Post-Tensioned Floors Design for Temperature

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ADAPT Concrete Design Software

Agenda

- Design objective
- Response of floor slabs to temperature effects
- Design procedure for control of temperature cracks
- Example

Design Objective

- To mitigate the probability of undesirable effects in floor slabs due to changes in ambient temperature
- Primarily crack formation as a result of tensile stress
- Deflections and secondary strength impact largely ignored
- Addition of temperature rebar, where needed

Affected Structures

- Lowest levels of exposed structures
- Roof slabs
- Large slabs constructed in warm climates

Response of Floor Systems

- Response of beam and one-way slabs different than that of two-way systems

Beams and One-Way Systems

- Concrete section under bending and axial forces cracks when the tensile stress reaches the modulus of rupture fcr given in ACI 318

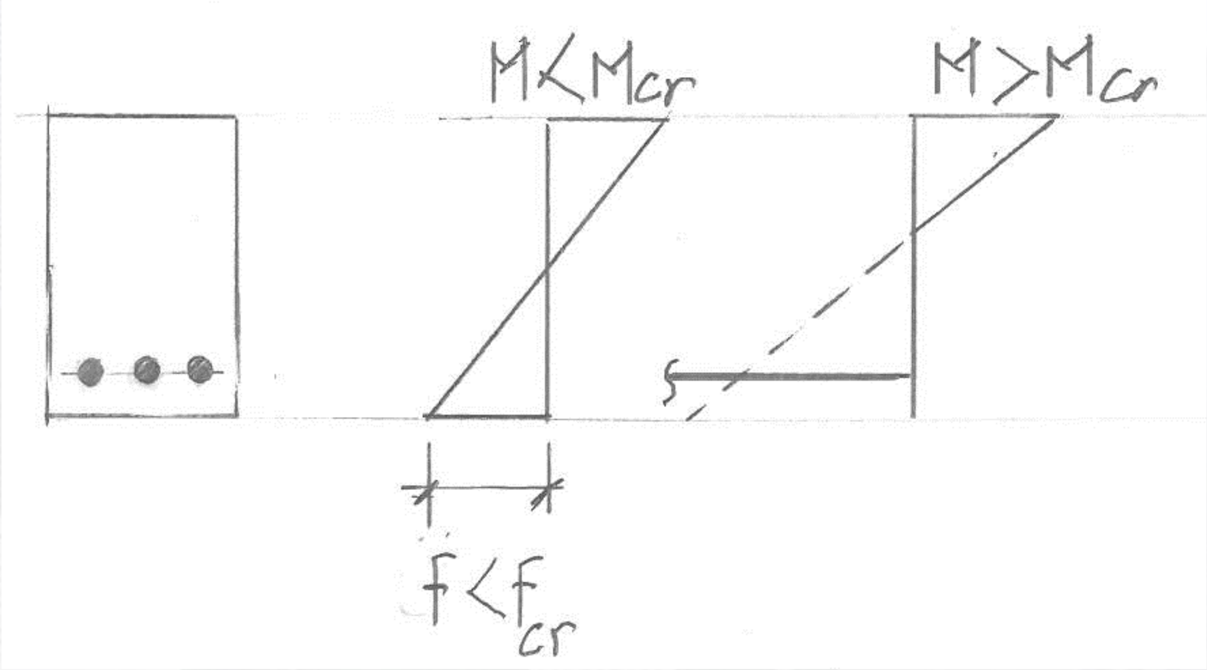
  - fcr = 7.5 sqrt f'c
  - The cracking moment Mcr is given by:
  - Mcr = (fcr + P/A)S

  where

  - P = Axial force in design section;
  - A= area of design section; and
  - S = section modulus of design section.

Beams and One-Way Systems

Pre- and post-cracking stress distribution

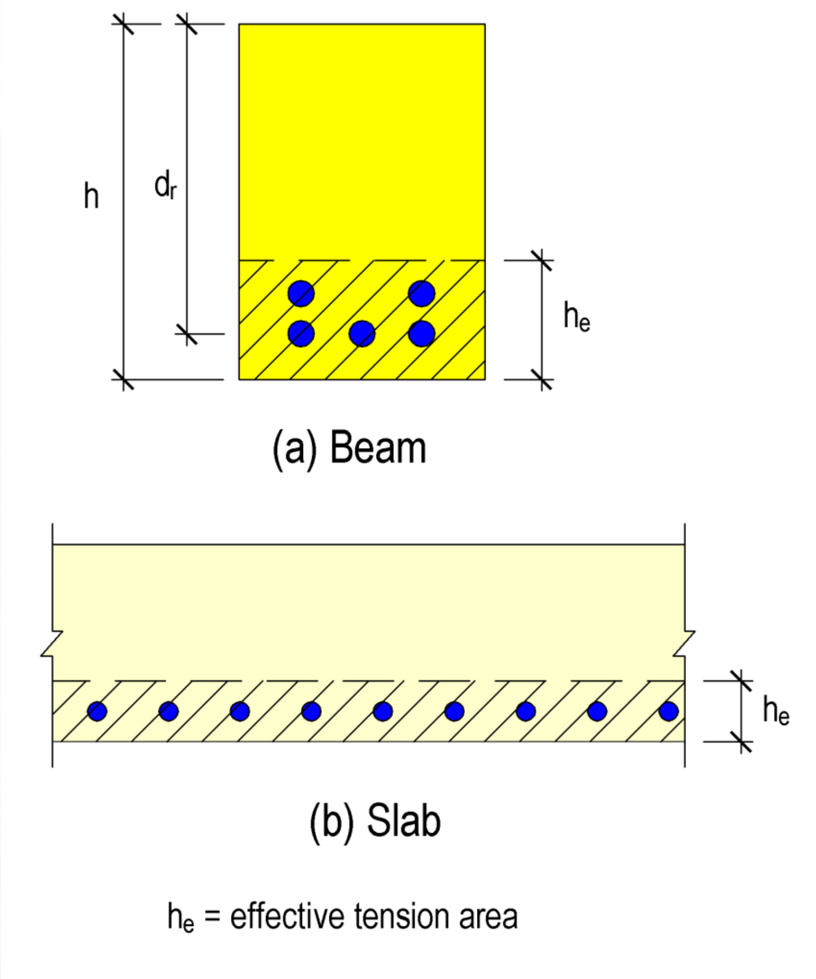


At initiation of cracking and for applied moments exceeding Mcr, the added contribution of reinforcement in the element will develop the resistance to the applied moment.

Beams and One-Way Systems

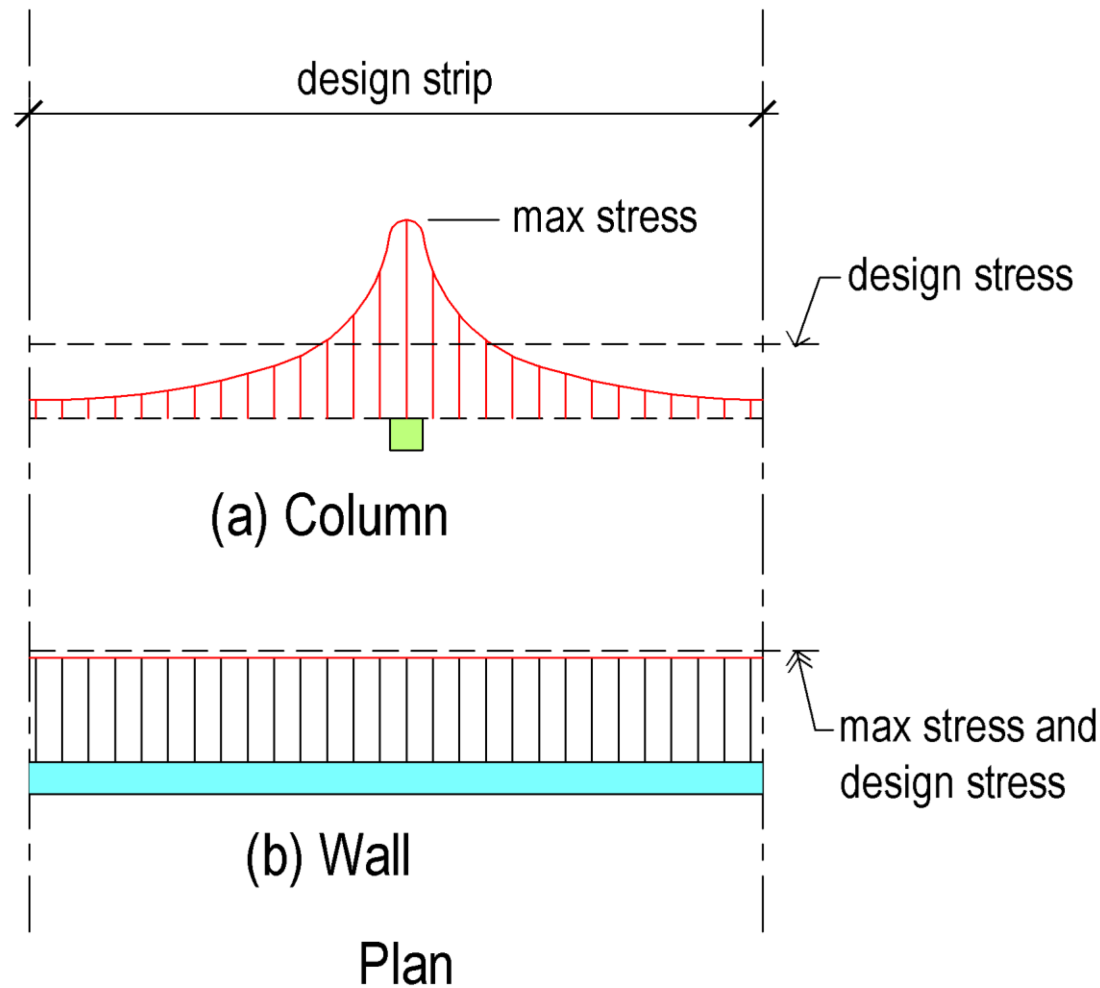
If crack width is of concern, the amount and disposition of reinforcement should be designed for:

- Closely spaced bars
- Small diameter
- Close to tension face



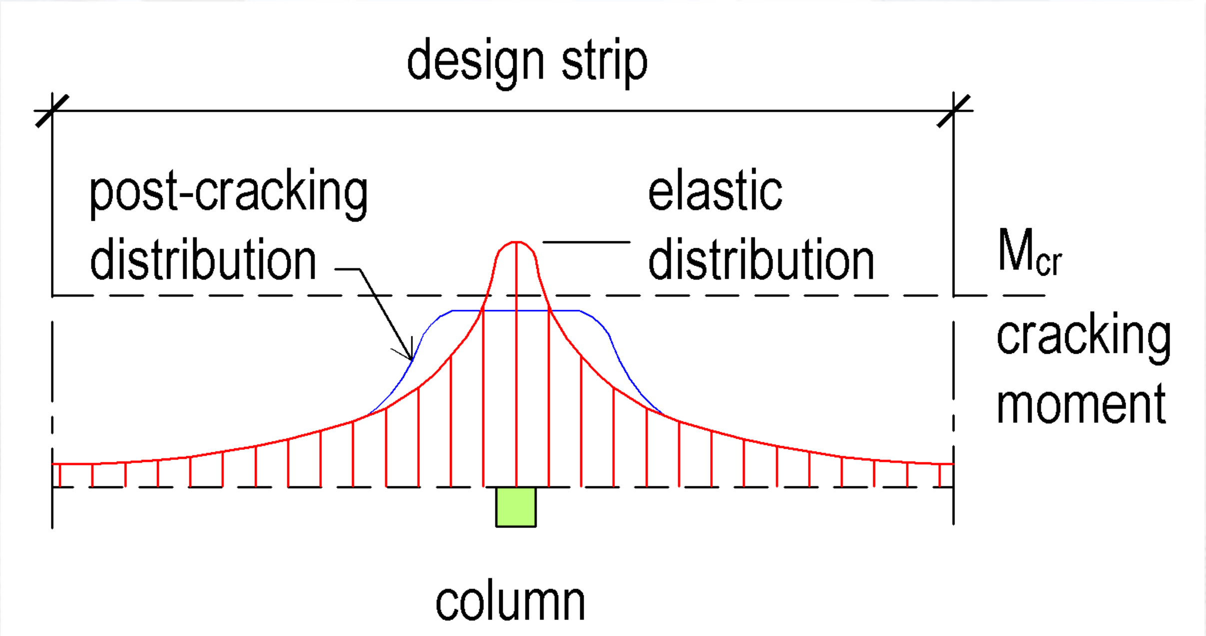
Two-Way Systems

Design (hypothetical) and elastic stress distribution for column and wall supports



Two-Way Systems

Distribution of elastic and cracked section stress



Cracking moment at the peak of the stress distribution results in local cracking coupled with a drop of the moment at the peak and redistribution of the applied moment. The redistribution of the moment results in automatic limitation of the length of crack and the ability of the section to resist moments in excess of the cracking value.

Design Procedure

- Procedure is empirical
- Based on “hypothetical” stress across design section
- Where computed stress exceeds code limit add crack control reinforcement
- Place crack control reinforcement in tension zone

Design Procedure

Calculation of crack control reinforcement

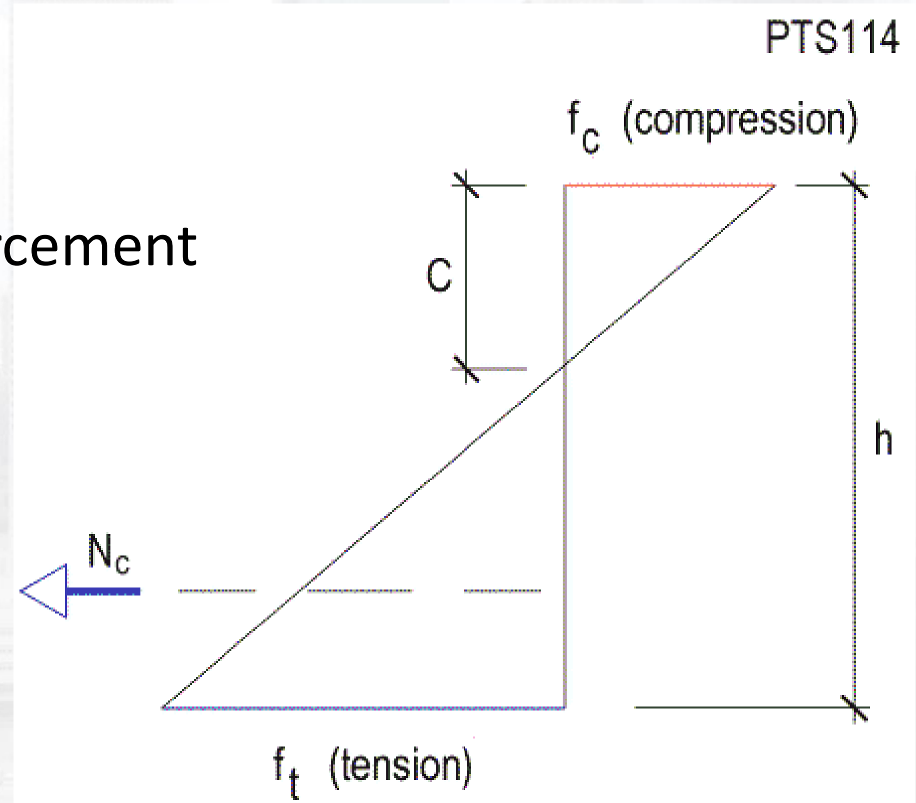
Ast = Nc/(0.5fy)

Where,

Ast = Area of added reinforcement

Nc = Tensile force

fy = yield stress of steel



Design Procedure

- Temperature load design is carried out with Dead and Live Loads
- Lateral loads are not considered
- Use sustained (quasi permanent) loads

Design Procedure

- Analyze structure for regular gravity loads and dT
- dT = change in ambient temperature
- Calculate design strip stresses for load combinations

U1 = 1.00T

U2 = 1.00DL + 1.00PT + 1.00T
U3 = 1.00DL + 1.00PT - 1.00T

U4 = 1.00DL + 1.00PT + 0.30LL + 1.00T
U5 = 1.00DL + 1.00PT + 0.30LL– 1.00T

Where,
T = Change in ambient temperature (dT)

