A guide to using LECWall for partially composite slender wall analysis:

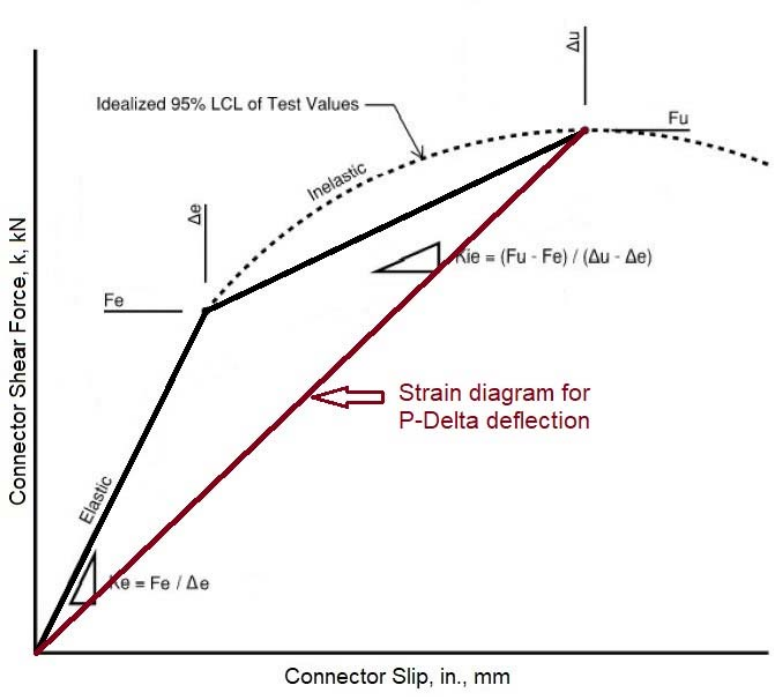
Main reference: *Tilt-Up Partially Composite Insulated Wall Panels* - A research report prepared for the Tilt-Up Concrete Association in 2022. Prepared by: Marc Maguire, PhD, Assistant Professor, Salam Al-Rubaye, PhD Candidate, Graduate Research Assistant, Durham School of Architectural Engineering and Construction, University of Nebraska-Lincoln.

From the Report: "This research project was initiated to investigate the behavior of load-bearing concrete insulated wall (CIP) panels for use in tilt-up construction. The primary objective was to understand the inelastic behavior of these panels so that engineers could perform a proper second-order analysis for combined axial and out-of-plane loading."

Five connector types were tested in double-shear, and then 40 ft. long panels were constructed using each system type. These were then tested to failure and deflections noted.

A slender wall analysis is generally required for mild-reinforced, load-bearing, unbraced slender walls. For a classic ACI slender wall analysis, maximum cracked-section deflection is estimated under ultimate lateral and eccentric gravity loads. An iterative "P-Delta" analysis is then used to magnify this deflection, which is then applied to find the maximum moment in the panel.

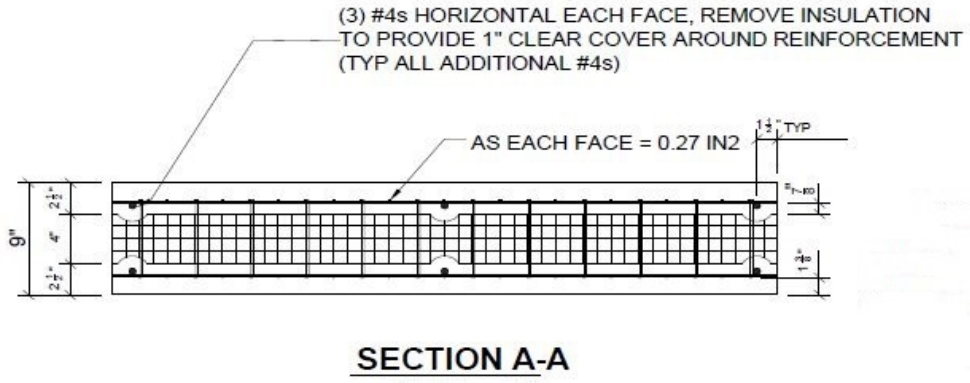
LECWall can be used to perform this type of analysis. Make sure you have the latest update first. (Select *Check for Updates* from the startup screen.) To use, select the *Pre-cracked* option from the Capacity screen. This will change the following: Instead of I-gross or I-effective, I-cracked will be used for the middle 2/3 of the panel length (it is assumed that the L/6 portions at the ends remain uncracked). For partially composite panels using Beam-Spring analysis, both wythes are considered to be fully cracked for the deflection calculation. In addition, cracked concrete area is substituted instead of A-gross (it is estimated to be ¼ A-gross for both wythes). Lastly, the wythe connectors are assumed to be in the full inelastic range for deflection (see graph):



