Calculations for Handling and Shipping Precast Concrete Deck Panels

by Dr. Krista Brown

A common misconception is that increasing the amount of reinforcement in concrete will prevent cracking. Not so! When the stress in concrete reaches its tensile strength, cracking results. Reinforcement will control the width and distribution of cracks, but it does not prevent cracking.

Precast concrete deck panels may be more susceptible to cracking during handling and transportation stages, when strengths are typically lower and support points fewer, than in service. Cracking is a risk as panels are stripped from forms, transported to the storage yard, loaded onto a truck, shipped, and installed.

Precasters of building components, especially wall panels, have successfully designed panels with specific pick-point locations to avoid cracking during handling and transportation. This article presents simple calculations and measures to help designers, owners, precasters, and contractors ensure that precast concrete deck panels do not experience unacceptable cracking during handling and transportation. Cracking that may occur due to drying shrinkage, thermal factors, and other causes will not be addressed.

Methodology

Section 8.3 of the *PCI Design Handbook: Precast and Prestressed Concrete*[1] provides a procedure and examples for determining stresses in flat panels during handling and transportation. With this procedure, which includes the effects of openings and other changes in cross-section geometry, tensile stresses in a precast concrete deck panel are calculated using basic mechanics of materials and compared to the allowable tensile stress. The notation of the *PCI Design Handbook* is used in this article. Because only tensile stresses are calculated, all stresses will be shown as positive. Stresses are also shown in psi units rather than ksi used in bridge design.

The allowable tensile stress, $f_{allowable}$, is a criterion for no-discernible cracking that is used in the building industry.[1] It is determined by applying a factor of safety of 1.5 to the concrete modulus of rupture, which is a function of compressive strength.

$$f_{allowable} = \frac{7.5\sqrt{f'_c}}{1.5} = 5\sqrt{f'_c}$$

where

f'_c = concrete compressive strength at the time of handling or transportation, psi

Note $5\sqrt{f'_c}$ is equivalent to $0.158\sqrt{f'_c}$ with both f'_c and $f_{allowable}$ in ksi.

The tensile stress in the concrete section, f_t, is calculated by

$$f_t = \frac{M}{S}$$

where

M = moment at the concrete section with a PCI-recommended load multiplier applied for handling or transportation, kip-in.

S = section modulus, in.^{3}

Table 8.3.1 in the *PCI Design Handbook* lists recommended load multipliers to account for forces caused by form suction and impact during handling and transportation. These multipliers are applied to the weight of the panel and are based on typical experience of precast concrete producers. The multipliers may be modified based on specific conditions and the experience or preferences of precasters or owners.

Because the multipliers and concrete strengths vary with each stage of handling and transportation, tensile stress and allowable tensile stress must be determined for each stage. The following examples demonstrate calculations for precast concrete deck panels at two stages—stripping from forms and shipping.

Example of Calculations for a Rectangular Deck Panel

Assume a 10 ft by 32 ft by 8¾ in. precast concrete panel with no openings, internal ducts, or other irregularities in the cross section.

Given

Normalweight concrete at 150 lb/ft^3

f'_{ci} = 4000 psi at stripping from forms

f'_c = 5000 psi at shipping

The panel will be handled with a four-point pick at locations shown in *PCI Design Handbook* Fig. 8.3.2, which equalizes positive and negative moments.

Calculate the allowable tensile stress at stripping:

$$f_{allowable} = 5\sqrt{4000} = 316 \text{ psi}$$

Calculate the maximum tensile stress in the panel's longitudinal direction using the equation from Fig. 8.3.2 of the *PCI Design Handbook* that assumes uniform loading.

a = 10 ft

b = 32 ft

t = 8.75 in.

$$w = \left(\frac{8.75}{12}\right)(150) = 109.4 \text{ lb/ft}^2$$

$$M = 0.214wab^2 = 0.0214(109.4)(10)(32^2)$$
$$= 23{,}973 \text{ lb-ft}$$

For a rectangular cross section:

$$S = \frac{at^2}{6} = (10)(12)\left(\frac{8.75^2}{6}\right) = 1531 \text{ in.}^3$$