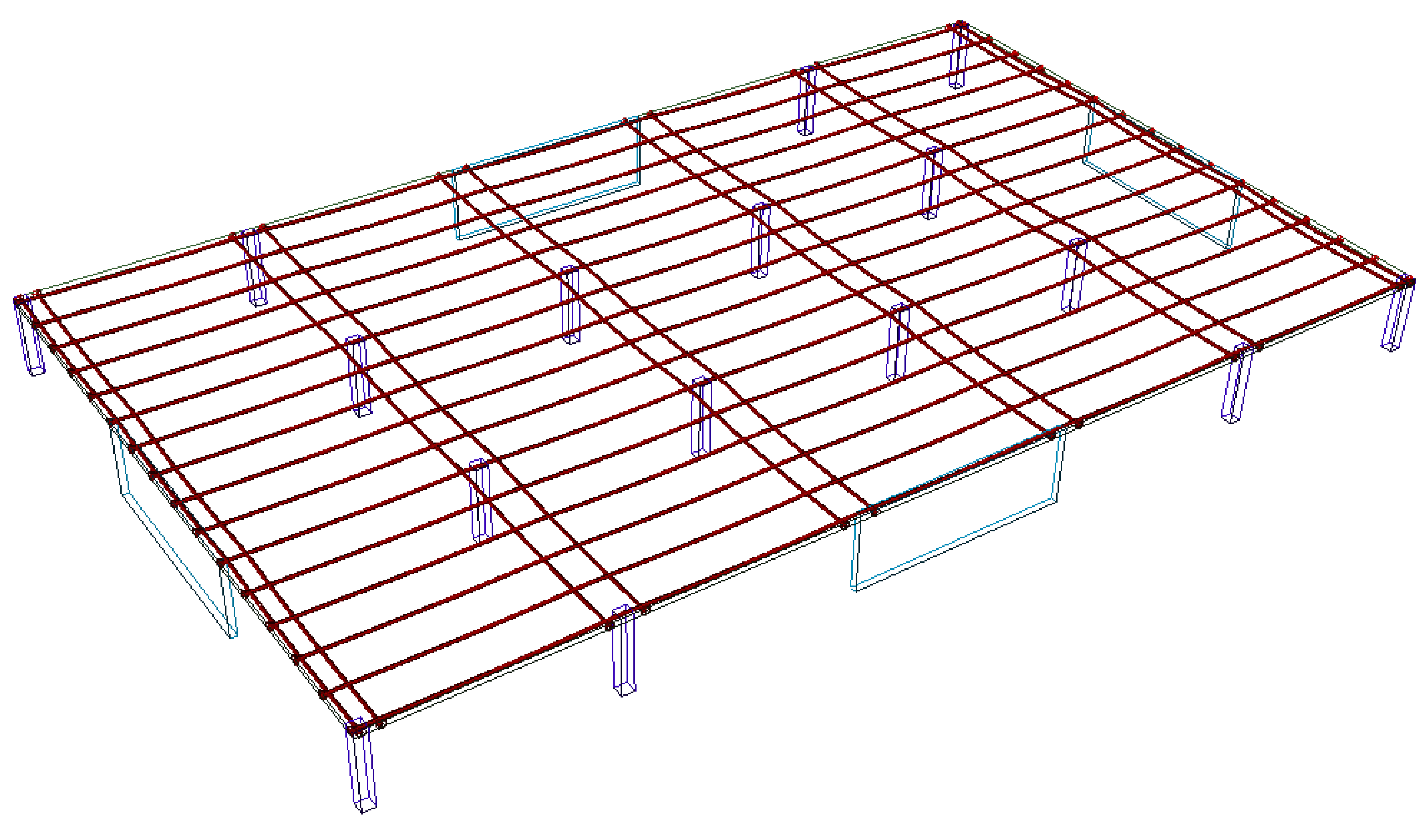
Design Procedure

- Identify sections where stress > 2 sqrt f'c
- Calculate required crack control reinforcement Ast
- Provide reinforcement on tension side if:

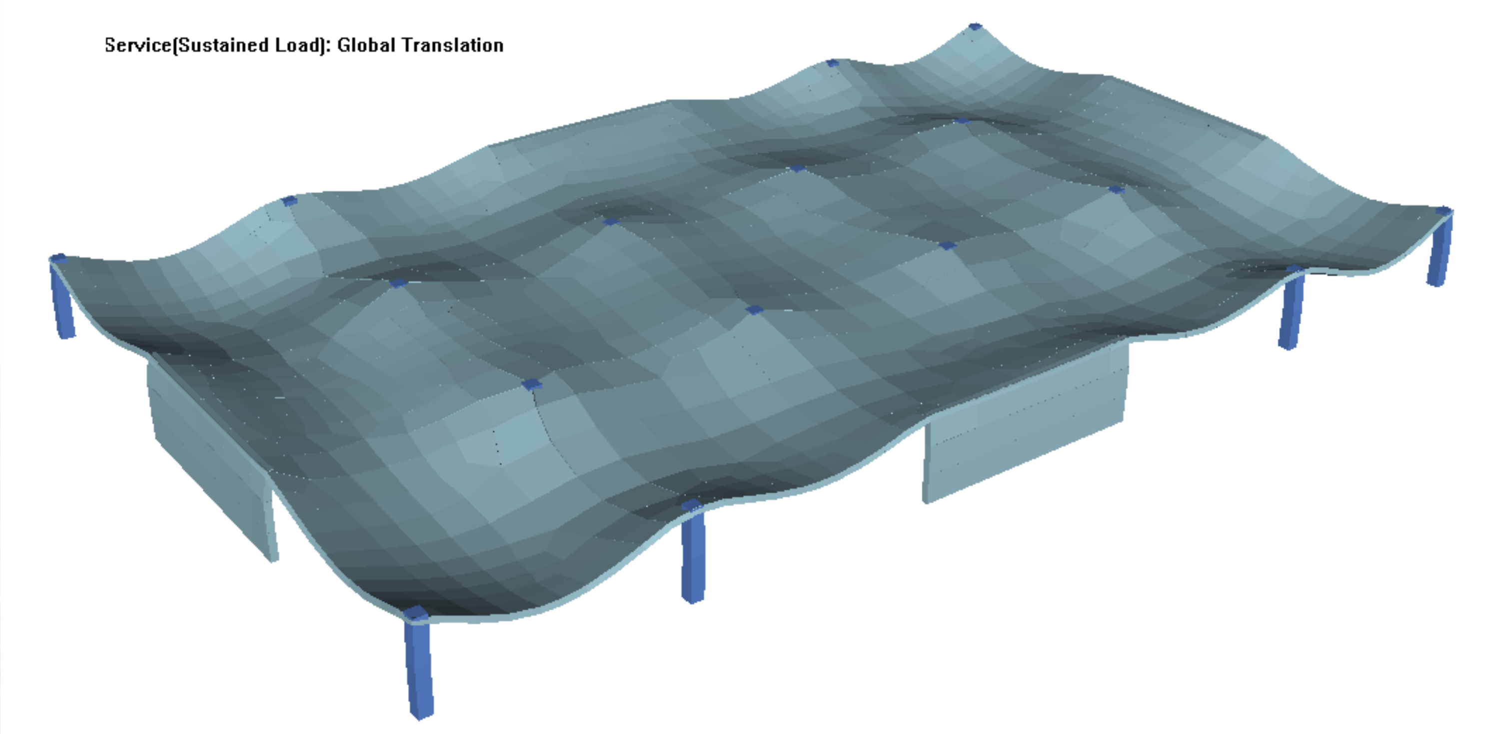
Ast > As + Aps

where As is the available rebar in the design section; and
Aps is the area of bonded reinforcement in the design section