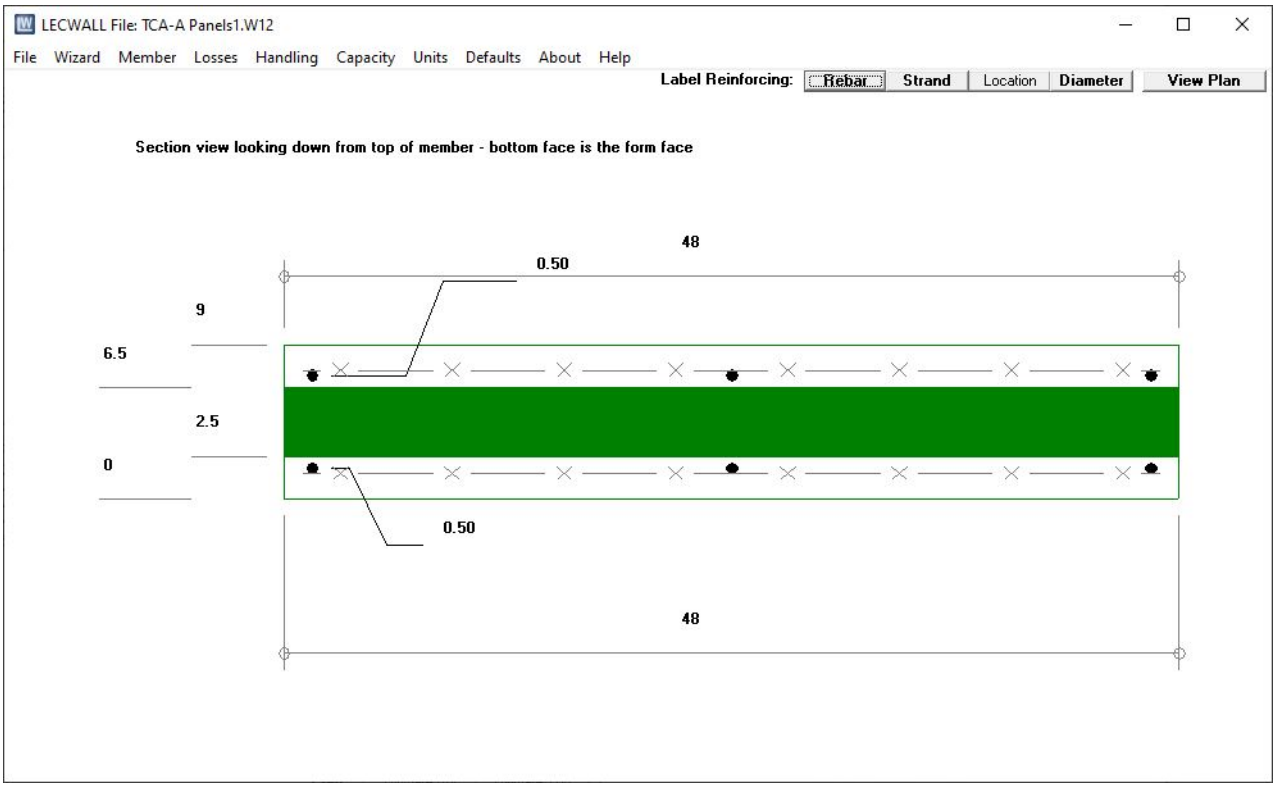
When the *Pre-cracked* option is selected, the P-Delta deflections estimated by LECWall compare favorably to the TCA research report results for the five connector system types.

The following example outlines this procedure for the Group "A" partially composite insulated panels tested in the TCA report (Innstruct):

