

Post-Tensioned Floors Design for Temperature

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ADAPT
Concrete Design Software



POST-TENSIONING INSTITUTE
Stressing the Stronger Concrete Solution™

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

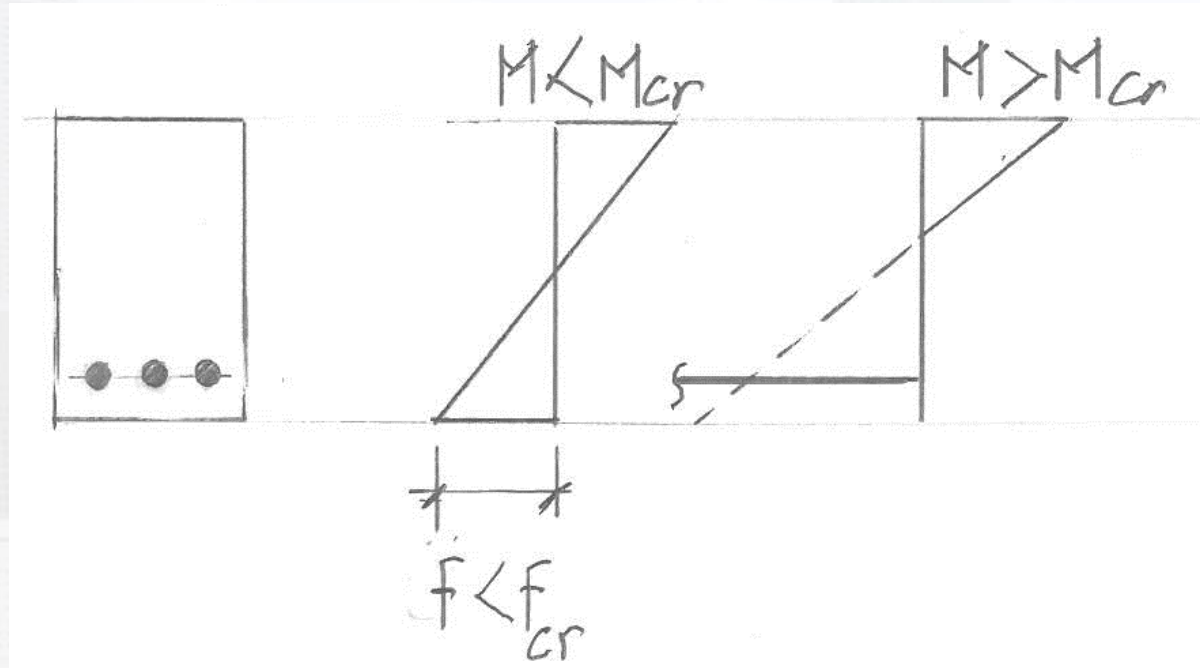
- Response of beam and one-way slabs different than that of two-way systems

Beams and One-Way Systems

- Concrete section under bending and axial forces cracks when the tensile stress reaches the modulus of rupture f_{cr} given in ACI 318
 - $f_{cr} = 7.5 \sqrt{f'_c}$
 - The cracking moment M_{cr} is given by:
 - $M_{cr} = (f_{cr} + P/A)S$
- 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

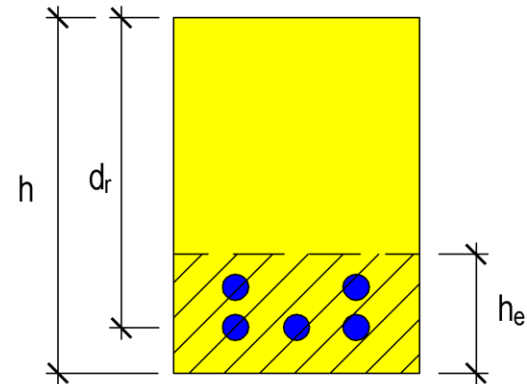


At initiation of cracking and for applied moments exceeding M_{cr} , the added contribution of reinforcement in the element will develop the resistance to the applied moment.