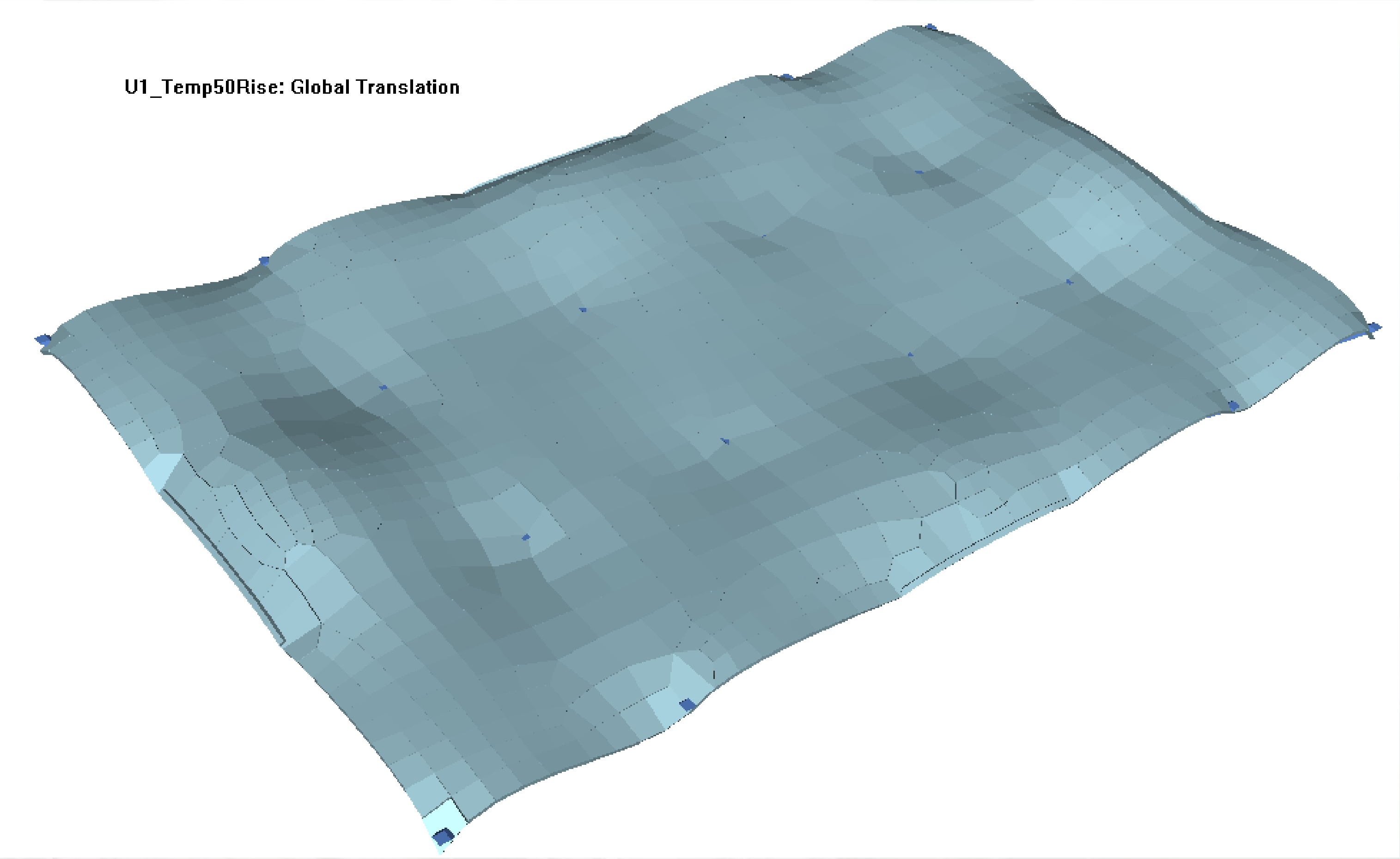
Example Post-Tensioned Slab



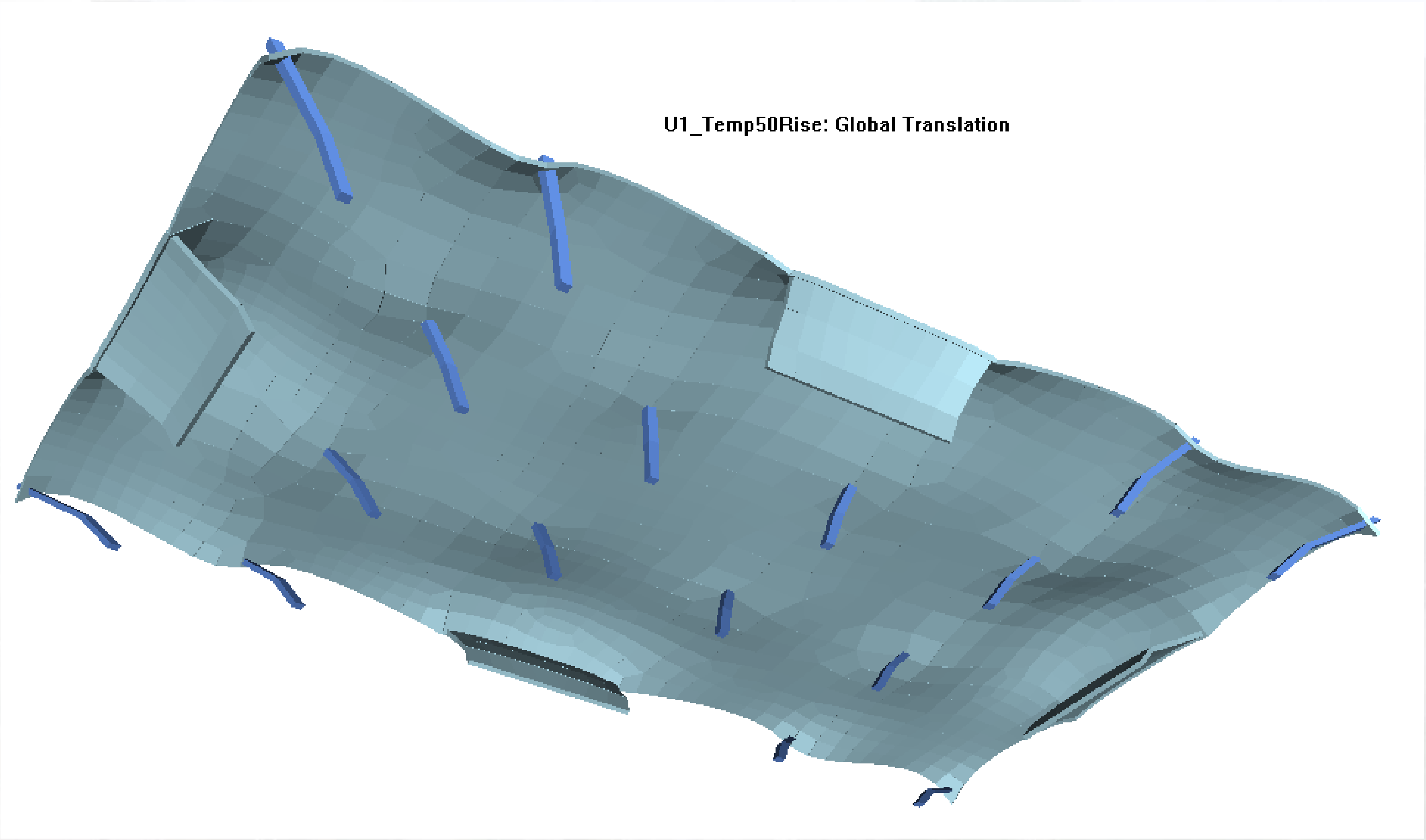
Sustained Load Deflection