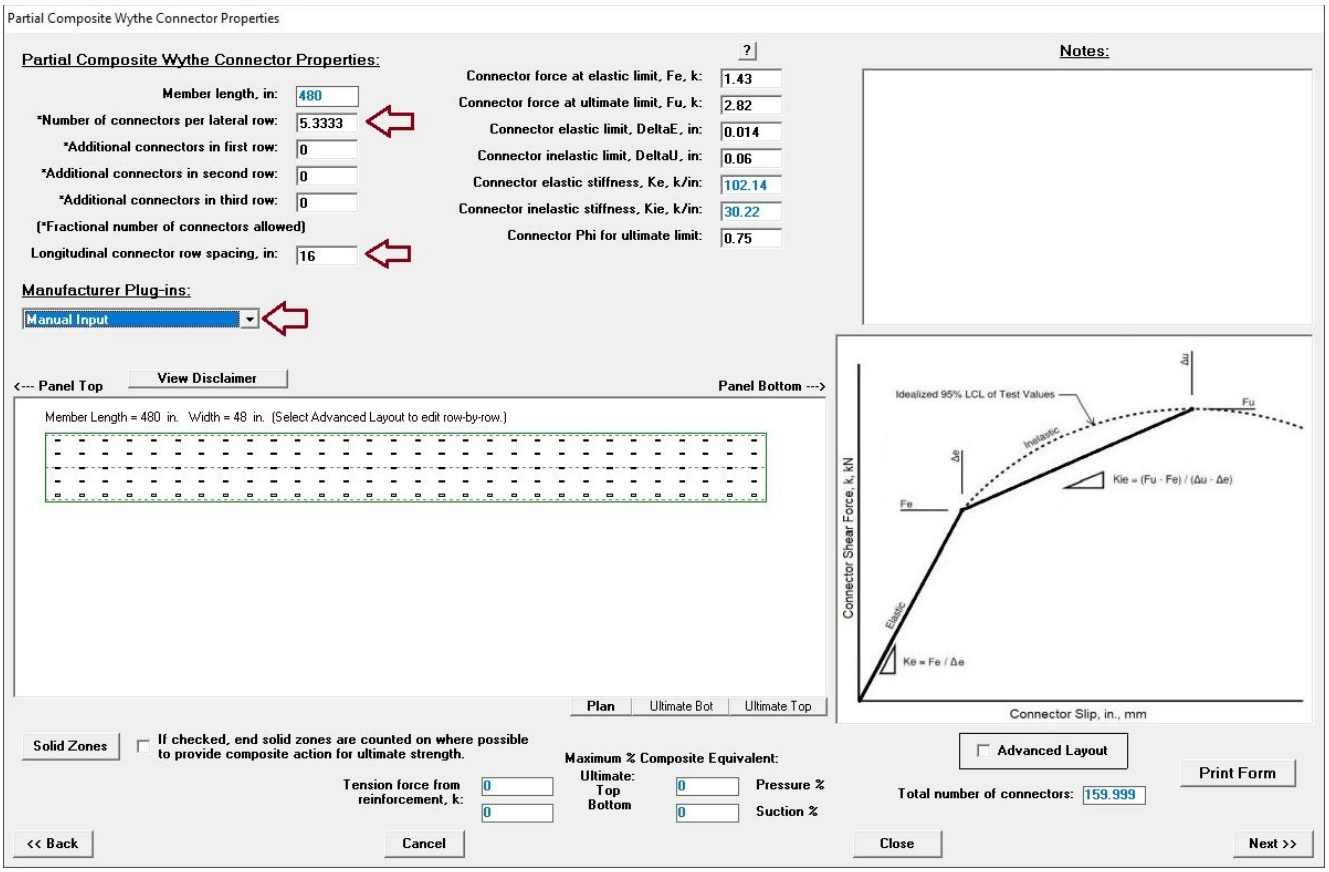
Since we are trying to duplicate the TCA tests, F'c = 3790 psi and Fy = 85 ksi for the rebar and 60 ksi for the WWF. The panel is 40 ft. long by 4 ft. wide.