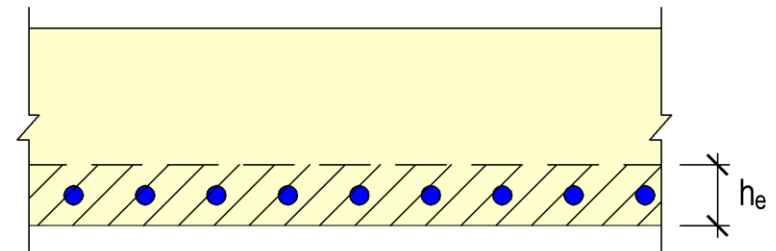
Beams and One-Way Systems

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



(a) Beam

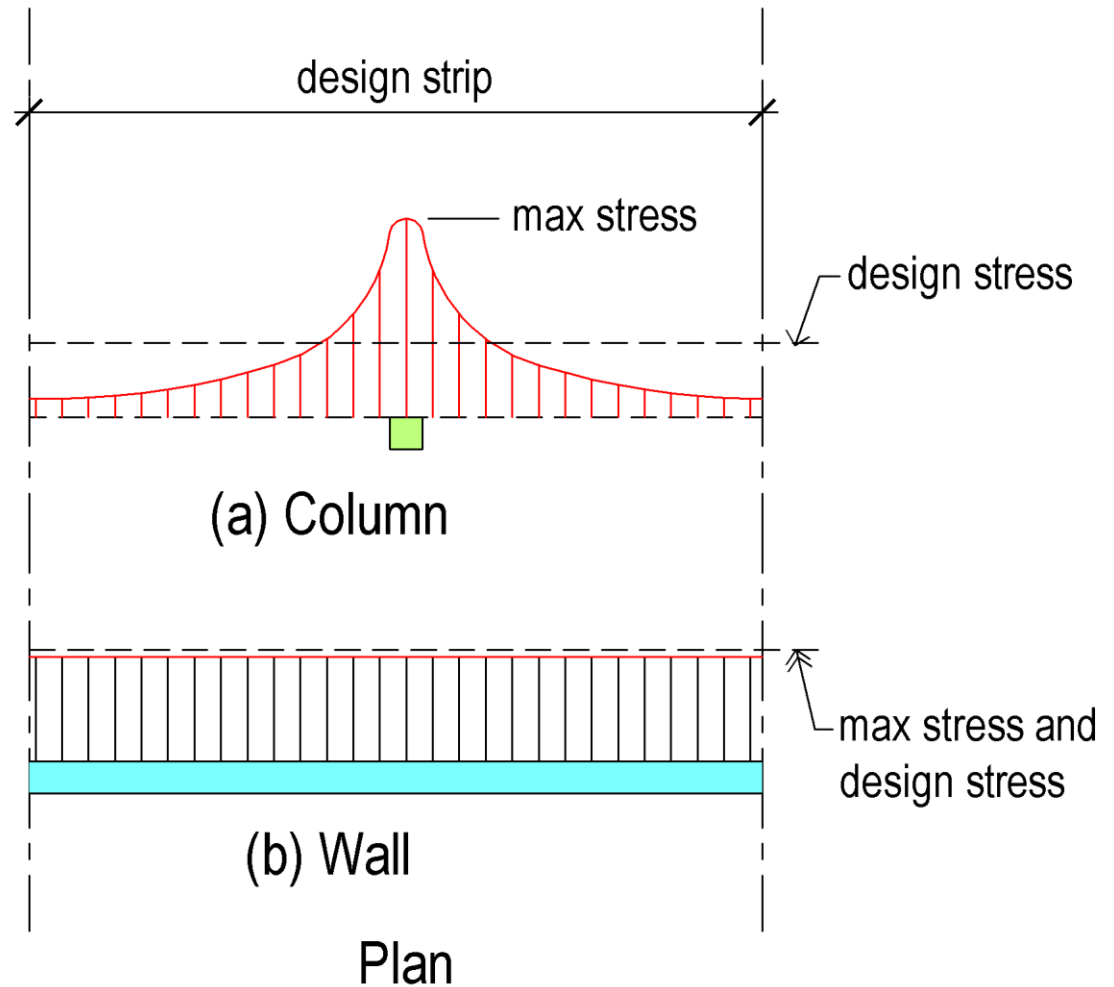


(b) Slab

h_e = effective tension area

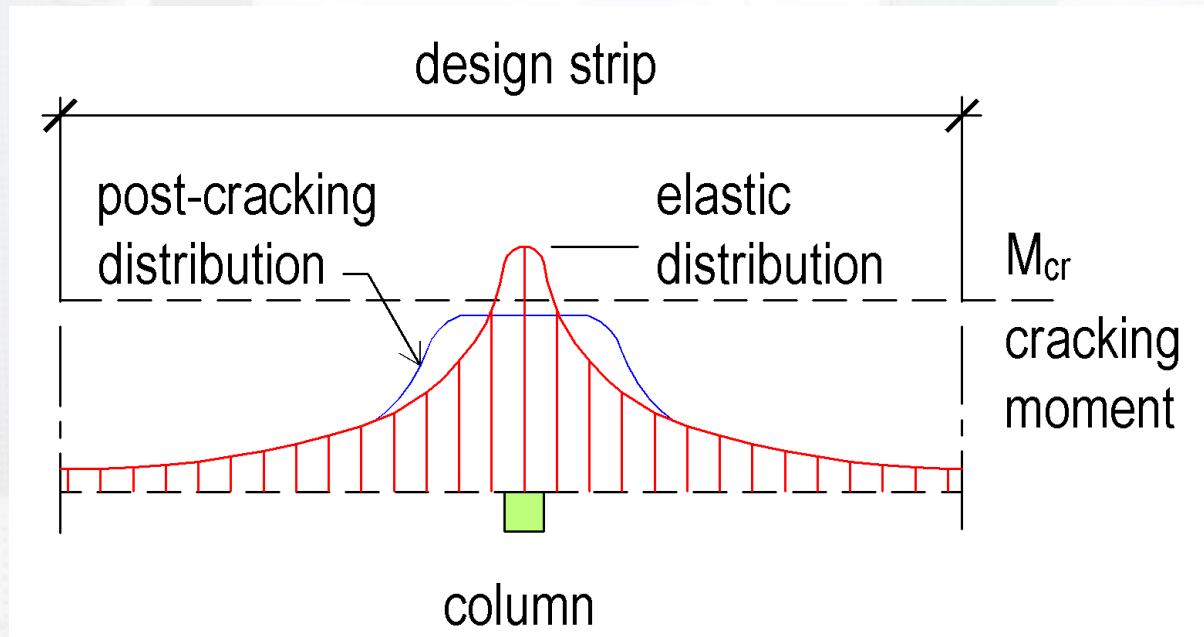
Two-Way Systems

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

$$A_{st} = N_c / (0.5 f_y)$$

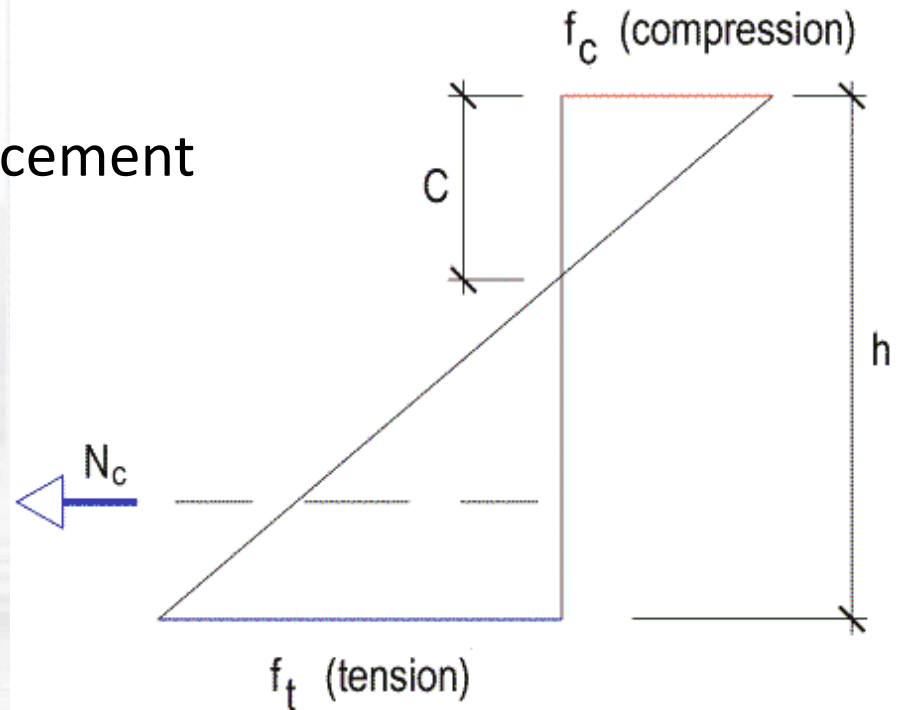
Where,

A_{st} = Area of added reinforcement

N_c = Tensile force

f_y = yield stress of steel

PTS114



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)

