Two surveys were conducted: one of literature addressing compressive transfer stress and one of professional and producer members of the Precast/Prestressed Concrete Institute (PCI) to ascertain their use of compression transfer stresses that were greater than current code limits. The purpose of these surveys was to determine the current states of research and practice regarding compression transfer stress of prestressed concrete members. After evaluation of the research papers, the authors conclude that compression transfer stresses up to 0.70 $f'_{ci}$ would be acceptable. The PCI survey of professional and producer members provided an indication of the number of plants using compression transfer stresses above the limits set in ACI 318-05, Section 18.4.1. The PCI study also provided information on the types of products that PCI members use with various compression transfer stresses and on any problems that members have encountered when using stresses greater than the current specified limits. Thirty plants reported using compression transfer stresses greater than 0.60 $f'_{ci}$. The most common problems encountered with greater compression transfer stresses, according to the survey, were related to tension cracking and release order of the strands. Camber and prestress loss predictions are slightly more variable with greater transfer stresses. The research reports recommend that care and experience are needed to refine predictive methods. The recommendation of this study is that ACI 318 should raise the permissible compression transfer stress to 0.70 $f'_{ci}$ to comply with the limit currently recommended in the PCI Design Handbook. Refined camber and prestress loss calculations based on the higher transfer stress may be needed.
To meet ACI 318\textsuperscript{1} limits for compression stresses immediately after prestress transfer, precast concrete producers resort to one of four strategies:

- They sleeve or debond the strand to reduce the pre-stress at the end of a member;
- They defer prestress transfer until the member attains a sufficiently high specified compressive strength;
- They exceed the ACI 318 limitations; or
- They depress the strands (this strategy is not typically used).

Each of these strategies has distinct drawbacks. Sleeveing or debonding the strand reduces both the nominal shear and flexural capacities of the beam at its ends. Deferring the transfer of prestress has schedule and economic ramifications for the producer. Exceeding ACI 318 limits exposes the producer to some risk because the owner’s representative may not accept the product, and depressing the strands has safety implications within the precast plant.

One solution to this issue is to raise the allowable compressive release stress for prestressed concrete members. The current allowable compressive stress at transfer of 0.60 $f'_{ci}$ has been in ACI 318 since 1963 and was selected based on production practices at the time of adoption. Several studies have been undertaken to assess whether a greater compression transfer stress is justifiable.\textsuperscript{2–5} These research programs examined a number of potential issues, including plant practice, excess camber, prestress loss, tensile-flexural cracking, and cracking around the strand. Not all researchers address all issues, nor does the research necessarily examine all industry practice.

To complement existing research, a survey of PCI professional and producer members was conducted to evaluate current practice. The principle objective of the survey was to obtain a snapshot of current production practice and assess in-service performance.

**SUMMARY OF RESEARCH**

Noppakunwaijai et al.\textsuperscript{2} examined a strength approach to transfer stress. The research does not address compression transfer stresses directly but, rather, proposes a strength design approach. Examination of this work indicates that the equivalent transfer stress proposed is above 0.75 $f'_{ci}$.

Hale et al.\textsuperscript{3} examined effects of prestress loss for beams with compression transfer stresses between 0.57 $f'_{ci}$ and 0.82 $f'_{ci}$. Four beams were fabricated and monitored for approximately one year. The paper examines models for the prediction of prestress losses and compares the prediction to measured response. It concludes that the various predictive methods are within 10% of measured values and that increasing the compression transfer stress to 0.70 $f'_{ci}$ does not affect the predictive models.

Frost et al.\textsuperscript{4} conducted a general overview of plant practice and release stress. The methodology looked at concrete strength gain versus release stress and generally described the life cycle of prestressed concrete beams. A full correlation of performance of beams with higher compression transfer stresses is not developed, yet the strength gain after transfer was judged acceptable to raise the transfer stress. The report concludes that increasing the compressive transfer stress to 0.66 $f'_{ci}$ would be feasible.

Castro et al.\textsuperscript{5} examined the camber growth of Texas Department of Transportation girders with compression transfer stresses.