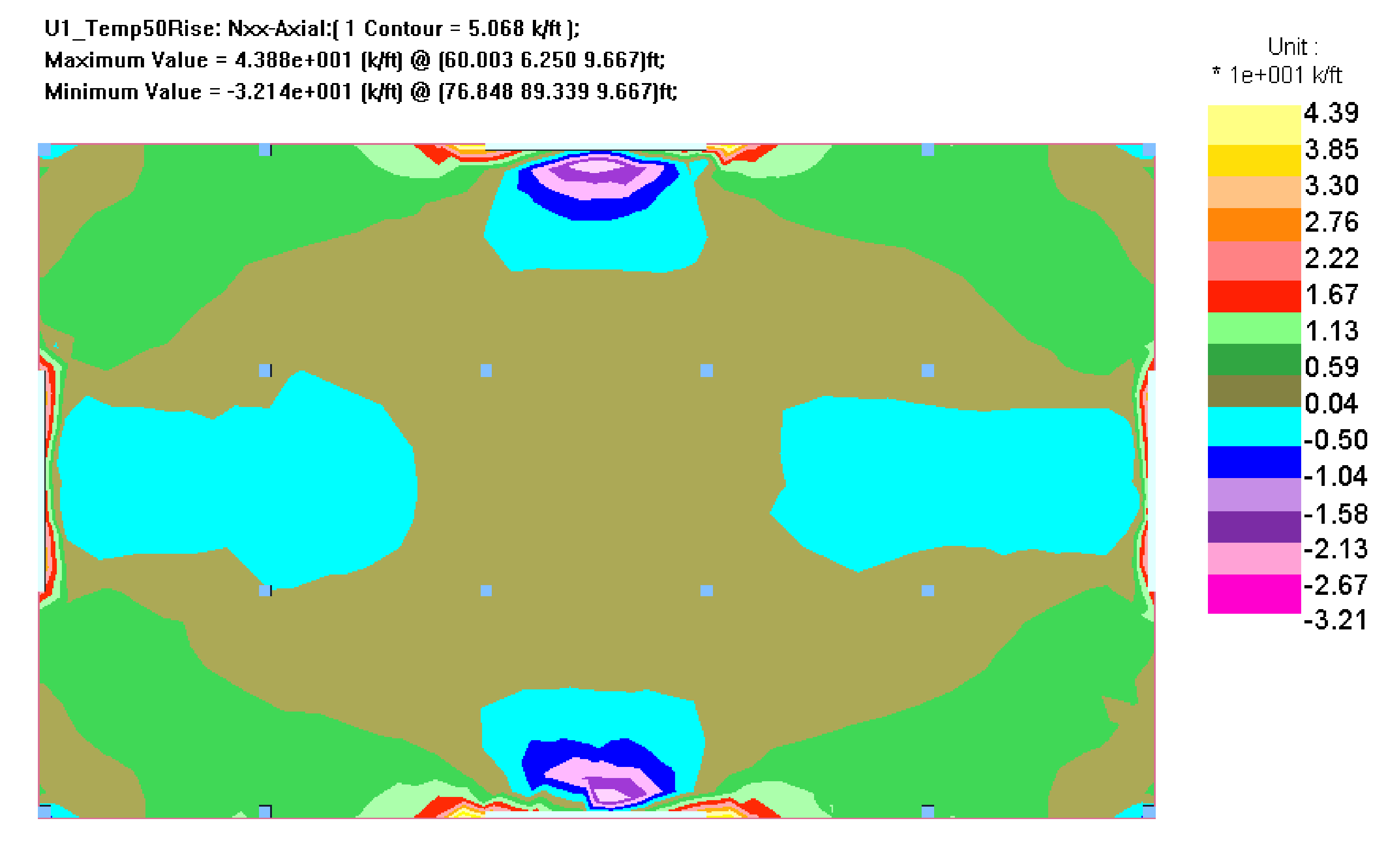
dT = 50 deg F Deflection



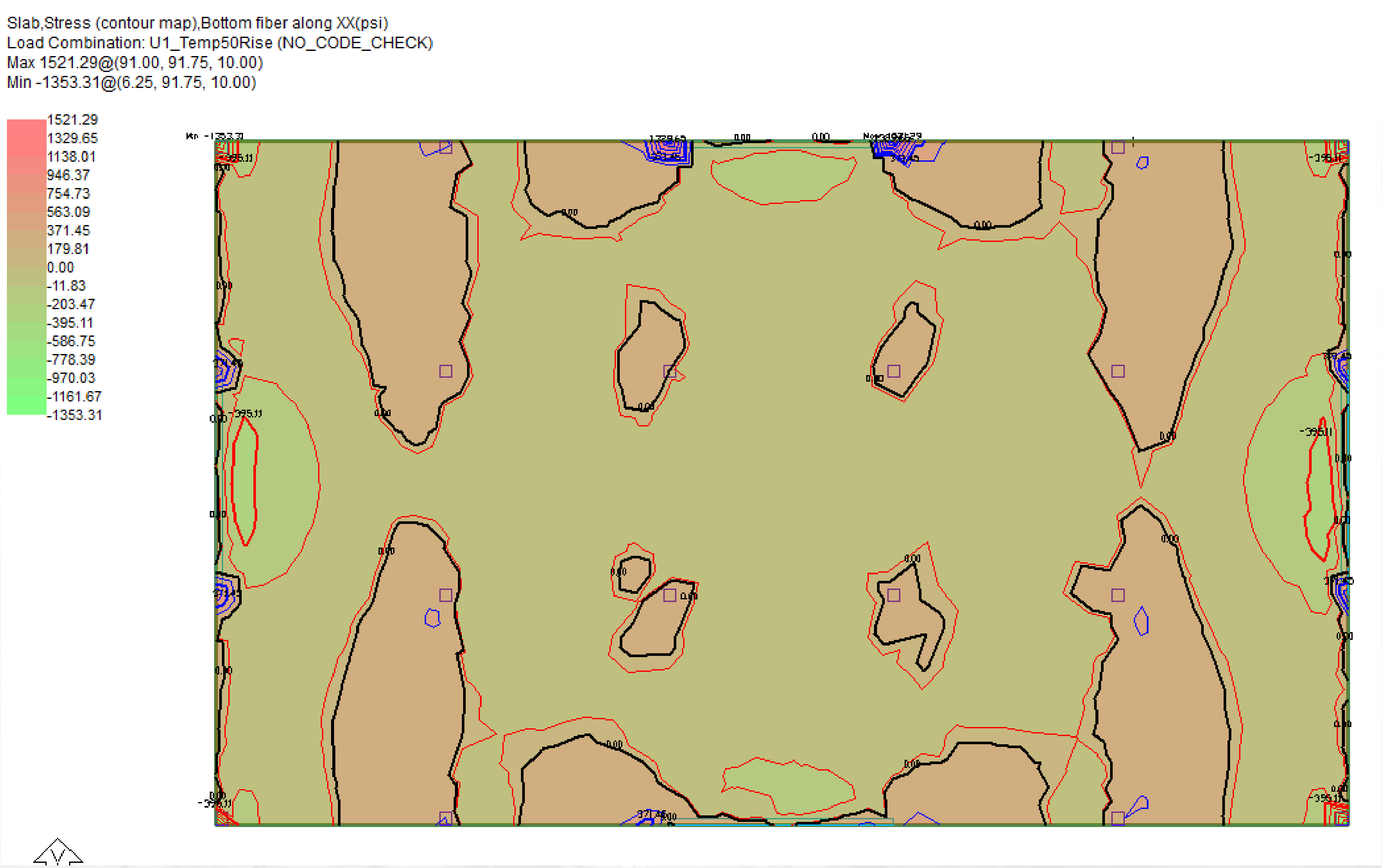
dT = 50 deg F Deflection



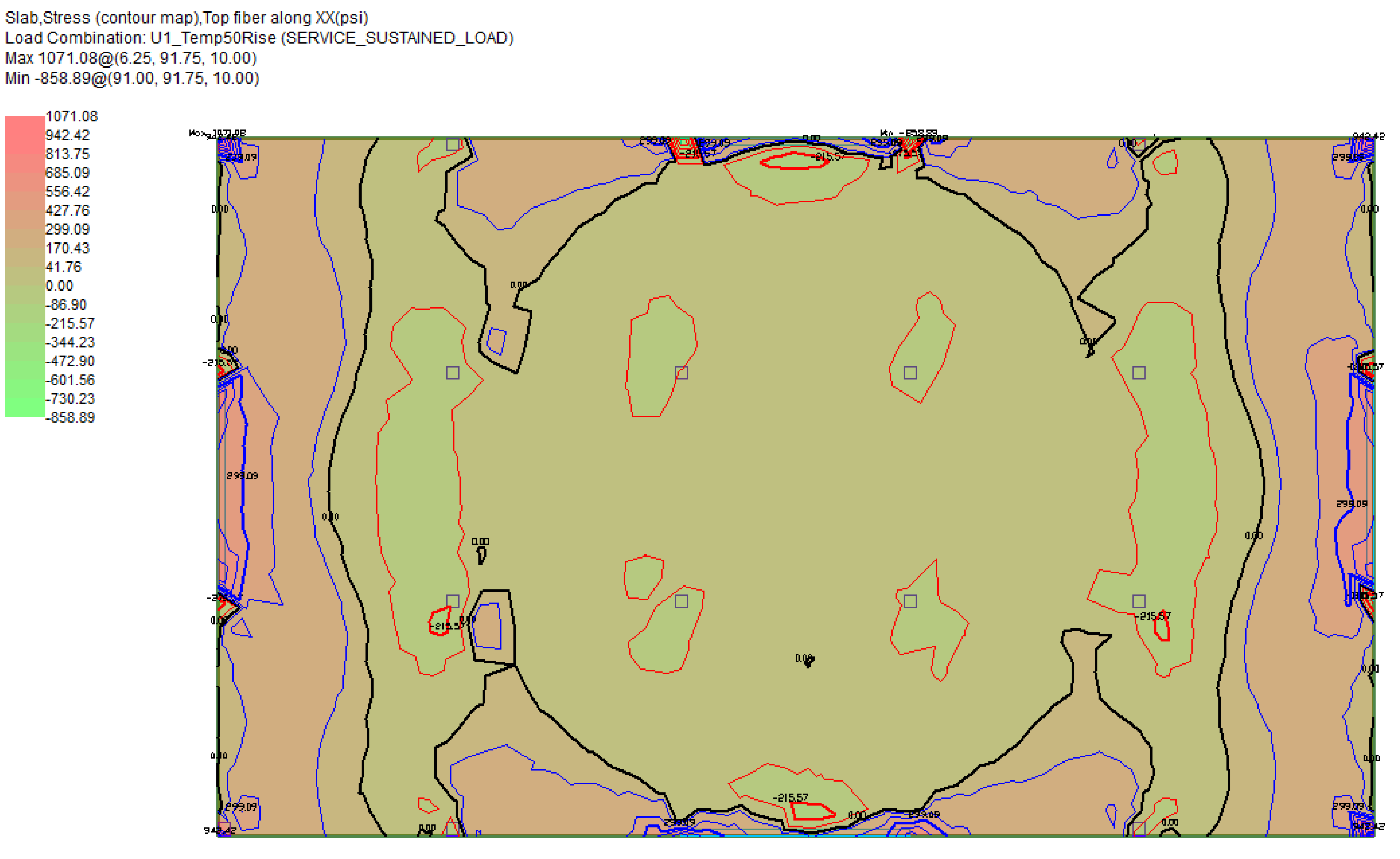