At stripping from forms, apply a 1.3 multiplier for suction to determine tensile stress.

$$f_t = \frac{M}{S} = \frac{1.3(23{,}973)(12)}{1531} = 244 \text{ psi} \le 316 \text{ psi}$$

Allowable stress is not exceeded when stripping from forms. **OK**

In this example, the design concrete strength at shipping is higher than for stripping from forms, but the PCI-recommended load multiplier, 1.5, is also higher. It is assumed that the panel is supported by dunnage placed at the same locations as the pick points.

Repeat the procedure using f'_c = 5000 psi and a 1.5 load multiplier:

$$f_{allowable} = 5\sqrt{5000} = 354 \text{ psi}$$

$$f_t = \frac{M}{S} = \frac{(1.5)(23{,}973)(12)}{1531} = 282 \text{ psi} \le 354 \text{ psi}$$

Allowable stress is not exceeded during shipping. **OK**

Stresses in the panel should be checked in both directions. However, in this example, the tensile stress in the panel's transverse direction is not checked and does not govern due to the panel's dimensions. Lifter capacities and moment and shear capacities of the panel should also be checked.

Deck Panel with Full-Depth Pockets

Next, consider the same deck panel, except that it has a series of five 6 in. by 24 in. full-depth pockets for a connection that will later be grouted. For the purposes of this example, the pockets are at or near the lifting points, but this is not recommended in practice since this is the location of maximum moment. Because of the pockets, the effective cross section will have a reduced width. The slight reduction in the weight of the panel will be neglected.

$$S = \frac{at^2}{6} = \left[10 - 5\left(\frac{6}{12}\right)\right](12)\left(\frac{8.75^2}{6}\right) = 1148 \text{ in.}^3$$

At stripping from forms:

$$f_t = \frac{M}{S} = \frac{1.3(23{,}973)(12)}{1148} = 326 \text{ psi} > 316 \text{ psi}$$

Allowable tensile stress is exceeded. **No good.**

At shipping:

$$f_t = \frac{M}{S} = \frac{1.5(23{,}973)(12)}{1148} = 376 \text{ psi} > 354 \text{ psi}$$

Allowable tensile stress is exceeded. **No good.**

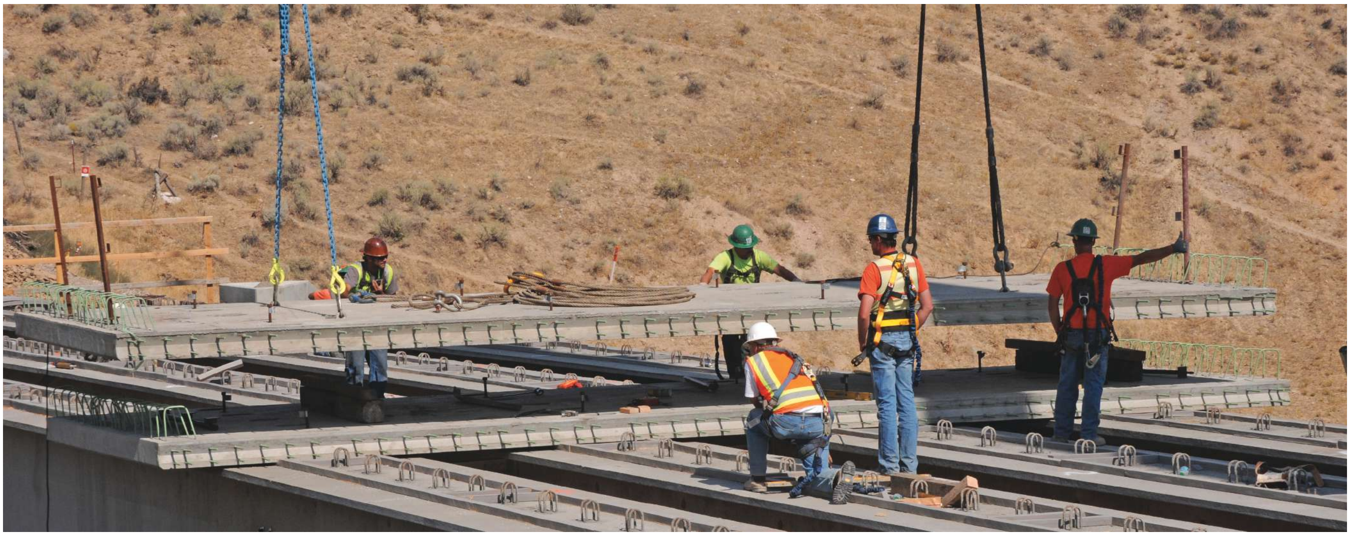
In this case, because the calculated and allowable tensile stresses are close, increasing the concrete compressive strengths may be an acceptable way of raising the allowable stresses. Using values of f'_{ci} = 4300 psi at stripping and f'_c = 5700 psi at shipping results in allowable tensile stresses of 328 and 377 psi, respectively, which are greater than the computed stresses and therefore satisfy PCI recommendations.