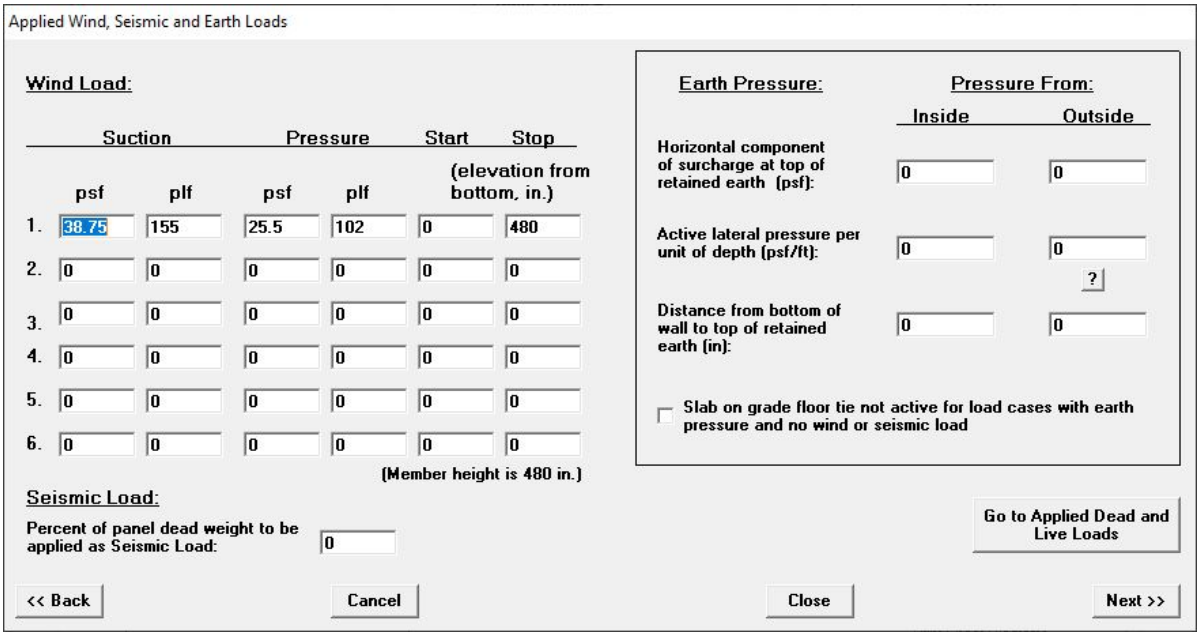
SECTION A-A



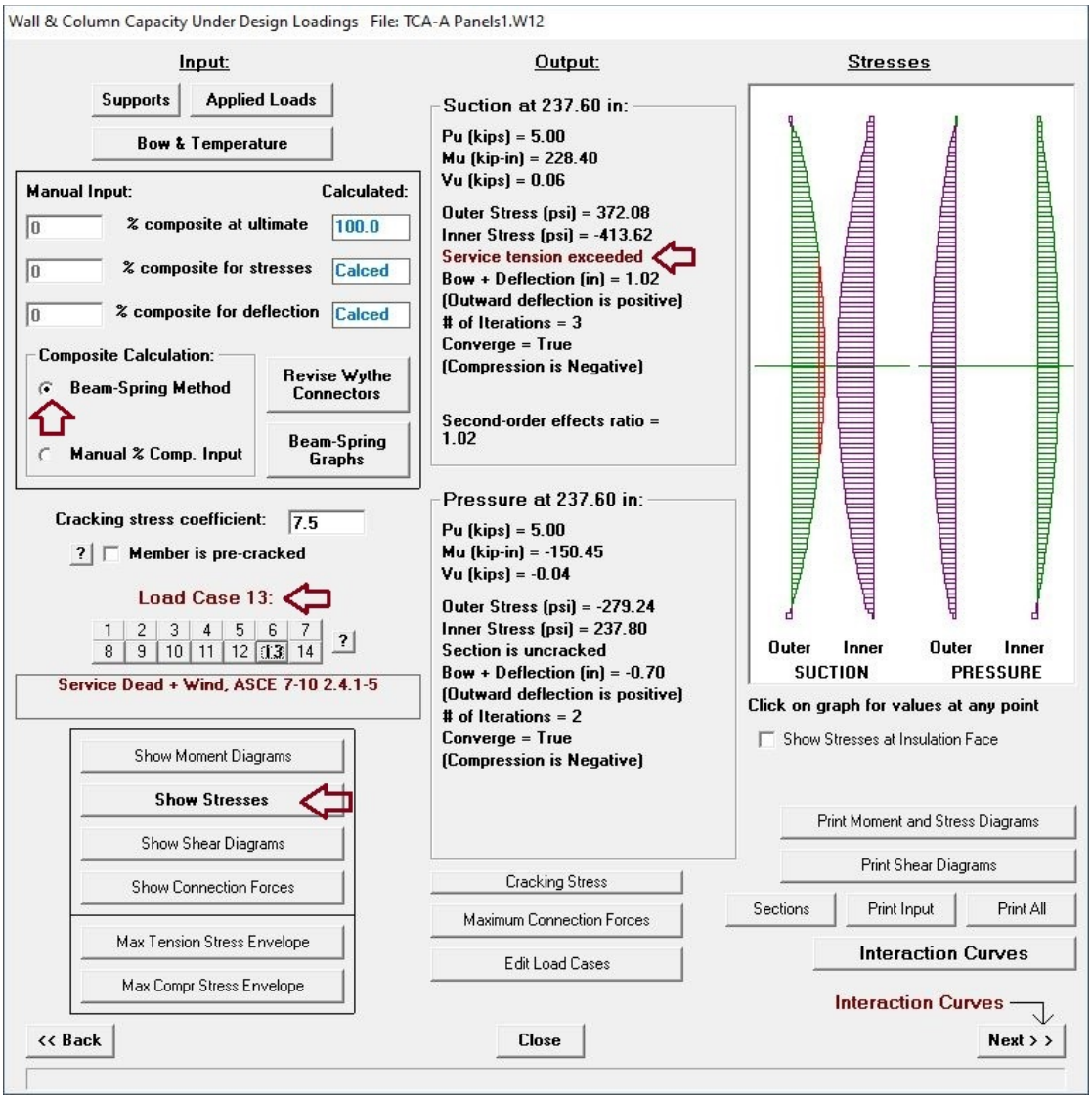
From pg. 98 of the Report, average Fu = 2.82 ksf, Δu = 0.06 in., Ke = 102 k/in, Δe = 0.014 in and Fe = 102*0.014 = 1.43 ksf. (Generally, the lower-bound values should be used instead of the average, but in this case we are trying to match the test conditions.) The values are per sq ft, so for a default 16" spacing, 5.333 connectors are required in each row (48/5.333*16 = 144 in2):



Wind load is applied, 38.75 psf Suction, 25.5 psf Pressure. Any gravity loads should also be applied, but we don't have any, just the panel self-weight, which can still be significant for P-Delta effects.