dT = 50 deg F Axial XX



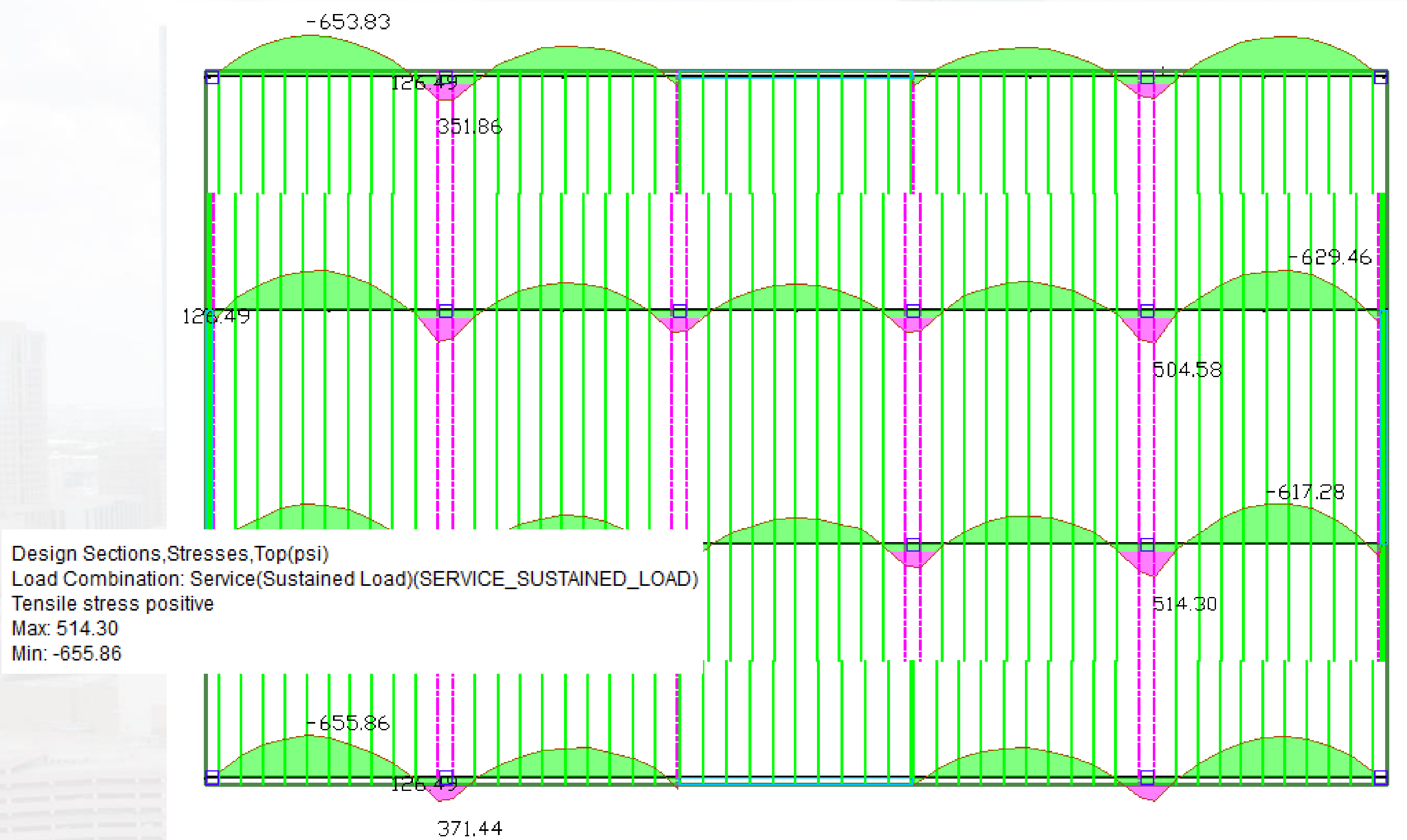
dT = 50 deg F Bottom Stress XX



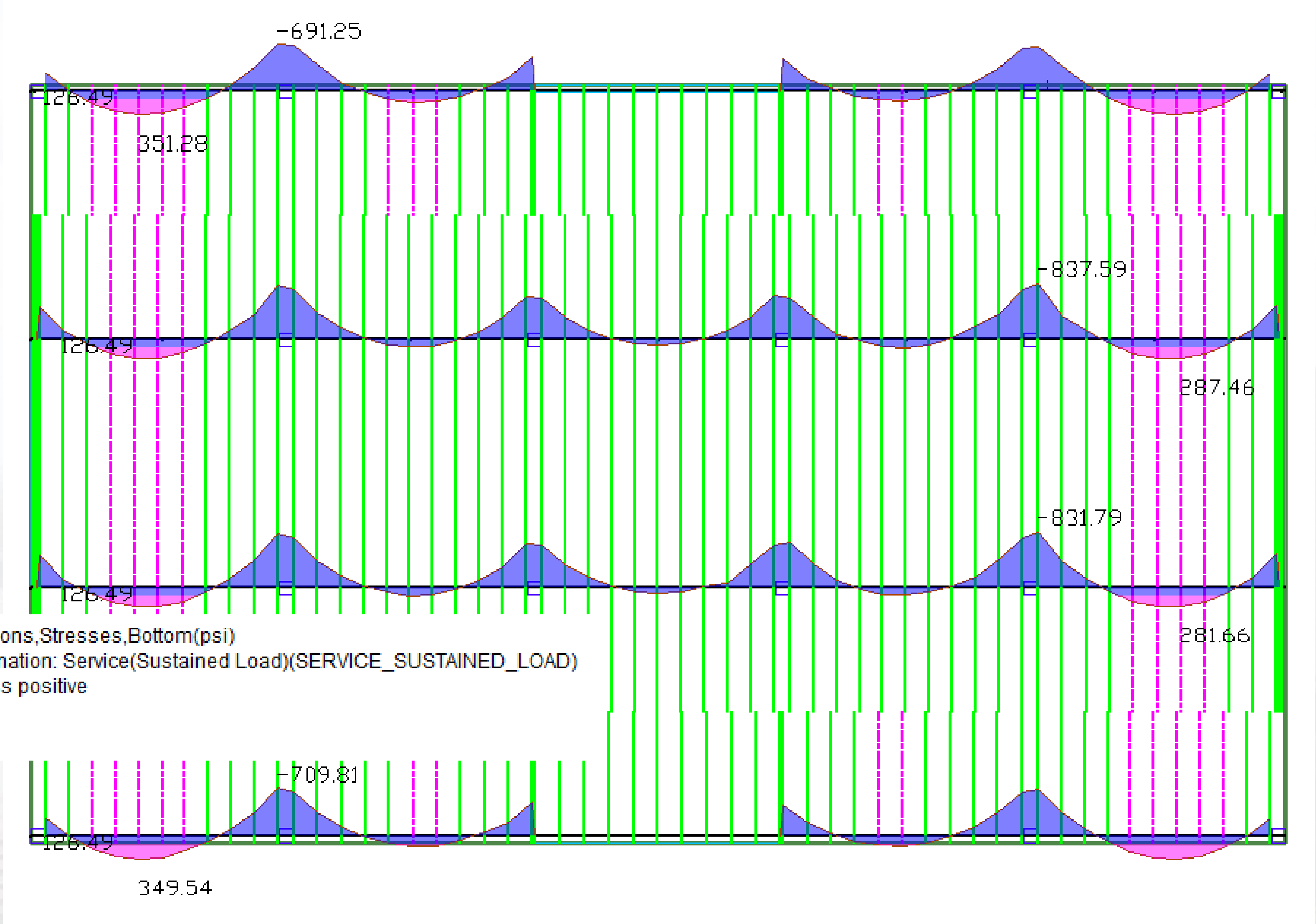
dT = 50 deg F Top Stress XX



