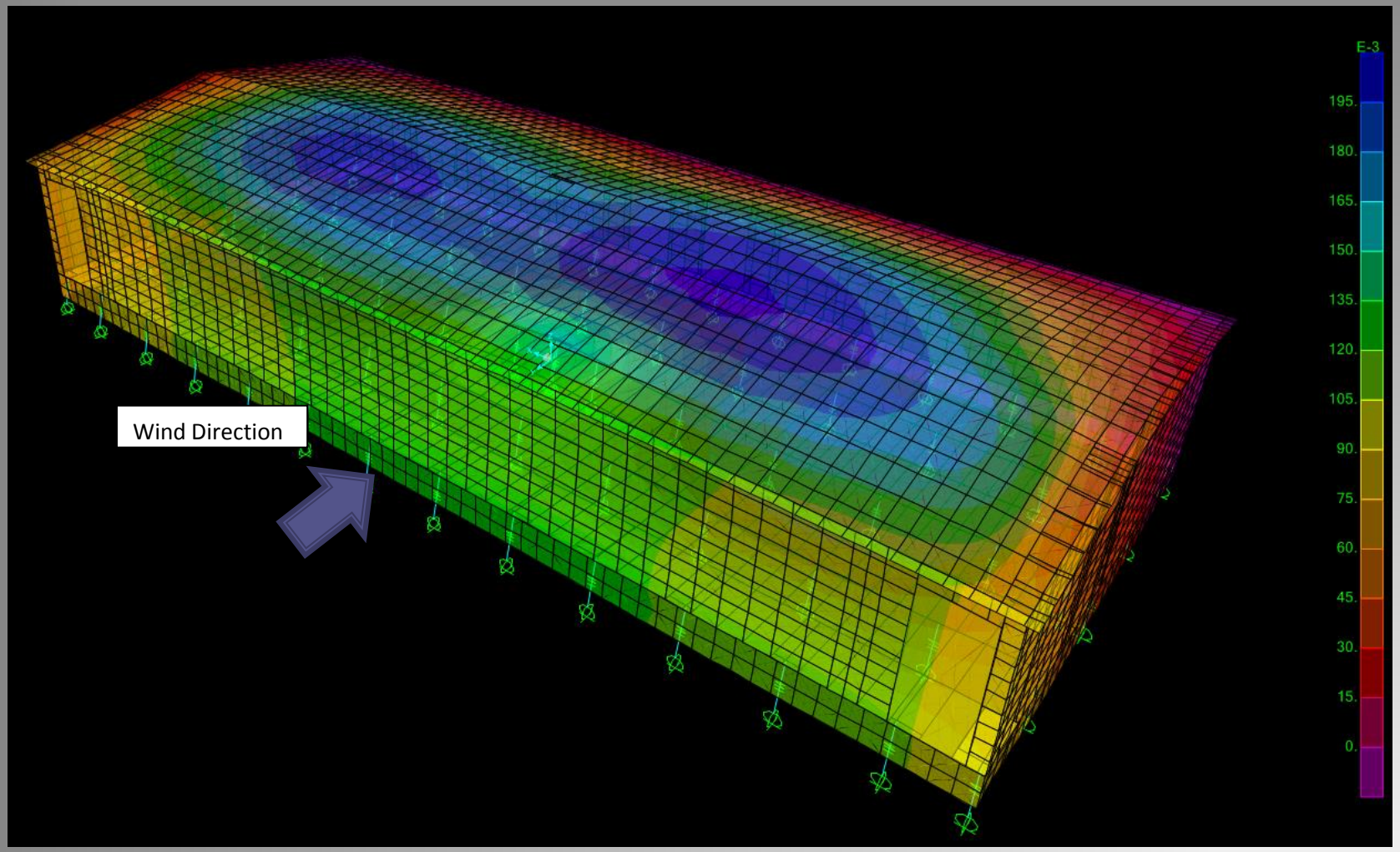


0.15in deflection in the global y direction

- Ties and CMU elements will engage to resist overturning
- Only ties resist horizontal displacements