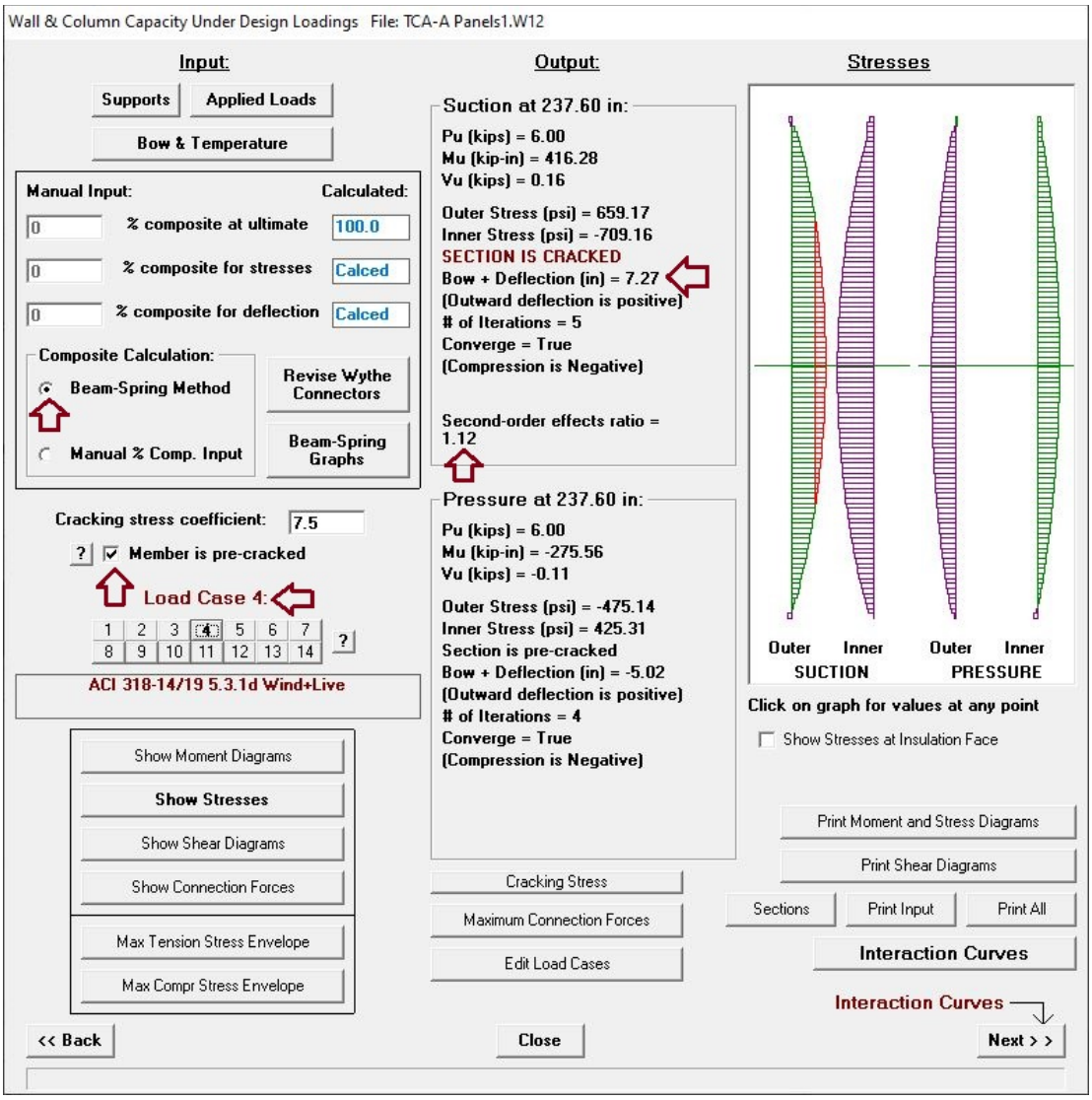


Check wind under service loads for cracking (the *Pre-cracked* option is not active for service load cases):



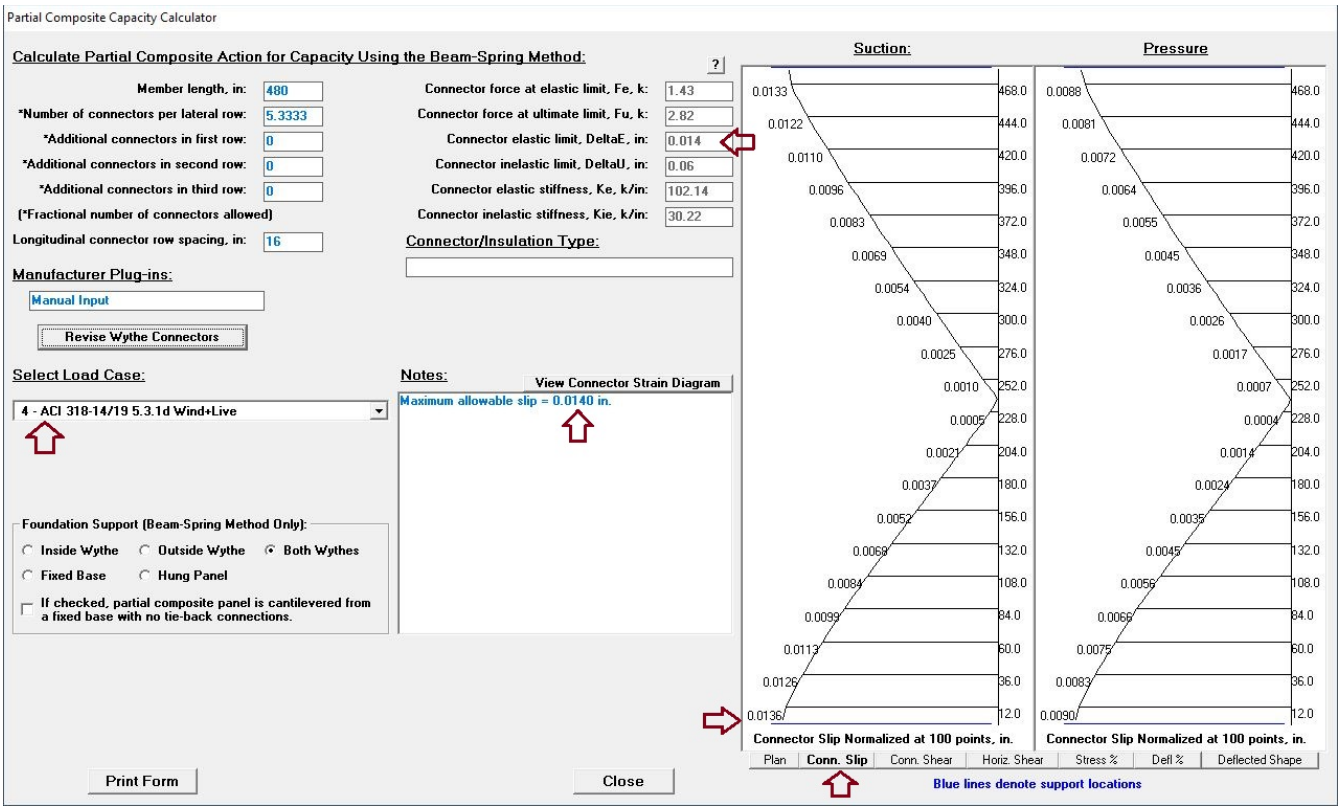
Service deflection is 1.02” (L/470, ok), compared to 0.57” in the TCA report. Tension stress is 372 psi (6 SQFC), less than 7.5 SQFC = 461 psi cracking stress, but greater than 5 SQFC = 307 psi, so could be a concern for appearance.