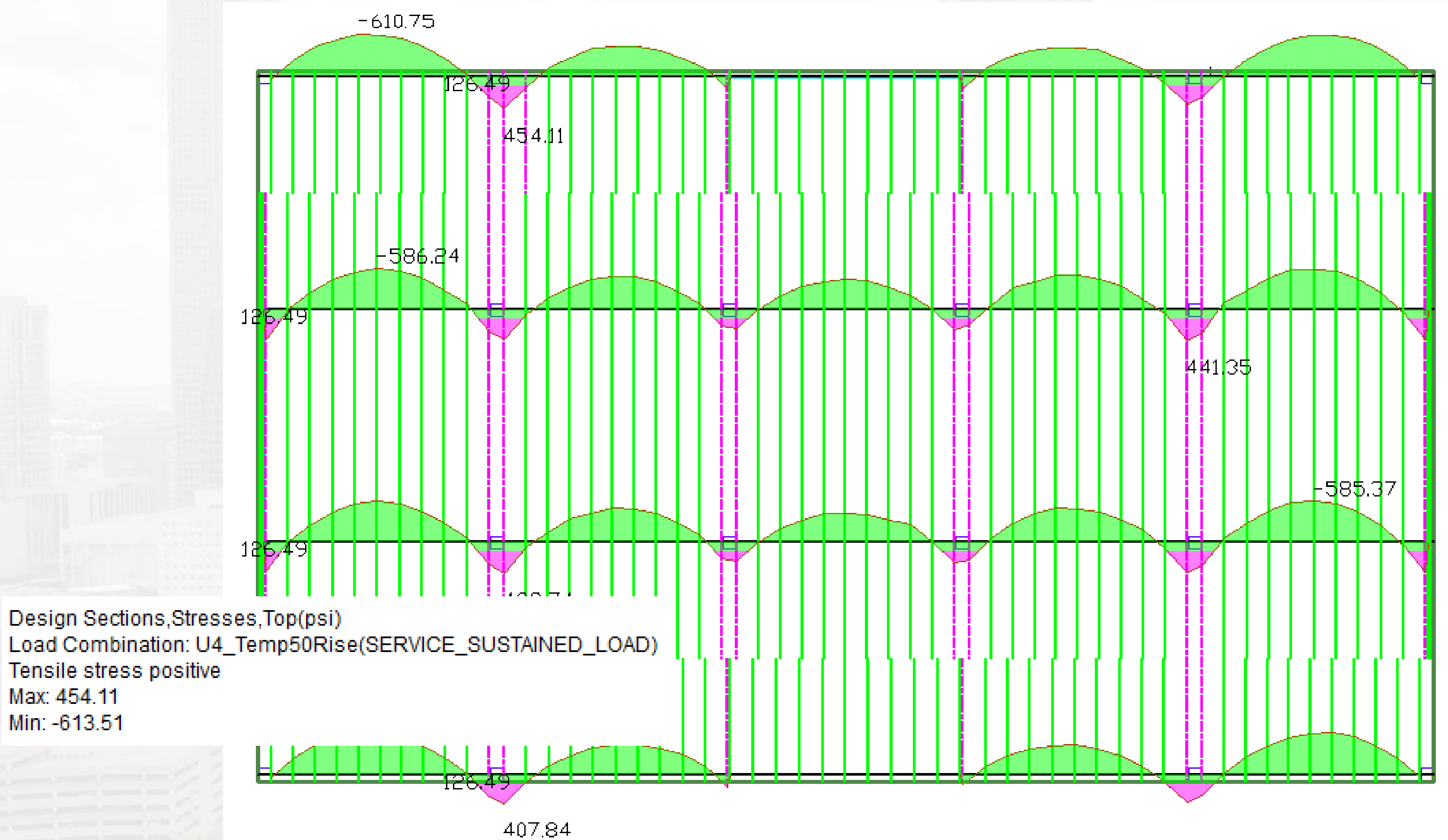
Sustained Load Design Stress Top



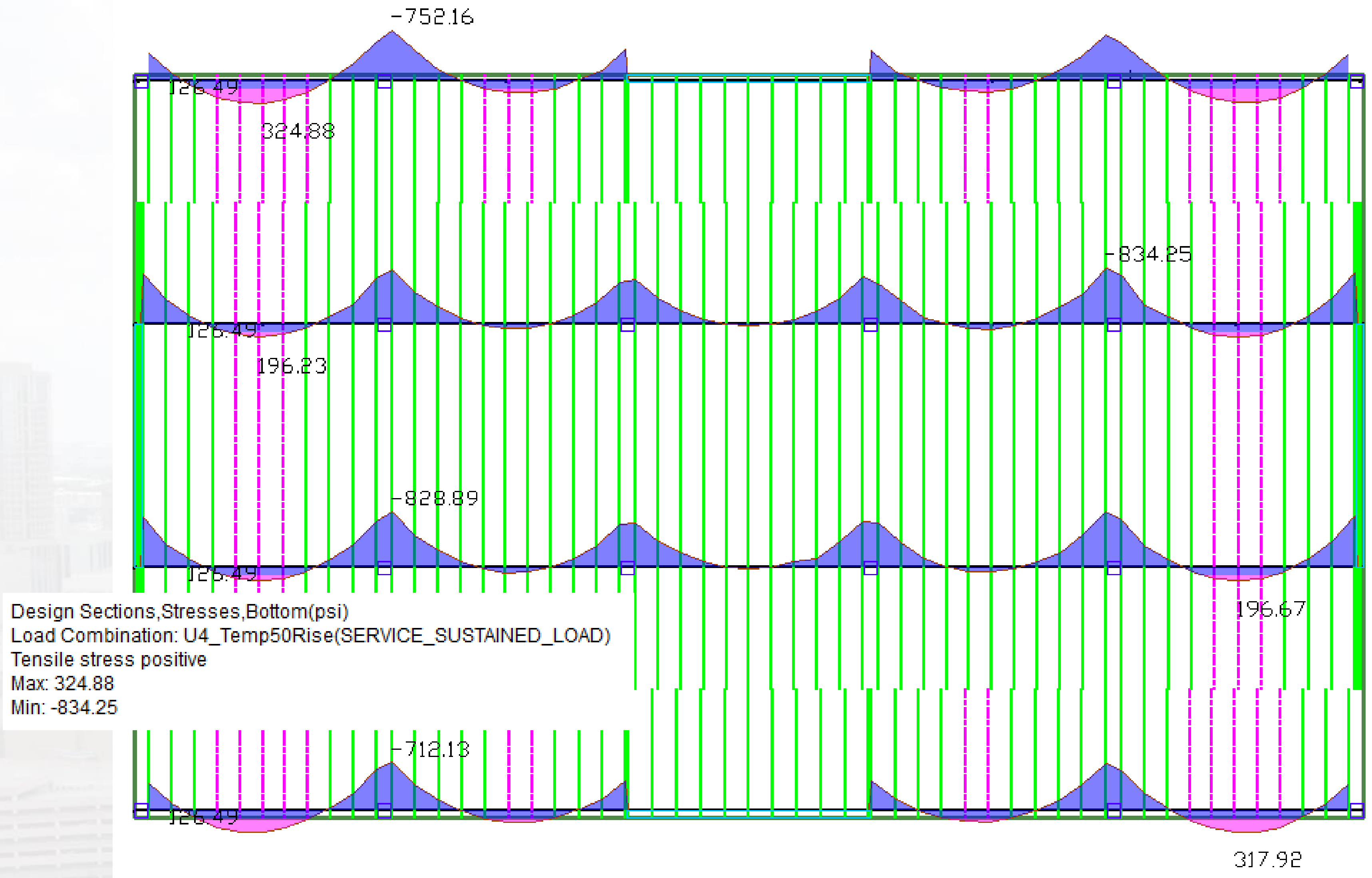
Sustained Load Design Stress Bot.