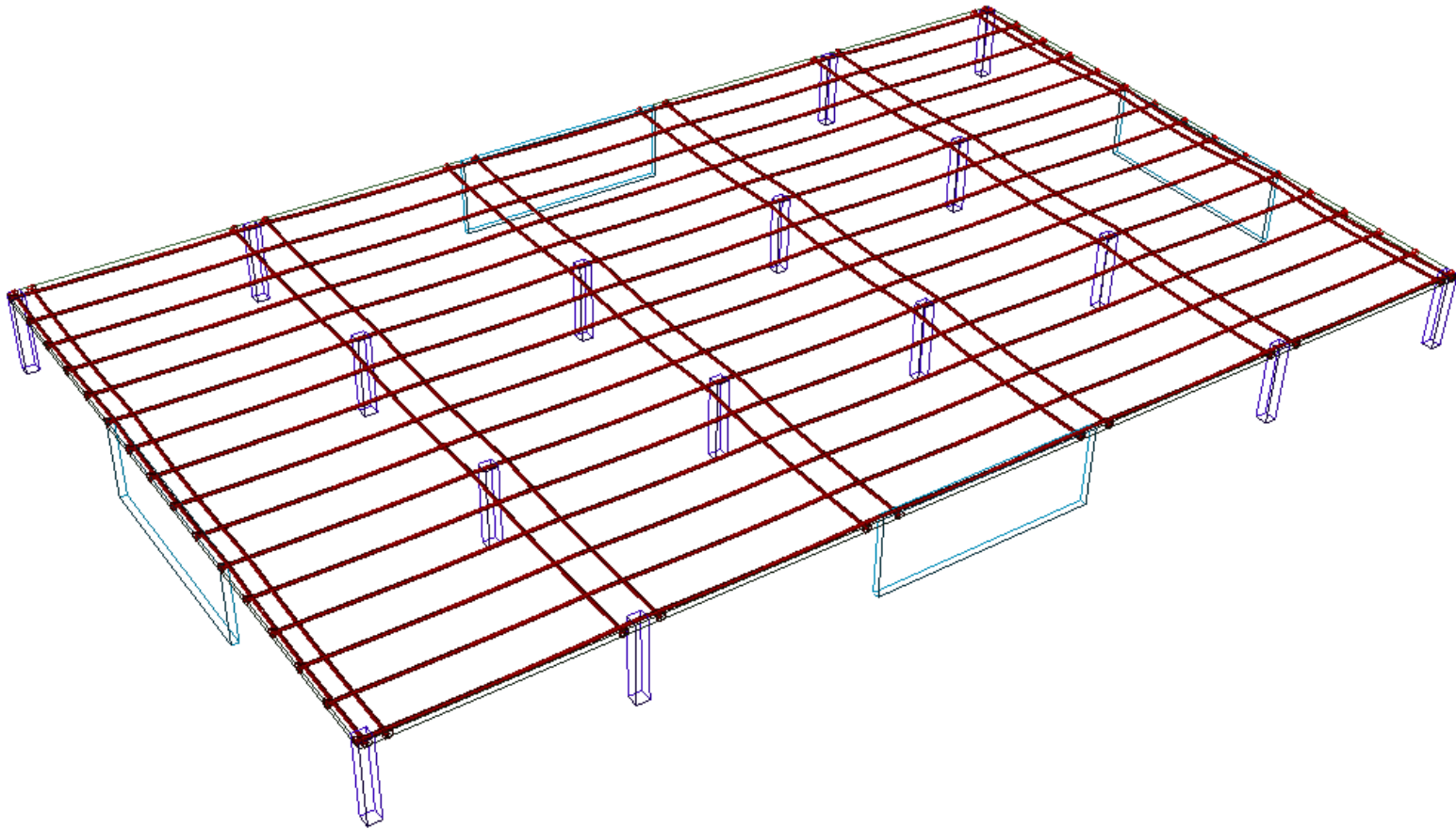
Design Procedure

- Identify sections where stress $> 2 \sqrt{f'_c}$
- Calculate required crack control reinforcement A_{st}
- Provide reinforcement on tension side if:

$$A_{st} > A_s + A_{ps}$$

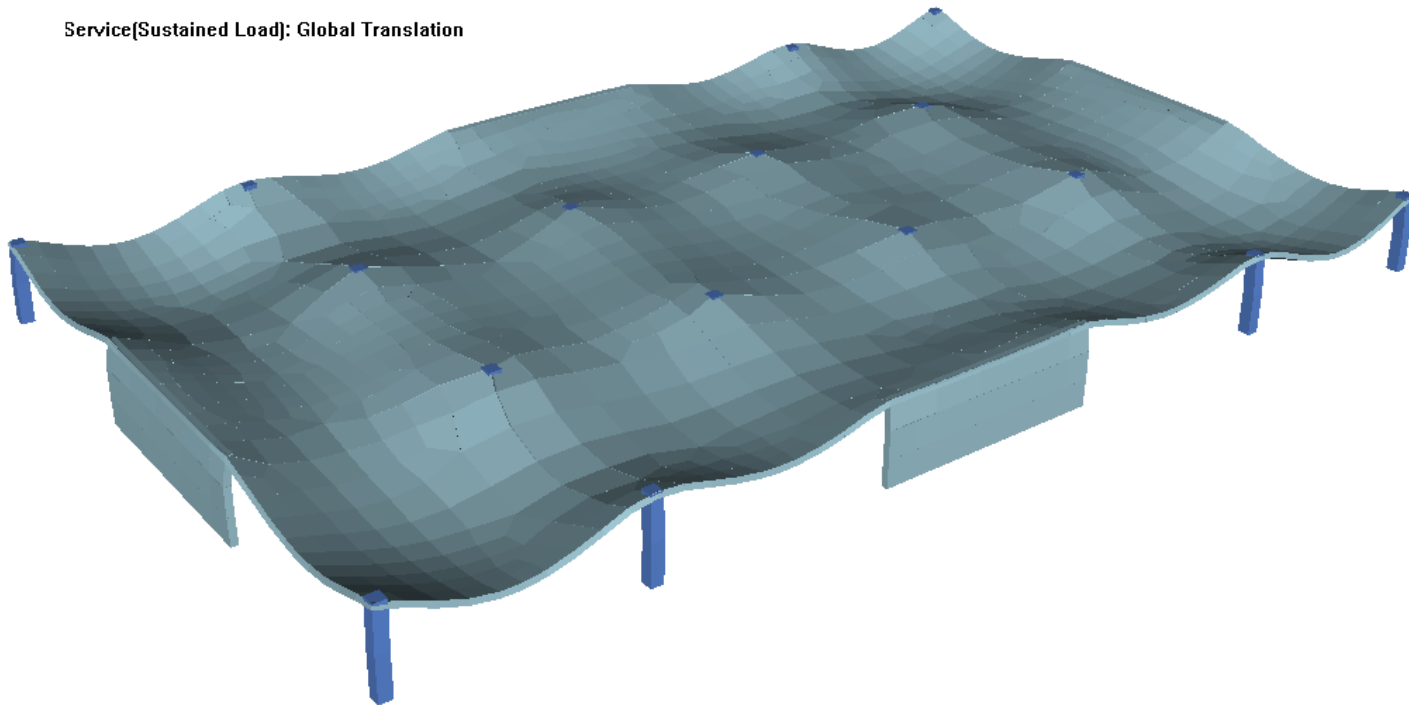
where A_s is the available rebar in the design section; and
 A_{ps} is the area of bonded reinforcement in the design section