Next, check Ultimate Wind as a Pre-cracked member:



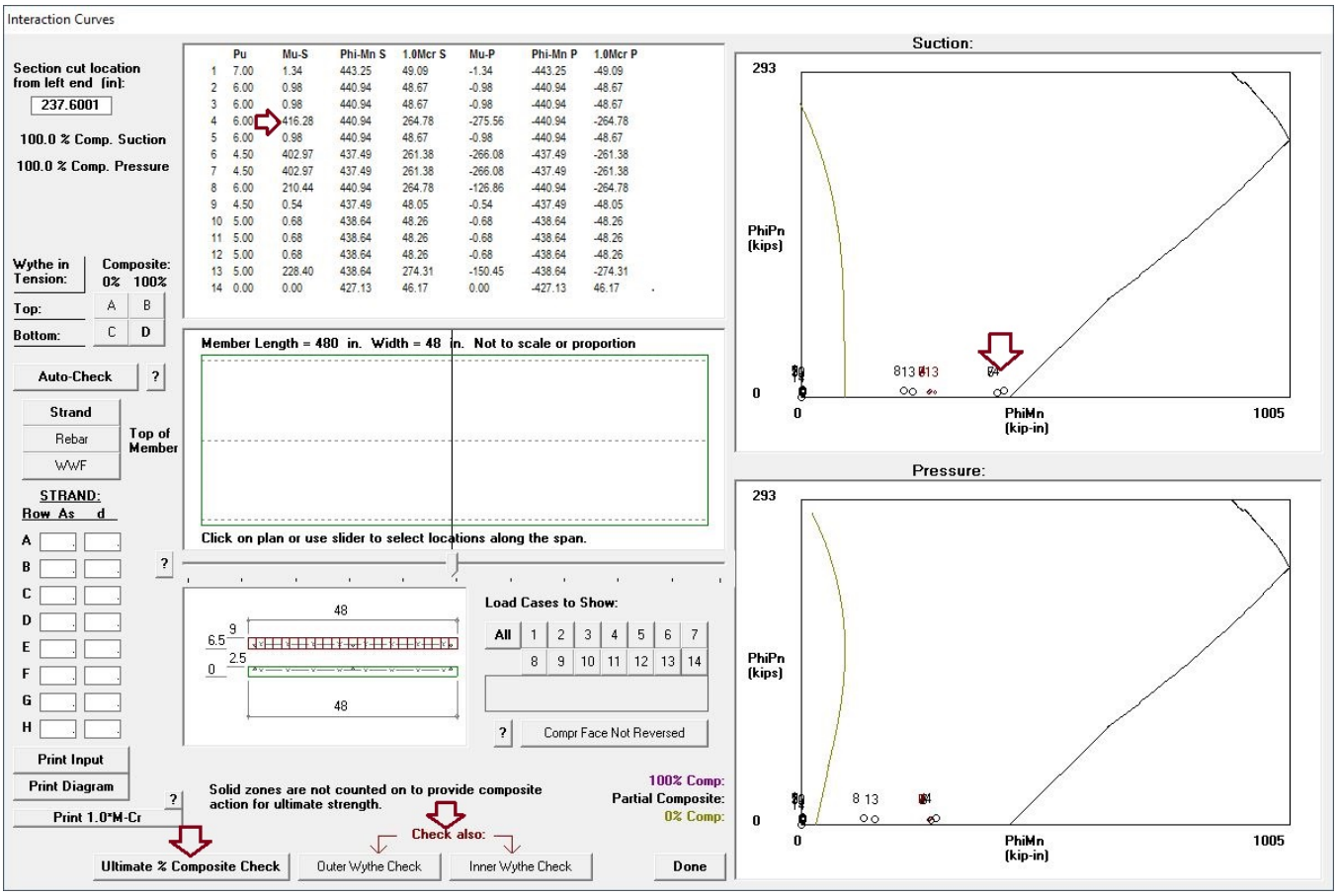
Deflection with P-Delta magnification is 7.27”, compared to 5.7” in the TCA report. LECWall applies a Phi-k stiffness factor of 0.875 to EI (per ACI 318). Without that, deflection would be 7.27*0.875 = 6.36”, still greater than 5.7”. The *Second-order effects ratio* shows that deflections were magnified 12% by P-Delta effects. ACI limits second-order effects to 40% maximum.