Dt = 50 deg F Design Stress Top

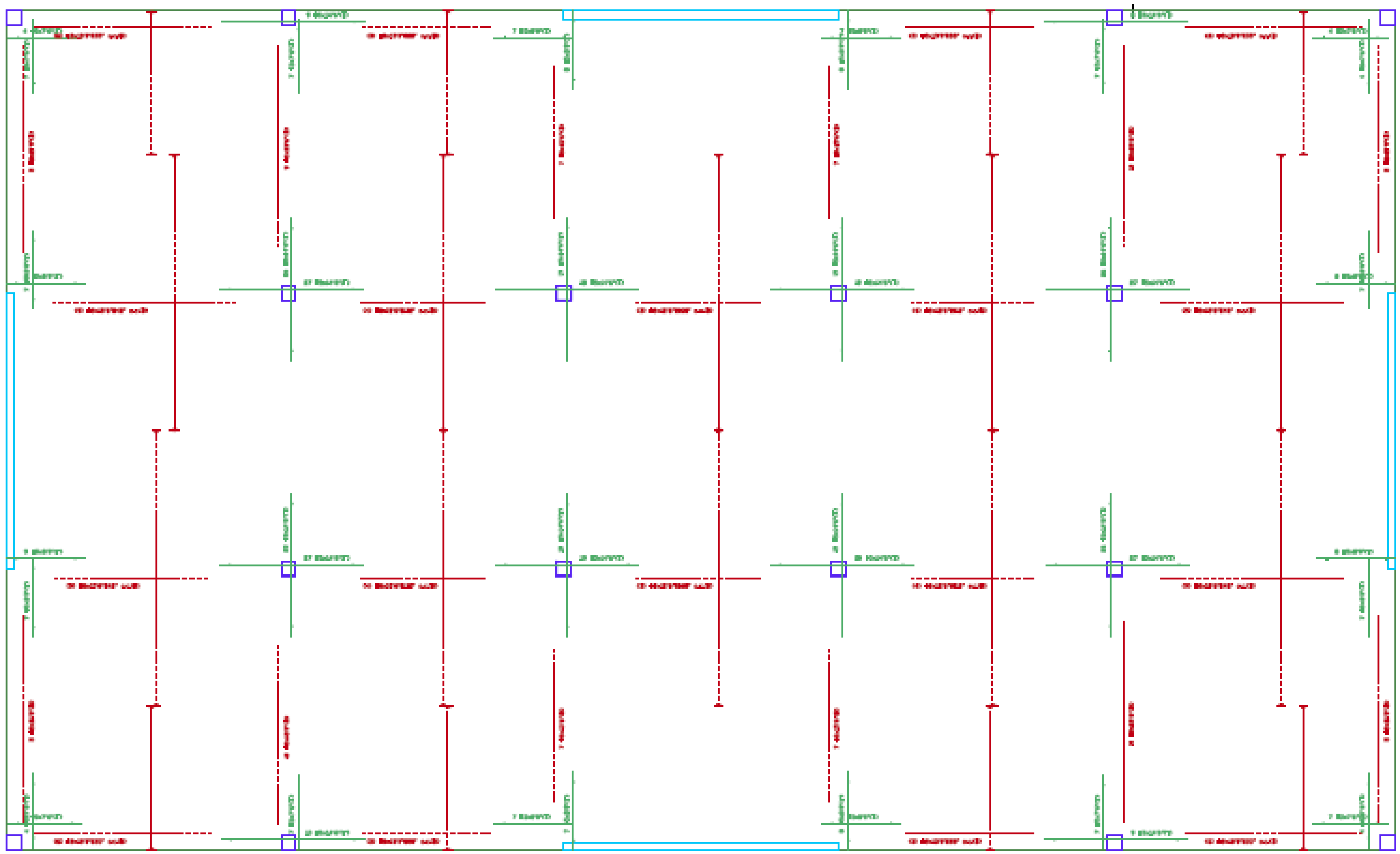


Dt = 50 deg F Design Stress Bot.



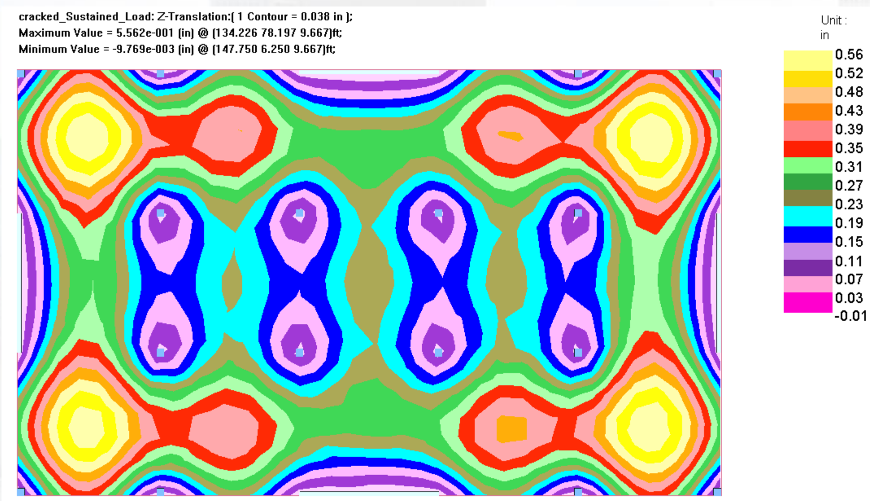
Envelope of Reinforcement

In this example, Total Load Service stresses governed design

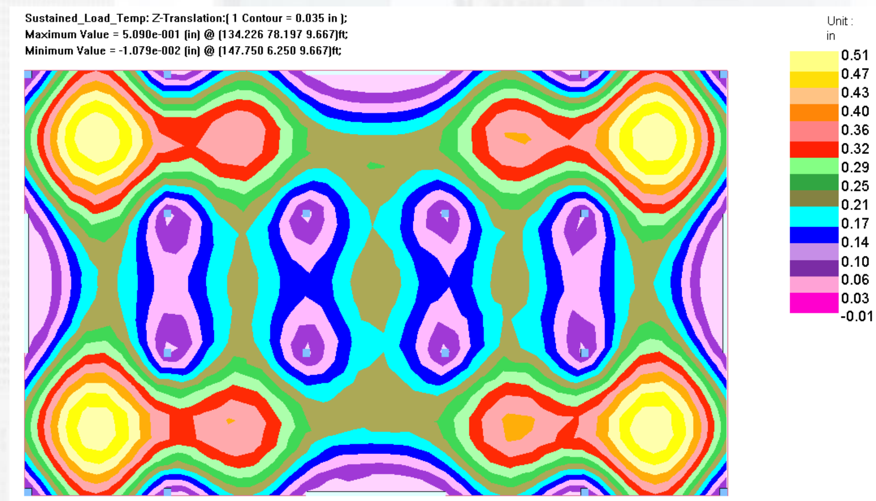


Deflections

In this example, temperature loads re-distribute stresses to slightly reduce cracked deflections



Cracked Sustained Load Deflection
0.56”



Cracked Sustained Load Deflection with Temperature
0.51”

Conclusion

- Exposed concrete floors can be subject to temperature loads
- Design objective is to mitigate crack formation
- Temperature induced stresses can be quantified
- Add reinforcement to control cracks, if needed