Example Post-Tensioned Slab



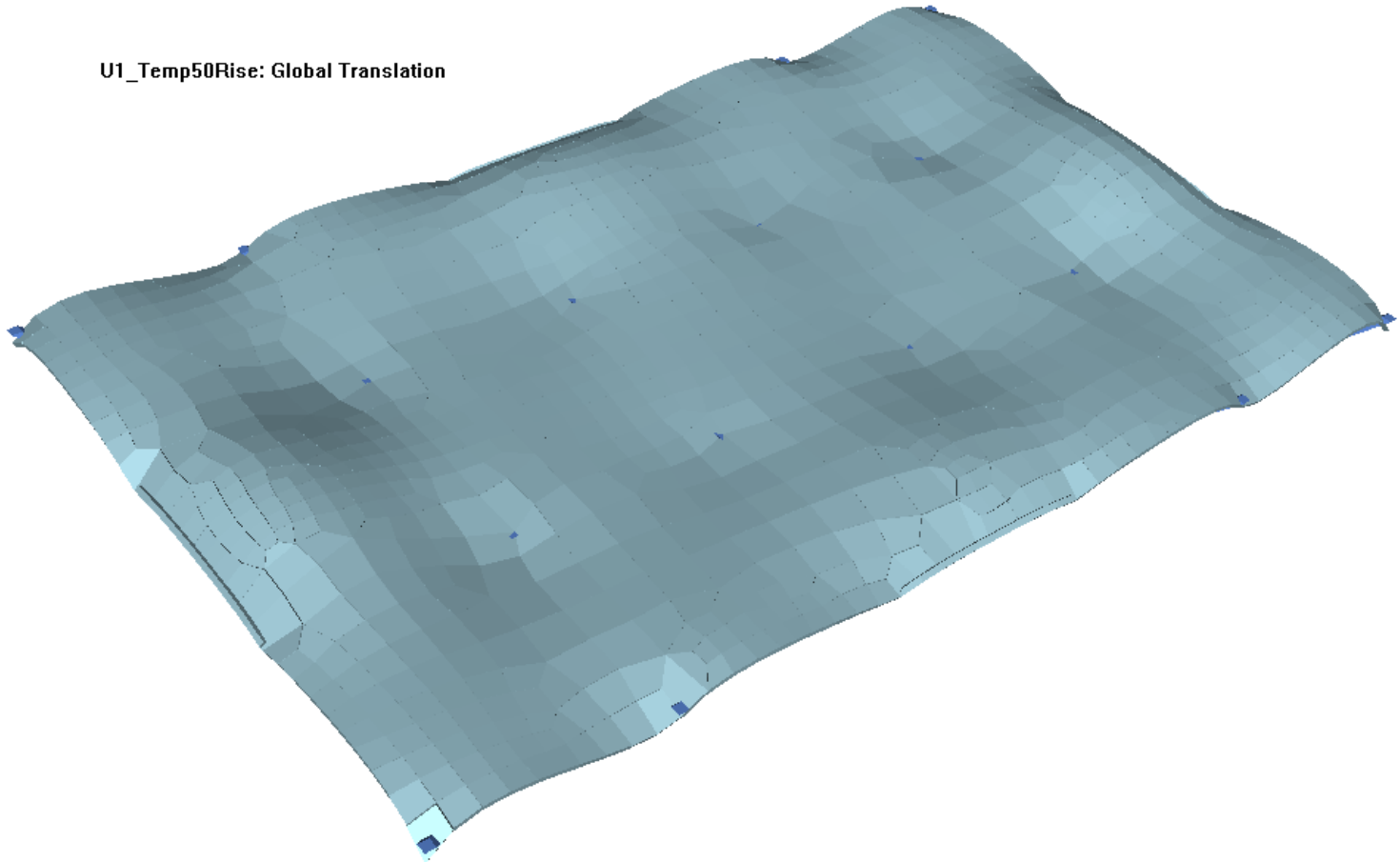
Sustained Load Deflection

Service(Sustained Load): Global Translation

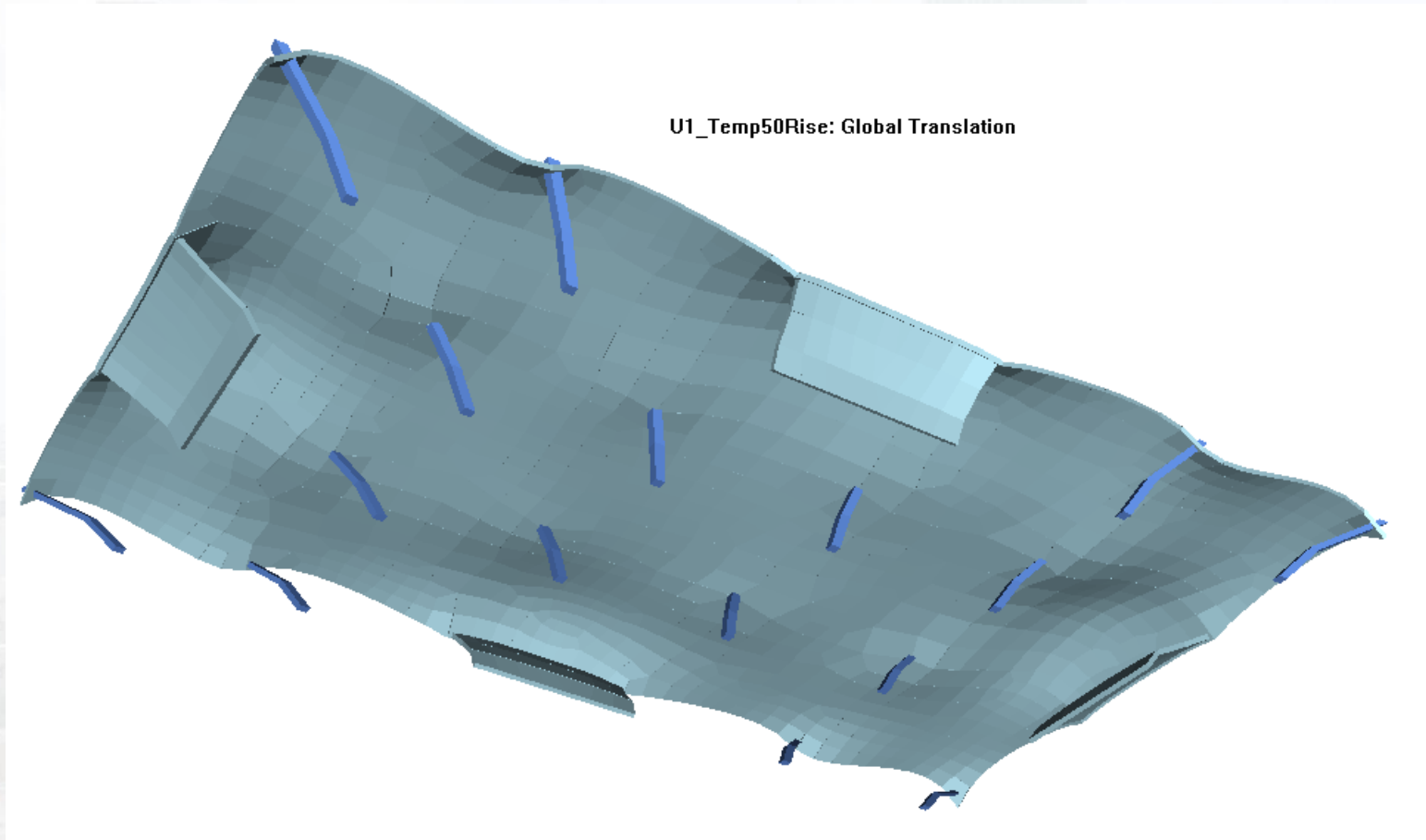


dT = 50 deg F Deflection

U1_Temp50Rise: Global Translation



dT = 50 deg F Deflection

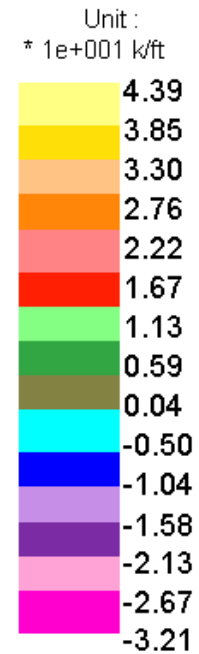
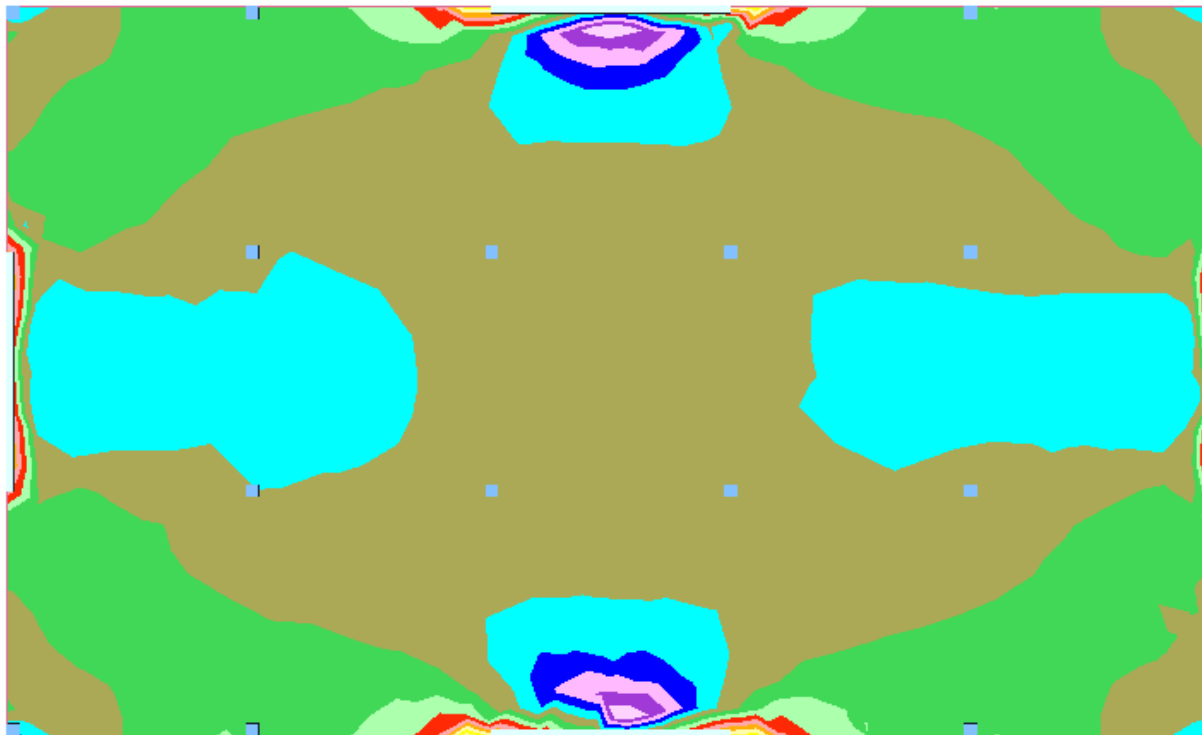


dT = 50 deg F Axial XX

U1_Temp50Rise: Nxx-Axial: (1 Contour = 5.068 k/ft);