Click on “Beam-Spring Graphs” to check the maximum connector slip:

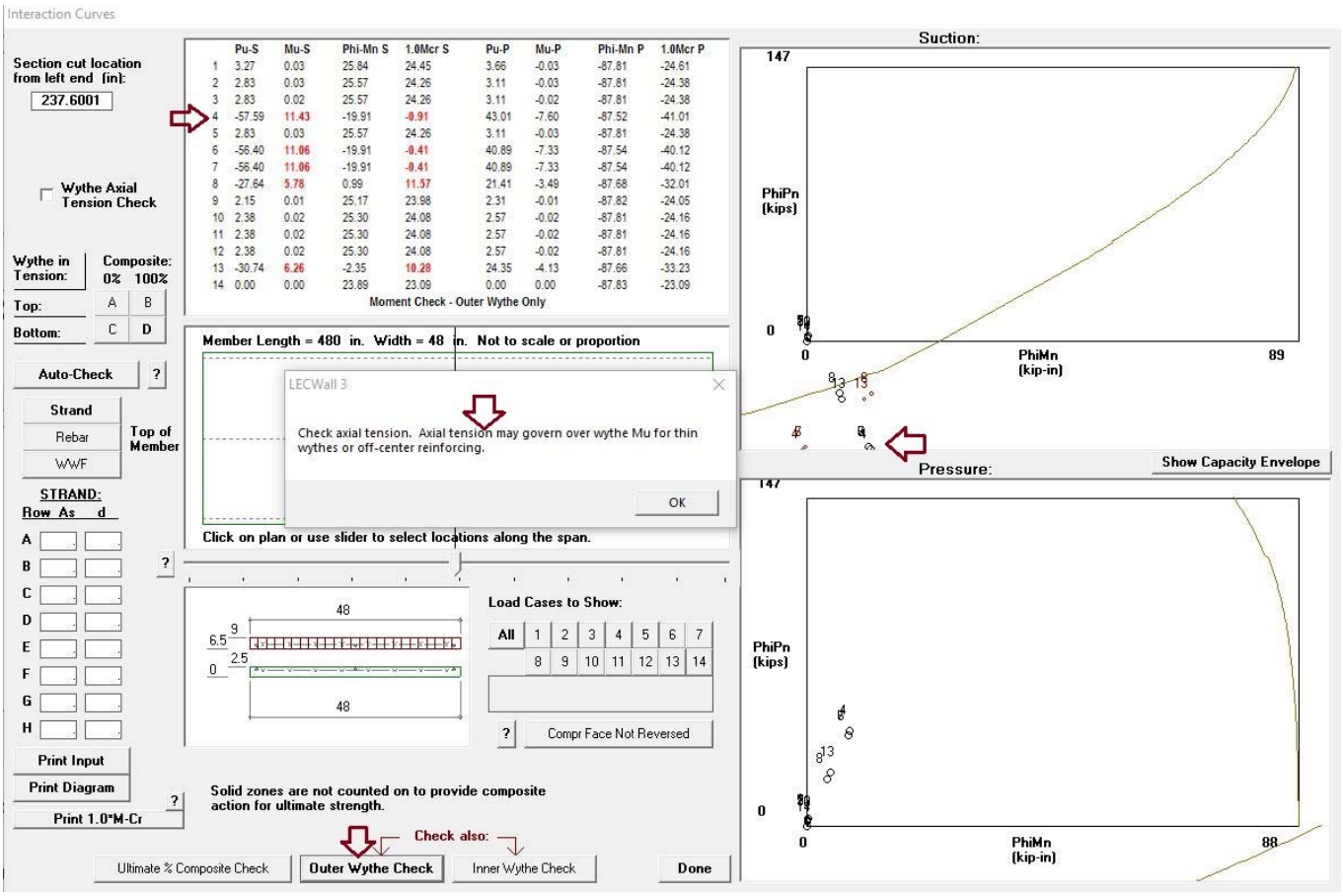


Maximum allowable slip to remain in the elastic range is 0.014”, compared to 0.0136” actual, so ok. (This provides a factor of safety to ensure that the connectors stay in the elastic range under service loads.) If exceeded, it doesn’t necessarily mean that the member has failed, just that it exceeds the limits of the Beam-Spring elastic analysis used by LECWall. If exceeded by a significant amount, the LECWall analysis could over-estimate the connector stiffness, as some connectors would be in the inelastic range. The cure is to simply add more connectors where slip is exceeded (use the Advanced Layout option on the Connectors screen, if needed).