Another option to bring the computed tensile stresses within the allowable tensile stresses might be to increase the thickness of the panel. Increasing the thickness from 8¾ in. to 9¼ in. would reduce the stresses to 308 psi at stripping and 356 psi at shipping. However, the 5.7% increase in panel weight and the ½-in. increase in panel thickness may not be desirable.

A third option, which is especially useful when there is greater disparity between the computed tensile stress and the allowable stress, is to use prestressing. In the previous example with the five blockouts, placing a total of six ½-in.-diameter strands initially tensioned to 31 kip at midheight of the panel cross section, allowing for a 10% prestress loss and assuming the blockouts are at a location where the pretensioning force is fully transferred, would add compressive stress in the reduced cross section:

$$f_{prestress} = -\frac{(6)(1-0.1)(31)(1000)}{\left[10 - \left(5\left(\frac{6}{12}\right)\right)\right](12)(8.75)}$$
$$= -213 \text{ psi (compression)}$$

Superimposing the effect of the prestressing force on the stress caused by the weight of the panel, the net stress at



Full-depth deck panel being installed using a four-point pick. Photo: Precast/Prestressed Concrete Institute.

stripping from forms is now:

$$f_t = 326 - 213 = 113 \text{ psi (tension)} \leq 316 \text{ psi}$$

Allowable tensile stress is not exceeded when stripping from forms. OK.

The net stress at shipping is now:

$$f_t = 376 - 213 = 163 \text{ psi (tension)} \leq 354 \text{ psi}$$

Allowable tensile stress is not exceeded for shipping. OK.

Therefore, prestressing the panel reduces the excessive tensile stress and brings the stresses within the allowable stress limits.

Another option would be to use an eight-point pick. For long panels, this may

Table 8.3.1. Equivalent static load multipliers to account for stripping and dynamic forces[a,b]

Product type	Finish	
	Exposed aggregate with retarder	**Smooth form (release agent only)**
Flat, with removable side forms, no false joints or reveals	1.2	1.3
Flat, with false joints and/or reveals	1.3	1.4
Fluted, with proper draft[c]	1.4	1.6
Sculptured and other conditions	1.5	1.7
Yard handling[d] and erection[b]		
All products	1.2	1.2
Transportation[d]		
All products	1.5	1.5

Notes:

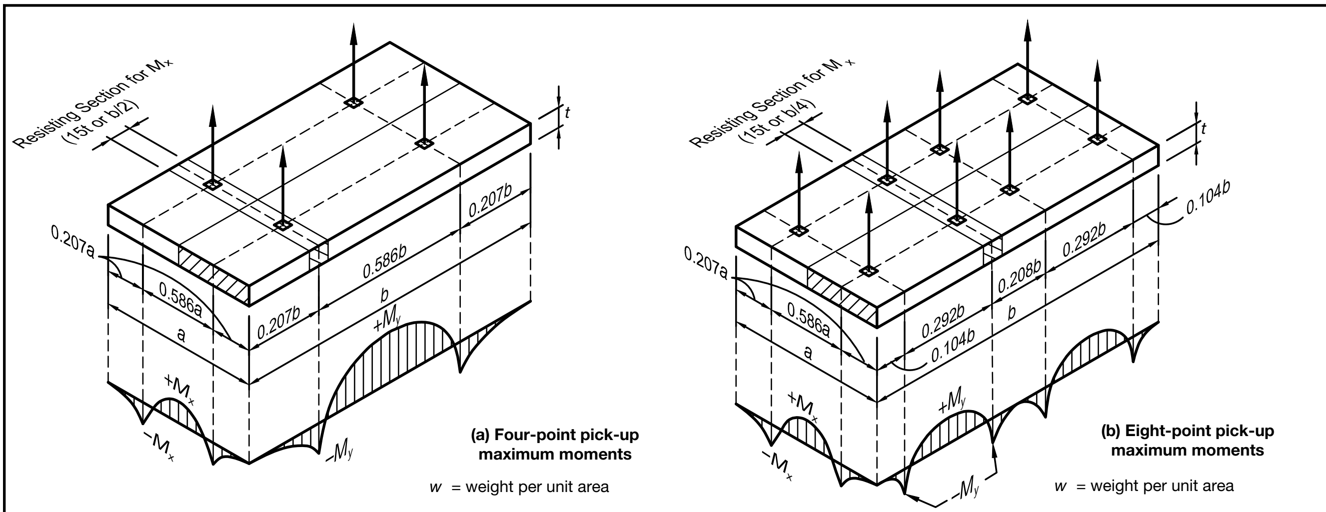
[a] These factors are used in flexural design of panels and are not to be applied to required safety factors on lifting devices. At stripping, suction between product and form introduces forces, which are treated here by introducing a multiplier on product weight. It would be more accurate to establish these multipliers based on the actual contact area and a suction factor independent of product weight.

[b] May be higher under certain circumstances.

[c] For example, tees, channels, and fluted panels.

[d] Certain unfavorable conditions in road surface, equipment, etc. may require use of higher values.

Source: Table 8.3.1 from the eighth edition *PCI Design Handbook: Precast and Prestressed Concrete*.



(a) Four-point pick-up maximum moments

w = weight per unit area

Locations shown for equal pick loads

$+M_x = -M_x = 0.0107wa^2b$

M_x resisted by a section of width $15t$ or $b/2$, whichever is less

$+M_y = -M_y = 0.0214wab^2$

M_y resisted by a section of width a

(b) Eight-point pick-up maximum moments

w = weight per unit area

Locations shown for equal pick loads

$+M_x = -M_x = 0.0054wa^2b$

M_x resisted by a section of width $15t$ or $b/4$, whichever is less

$+M_y = -M_y = 0.0054wab^2$

M_y resisted by a section of width a

Moments developed in panels stripped flat. Source: Figure 8.3.2 from the eighth edition *PCI Design Handbook: Precast and Prestressed Concrete*.

be necessary. Equations for calculating stresses for an eight-point pick are found in the *PCI Design Handbook*. Other options are to change the location of pick points and to use rockers during shipping, which are also discussed in the *PCI Design Handbook*.

Resources

Precasters, contractors, engineers, and owners of precast concrete deck panels can perform a few calculations and take steps to prevent undesirable cracking during handling and shipping. This article has presented the options of increasing concrete strengths, thickening the panels, prestressing, and adding more pick points. The examples in this article checked tensile stresses in the panel's longitudinal direction and for only two cases. Stresses in the transverse direction, lifter capacities, effects of rigging angles, and shear and moment capacities of the panel should also be checked.

In addition to the *PCI Design Handbook*, guidance on handling and shipping of precast concrete deck panels is available in references 2–7.

References

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