Maximum Value = 4.388e+001 (k/ft) @ (60.003 6.250 9.667)ft;

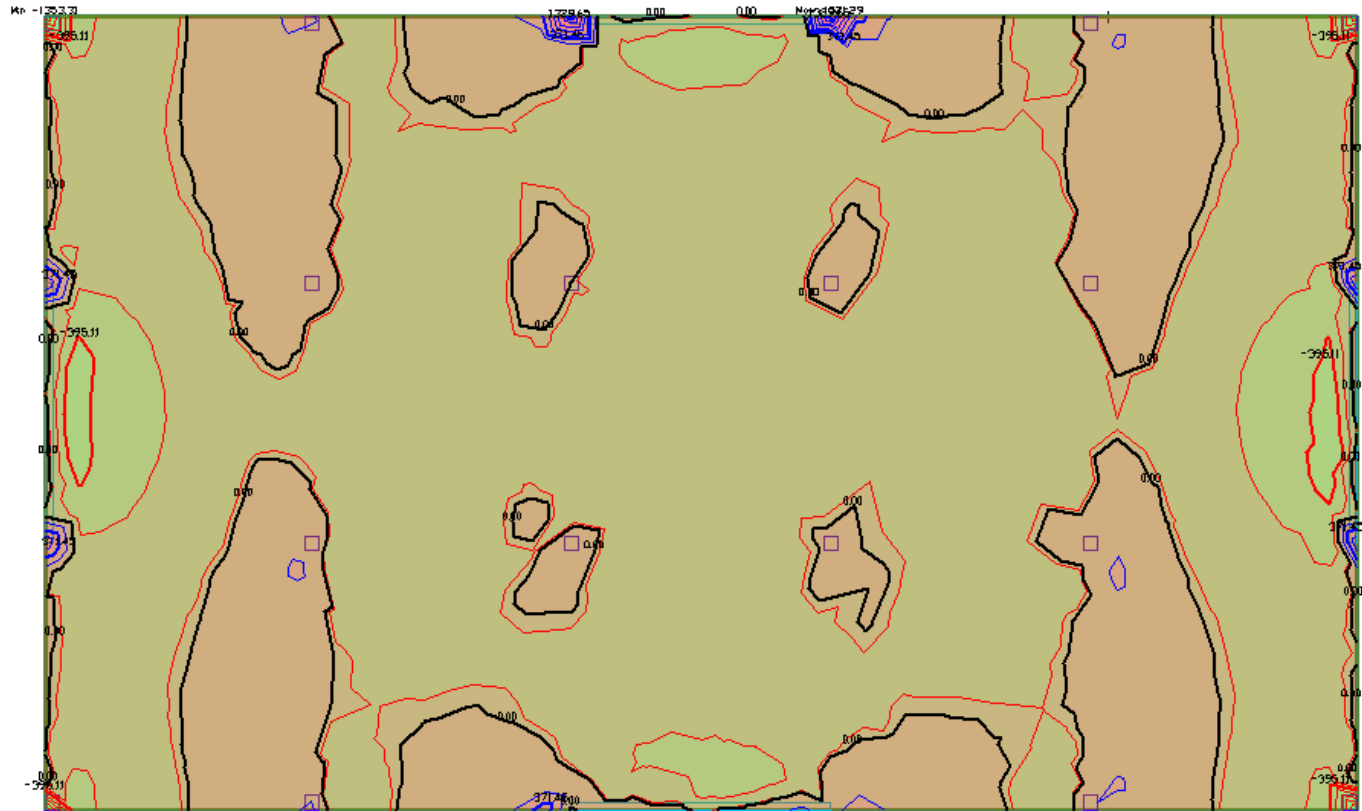
Minimum Value = -3.214e+001 (k/ft) @ (76.848 89.339 9.667)ft;



dT = 50 deg F Bottom Stress XX

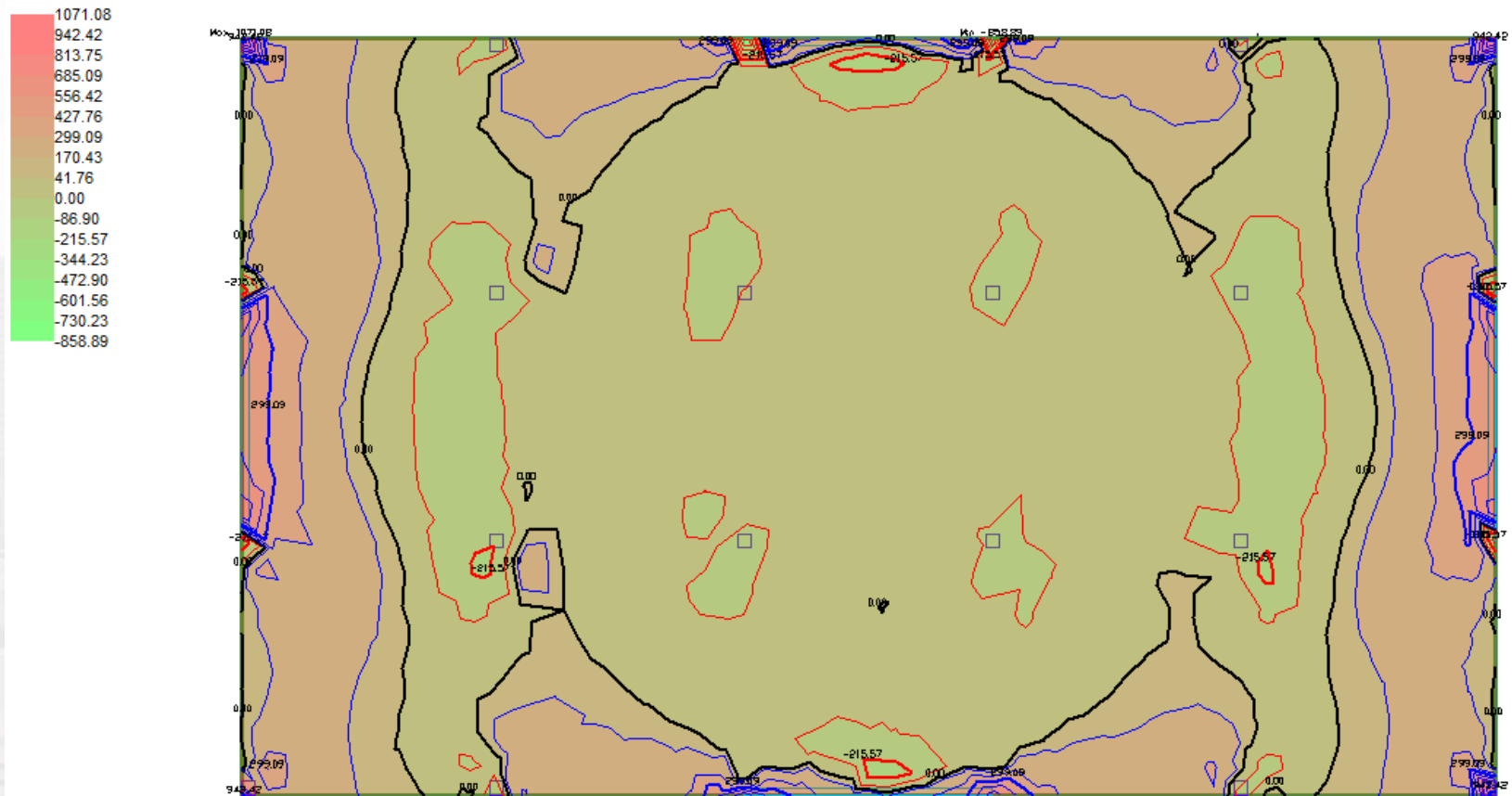
Slab.Stress (contour map),Bottom fiber along XX(psi)
Load Combination: U1_Temp50Rise (NO_CODE_CHECK)
Max 1521.29@(91.00, 91.75, 10.00)
Min -1353.31@(6.25, 91.75, 10.00)