Qualitative Check

SAP 2000 Output Verification– Qualitative Check

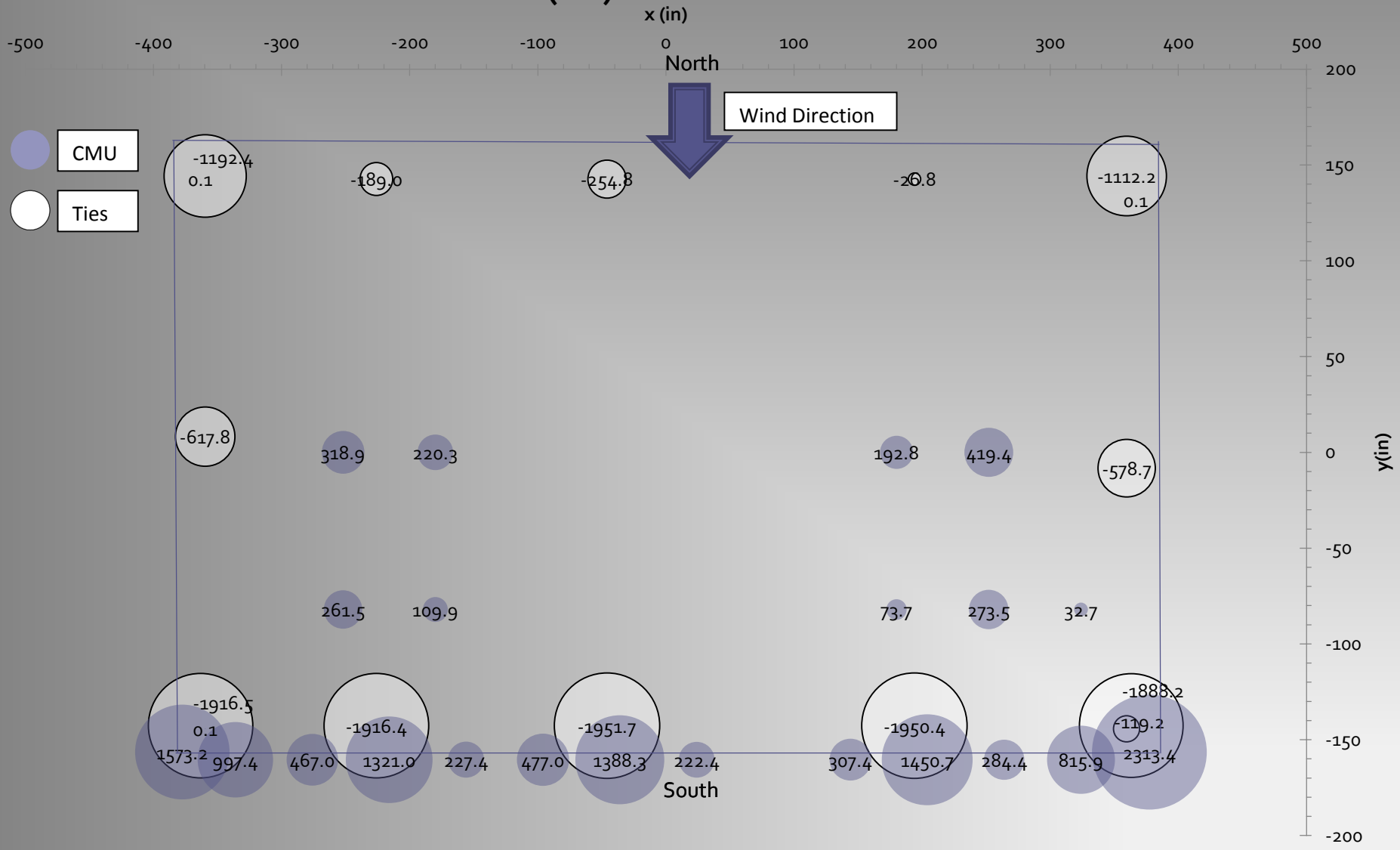


Displacement in the global z direction (in)

- Largest upward deflections at center of roof.
- Deflections are upward in the direction of roof uplift.
- Smaller upward deflection due to steel column elements at the center.

SAP 2000 Discussion

Location and Reactions in the z (lbs)



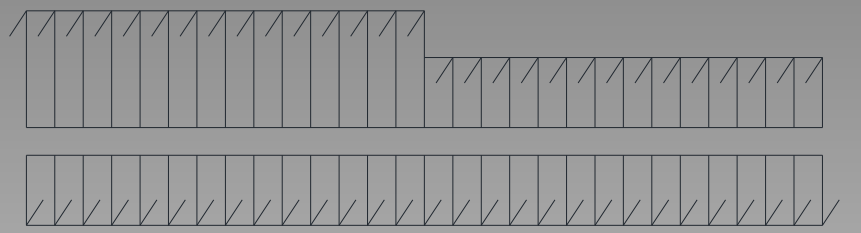
- Reactions in ties and CMU from 0.6D+0.6W Northwest Corner Load Case A