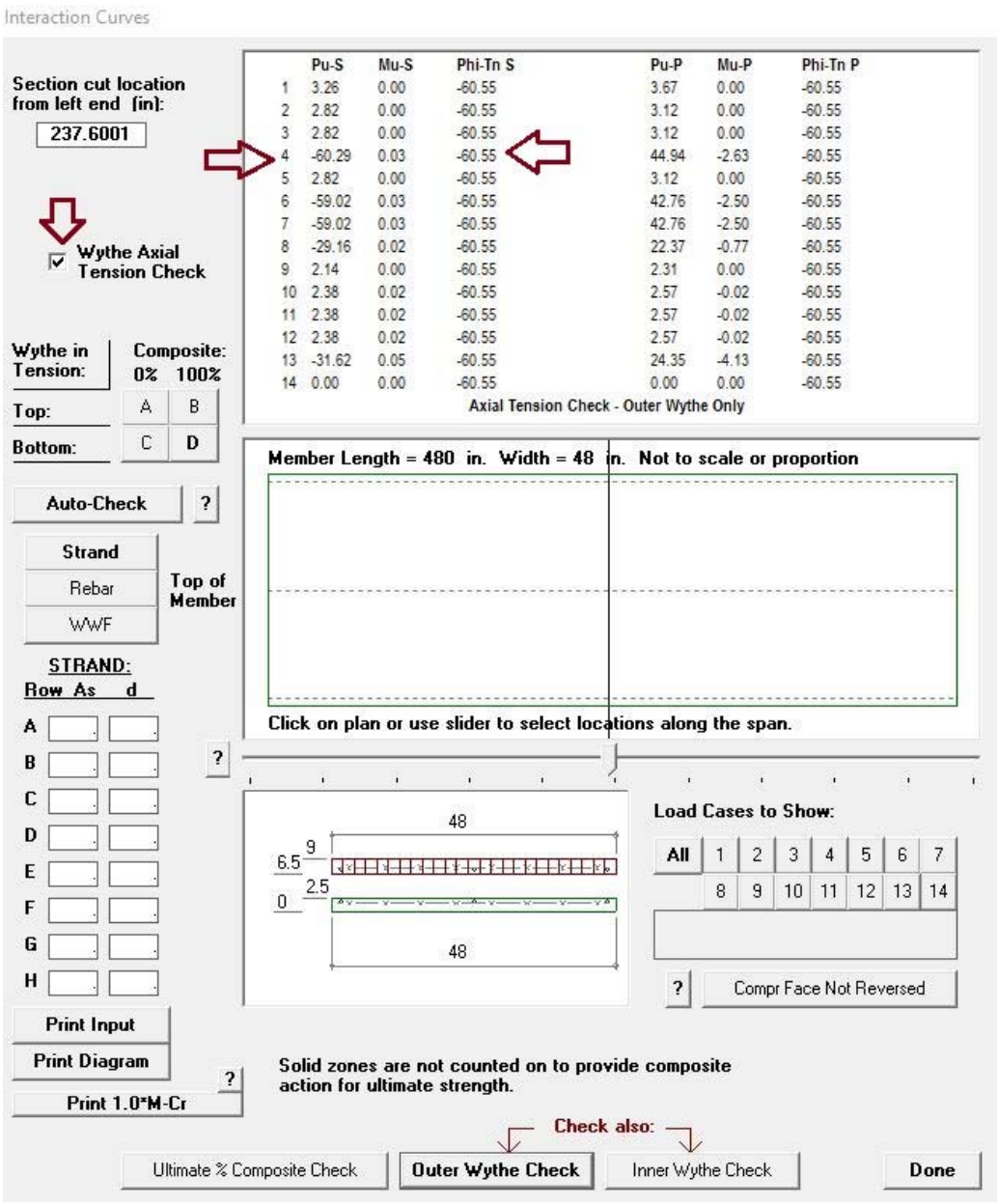
Click on *Interaction Curves* from the Capacity screen to check the member capacity (Use *Auto-Check* to find the critical locations along the span).



The % Composite check looks ok, but this is misleading, as the individual wythe checks are usually more accurate. Checking the Outer Wythe:



Here it is not surprising that the outer wythe fails in flexure. The wythes are very thin and the reinforcing is located off-center toward the insulation face, so the moment arm is small. By this criteria the member capacity would be much less than expected or shown by the TCA tests. As such, we can assume that the outer wythe yields when cracked and forms one or more plastic hinges. The flexural stiffness of the wythe becomes very small and it essentially becomes a tension chord. It is necessary to check the axial tension in the wythes. To do this, select *Wythe Axial Tension Check* at the upper left of the window:



The axial tension is 60.29k, slightly less than the Phi-Tn tension capacity of 60.55k. The loading we have chosen corresponds almost exactly to the tension wythe capacity, how about that? Therefore, the member moment capacity (without 0.9 Phi) according to LECWall is 462 k-in, compared to 680 k-in actual from page 108 of the TCA Report (LECWall 416 k-in max with 0.9 Phi). Conservative, but not excessively so. The LECWall capacity based on maximum connector slip is 426 k-in and Phi-Mn capacity based on the Percent Composite check is 441 k-in, but axial tension would govern (416 k-in max for Phi-Mn).

Conservative results were also obtained with the other four connector systems (B-E) when the *Pre-cracked* option was selected.