1521.29
1329.65
1138.01
946.37
754.73
563.09
371.45
179.81
0.00
-11.83
-203.47
-395.11
-586.75
-778.39
-970.03
-1161.67
-1353.31

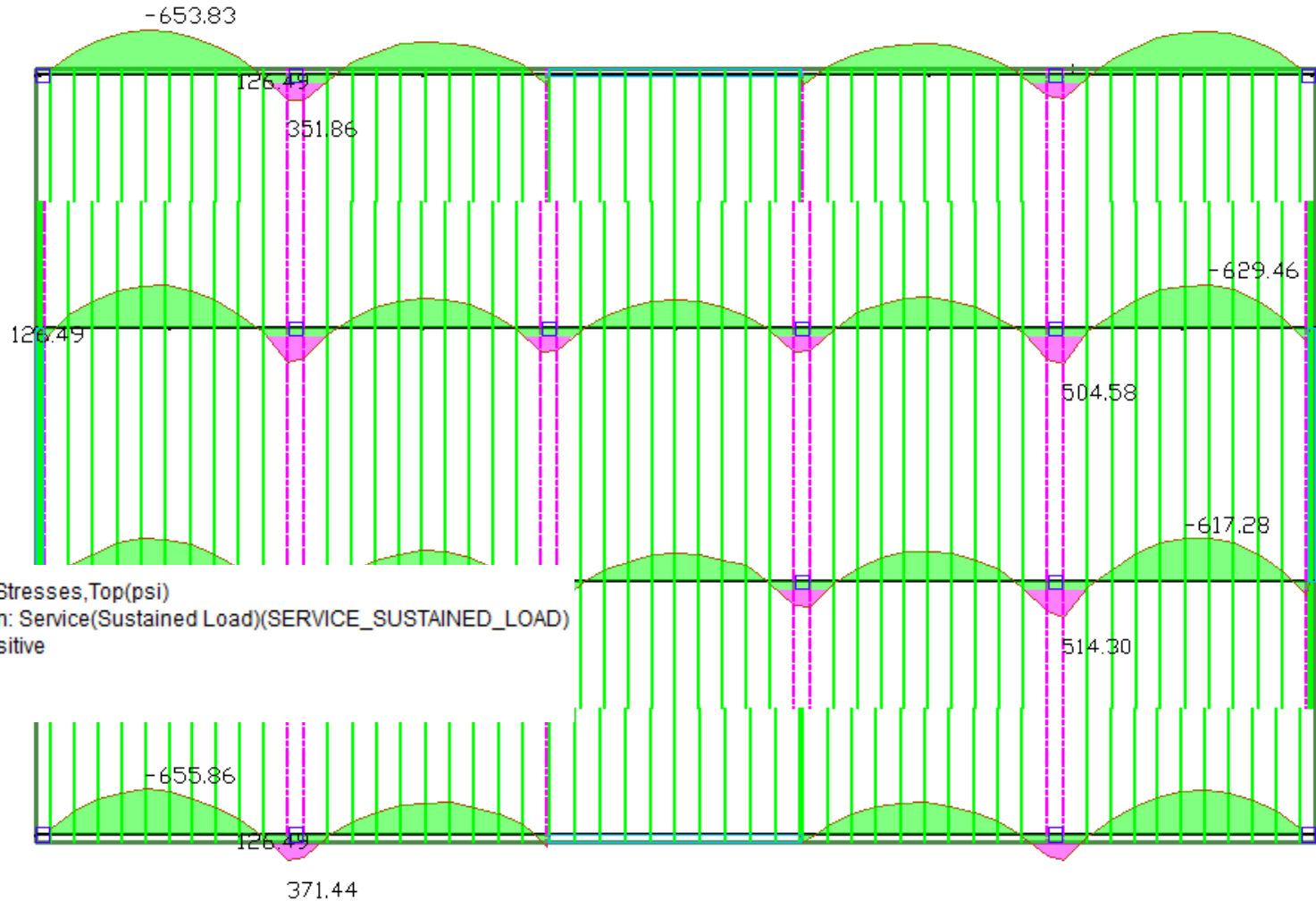


dT = 50 deg F Top Stress XX

Slab, Stress (contour map), Top fiber along XX (psi)
Load Combination: U1_Temp50Rise (SERVICE_SUSTAINED_LOAD)
Max 1071.08@(6.25, 91.75, 10.00)
Min -858.89@(91.00, 91.75, 10.00)



Sustained Load Design Stress Top



Design Sections, Stresses, Top (psi)

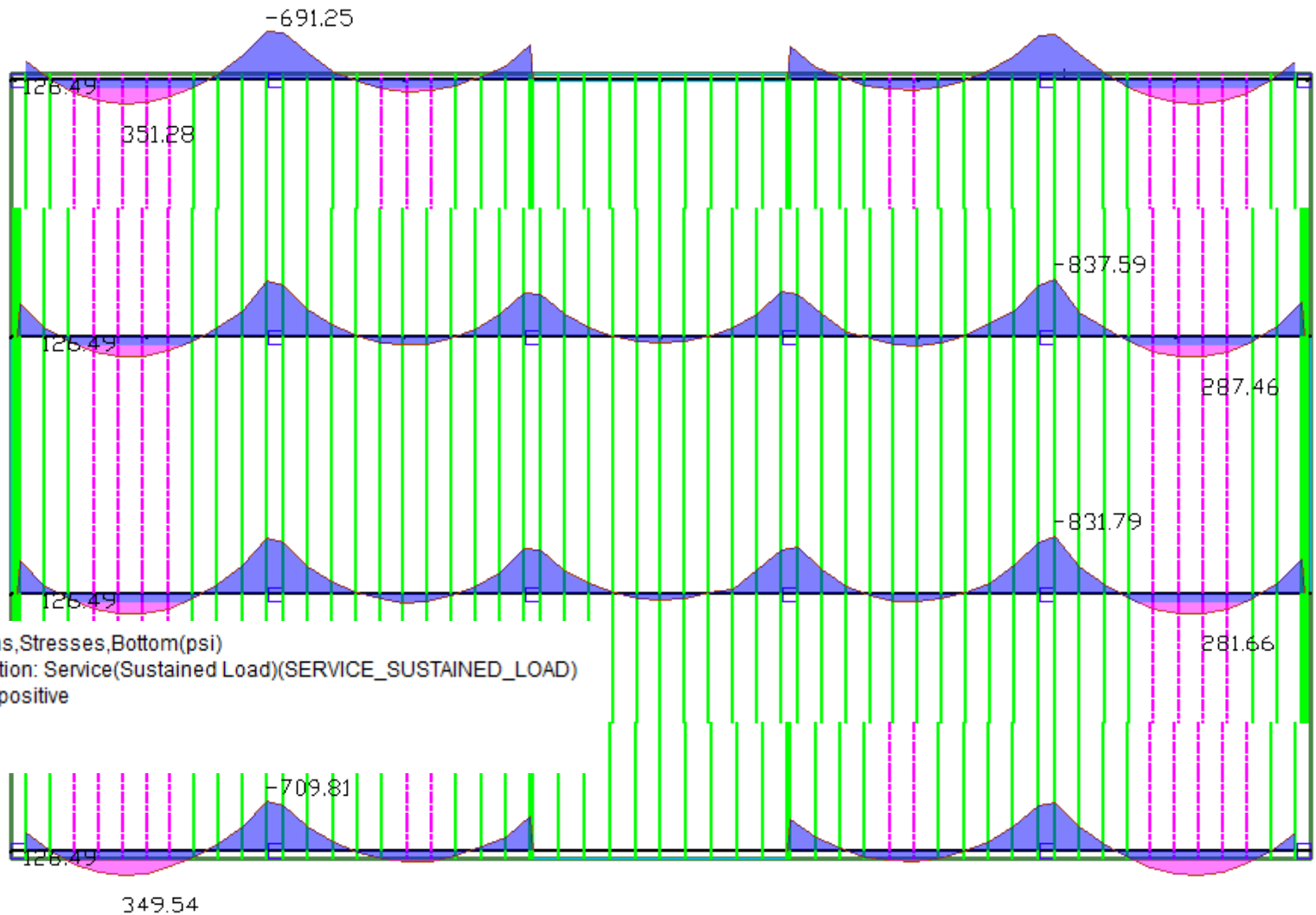
Load Combination: Service (Sustained Load) (SERVICE_SUSTAINED_LOAD)