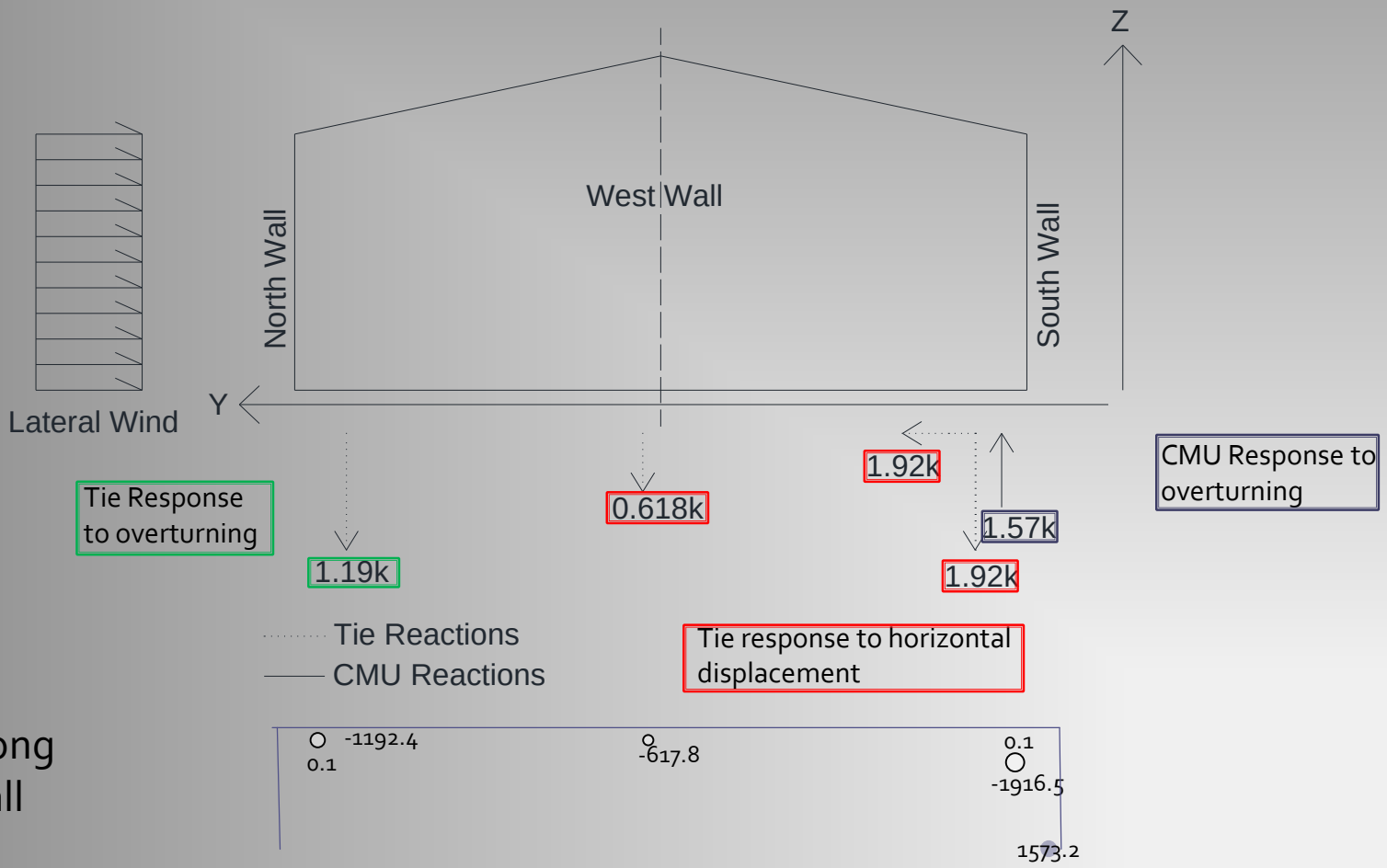
Tension in Ties 0.6D+0.6W NW A Case

SAP 2000 Discussion

FBD

Total vertical load at foundation level is negligible.





Ties along north wall are not engaged. (more horizontal than vertical displacement)

Snapshot of reactions along the West Wall

0.6D+0.6W NW A Case FBD

Phase 2 Options
Wall test

Future Work

Appendix Data