Tensile stress positive

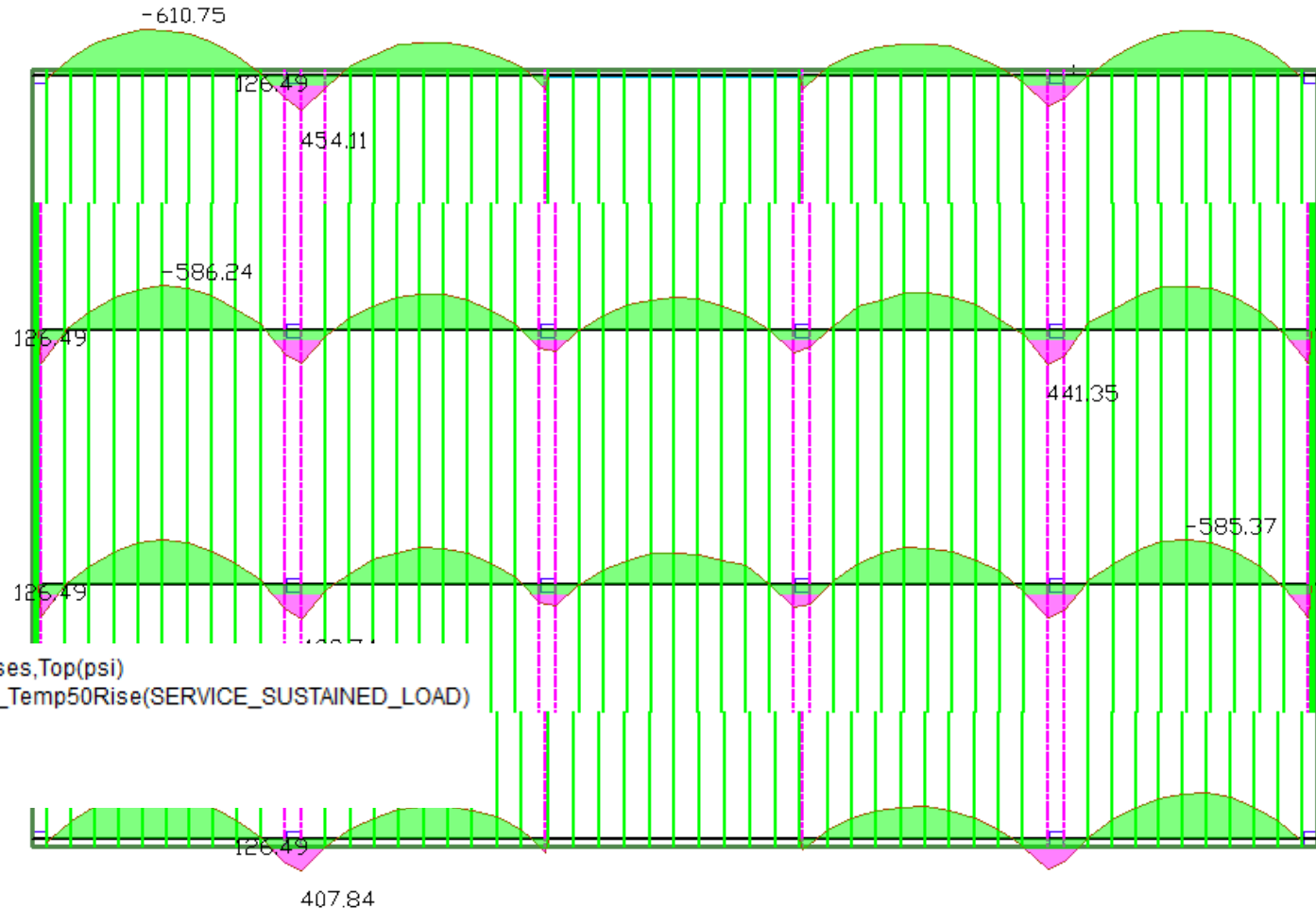
Max: 514.30

Min: -655.86

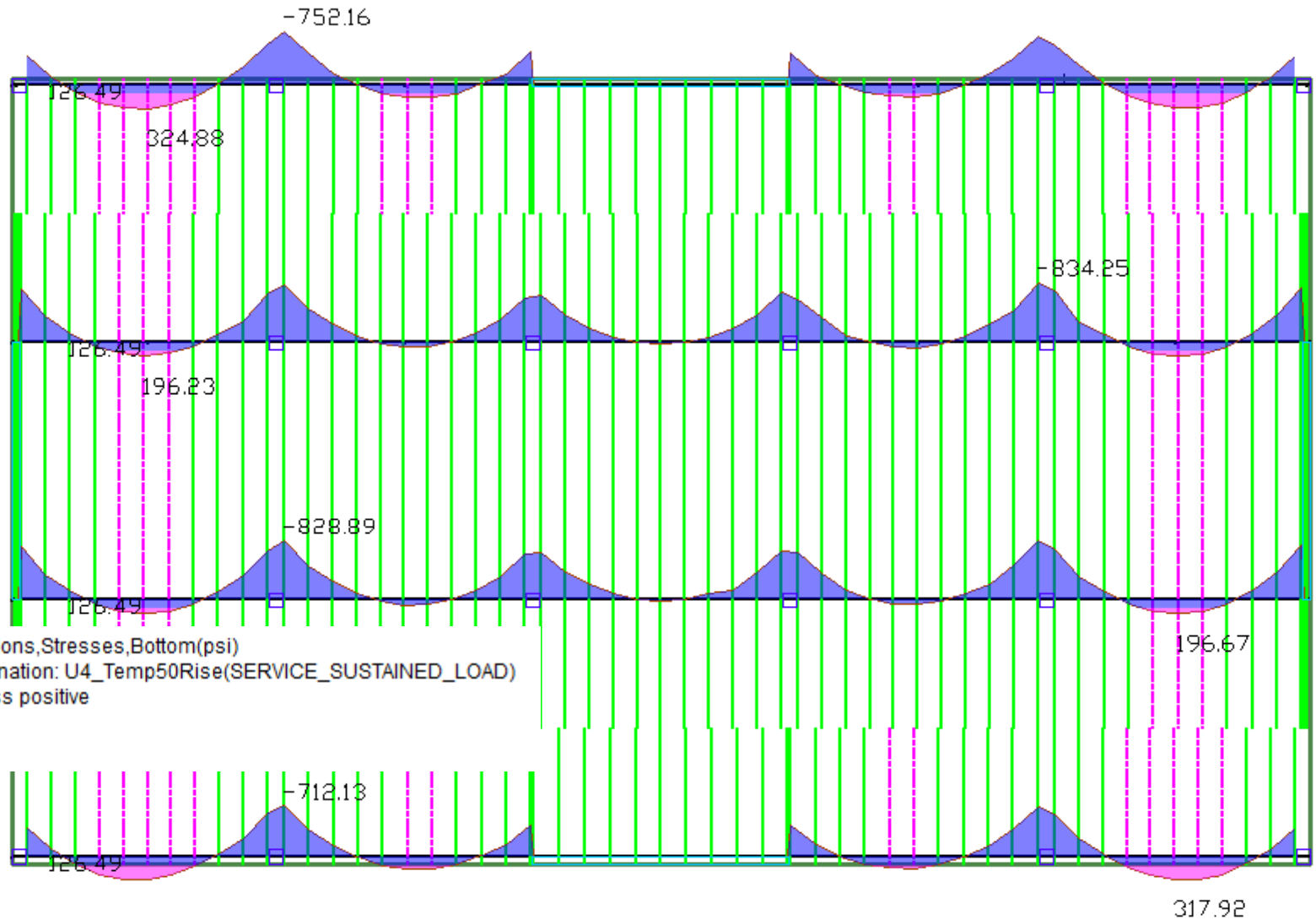
Sustained Load Design Stress Bot.



Dt = 50 deg F Design Stress Top



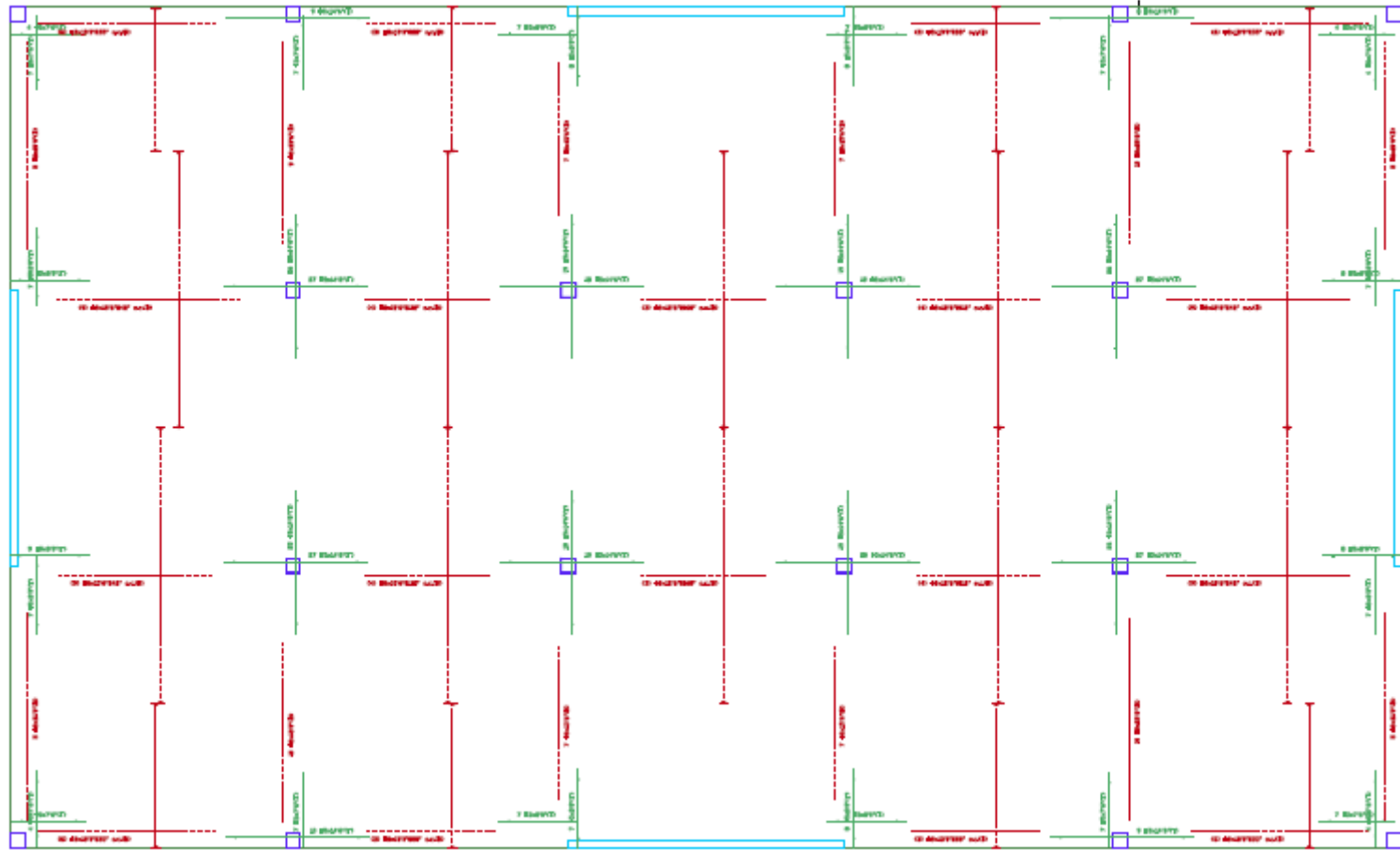
Dt = 50 deg F Design Stress Bot.



Design Sections, Stresses, Bottom (psi)
Load Combination: U4_Temp50Rise(SERVICE_SUSTAINED_LOAD)
Tensile stress positive
Max: 324.88
Min: -834.25

Envelope of Reinforcement

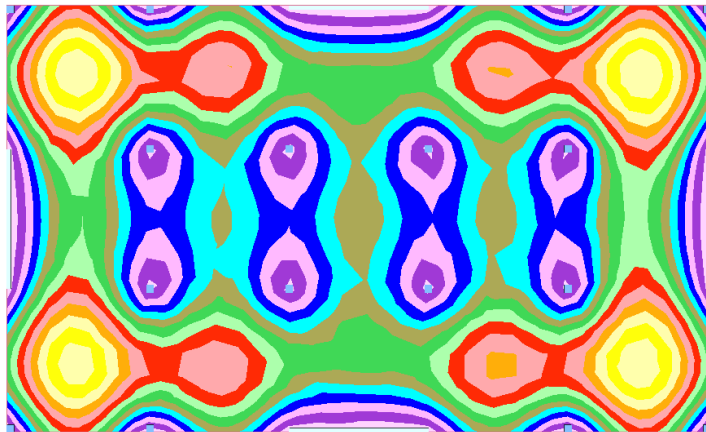
In this example, Total Load Service stresses governed design



Deflections

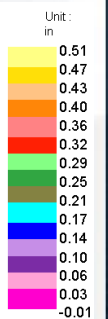
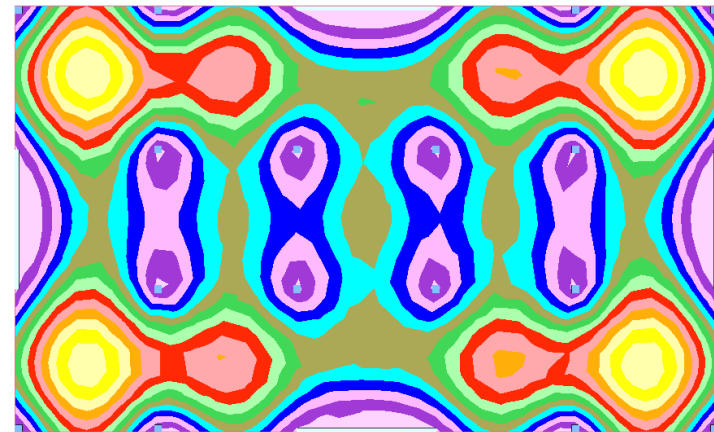
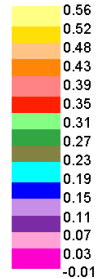
In this example, temperature loads re-distribute stresses to slightly reduce cracked deflections

cracked_Sustained_Load: Z-Translation: [1 Contour = 0.038 in];
Maximum Value = 5.562e-001 [in] @ [134.226 78.197 9.667]ft;
Minimum Value = -9.769e-003 [in] @ [147.750 6.250 9.667]ft;



Cracked Sustained Load Deflection
0.56"

Unit: in
Sustained_Load_Temp: Z-Translation: [1 Contour = 0.035 in];
Maximum Value = 5.090e-001 [in] @ [134.226 78.197 9.667]ft;
Minimum Value = -1.079e-002 [in] @ [147.750 6.250 9.667]ft;



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