![Fig. 1. Number of respondents and corresponding compression transfer stresses.](image-url)
stresses ranging from $0.46 f'_{ci}$ to $0.86 f'_{ci}$. The strands in a subset of 15 beams were released when the beams’ extreme fiber compression stresses were $0.75 f'_{ci}$. They conclude that variability in camber prediction correlated to greater compression transfer stresses and that the camber variability is partially dependent on product type. They also concluded, however, that camber can be adequately predicted for the greater compression transfer stresses. Although the results were not always conservative, they were within reasonable bounds. Castro et al. also commented that transverse reinforcement added at the ends of the beams was adequate to resist bursting stresses and concluded that additional research was needed to complete the study.

**PCI SURVEY**

The PCI survey was sent to both producer members and professional members of PCI. It was reported that the electronic survey site received 227 visits, and 61 surveys were completed. Of these, 46% were completed by producer members and 51% by professional members. Three percent of respondents classified themselves as “other.” Thirty-six respondents reported using a given compression transfer stress because it was specified by the customer being served. Also, 36 respondents (though not necessarily the same 36) stated that they routinely use compression transfer stresses above $0.60 f'_{ci}$. The survey was structured such that the distribution of compression transfer stresses used by those reporting could be quantified and specific problems resulting from higher compression transfer stresses could be identified.

**Survey Results**

Data from the respondents were assessed to determine the compression transfer stresses used in practice, the products that use the respective compression transfer stresses, and any problems encountered with greater compression transfer stresses. Figure 1 summarizes the responses on the question of magnitude of compression transfer stresses used in the industry. Thirty of the respondents reported using compression transfer stresses greater than those specified in ACI 318 on a regular basis with no problems. At least one respondent reported using the Nebraska recommendations, which would place the compression transfer stress at approximately $0.81 f'_{ci}$. Unless a specific compression transfer stress was reported, the data were not entered in the response calculations. Forty-four responses were recorded. Each respondent had the opportunity to list two different compression transfer stresses, depending on the product type. Thus, there are more data points than individual respondents. For example, many respondents noted that they use $0.60 f'_{ci}$ for bridge products and a different compression transfer stress for building products.

Greater compression transfer stresses were typically used in building products. Table 1 summarizes the distribution of concrete product types by compression transfer stress. The survey data were somewhat ambiguous on the topic of girders. Respondents reported compression transfer stresses related to I-girders, rectangular girders, or beams; these data are combined under the heading “Girders.”

Table 2 summarizes the reported performance of prestressed concrete members with compression transfer stresses above $0.60 f'_{ci}$. While some issues are identified, the majority of the respondents using or specifying greater compression transfer stresses experienced no problems with their use.

Concerns about excessive camber may be traced back to the variation reported by Castro et al. Considering that not all members provide consistent camber predictions, 7 of the 44 respondents confirm that the variation between product camber and prediction seems consistent with the research findings. Other comments listed in the PCI survey included: “I have used 0.75 $f'_{ci}$ for 10 years with no problems” to “deck cracking,” “minor stress cracks at the ends,” a “short horizontal crack for about 2 feet at the beam end that dies out quickly,” and “a short horizontal crack at the top of the web just below the flange.” Several respondents noted that a greater compression transfer stress did lead to more cracking in the tensile zone. Some of the cracking was associated with a tensile transfer stress of $7.5 \sqrt{f'_{ci}}$. Others reported that increased cracking occurred without an increase in the tensile transfer stress. Comments regarding tensile zone cracking were usually accompanied by a recommendation to place ordinary reinforcement in these tensile zones to control crack widths.

Two comments addressed the strand release sequence. These comments suggest that releasing from the inside to the outside—or from the middle out—resulted in less cracking than other transfer schemes. Such actions appear to be producer specific.

---

**Table 1. Product Type Distribution by Compression Transfer Stress**

<table>
<thead>
<tr>
<th>Transfer Stress</th>
<th>Tees</th>
<th>Inverted Tees</th>
<th>Girders</th>
<th>Hollow-Core</th>
<th>Box Girders</th>
<th>Bridge Girders</th>
<th>Spandrels</th>
<th>Railroad Ties</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.55 f'_{ci}$</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.60 f'_{ci}$</td>
<td>8</td>
<td>8</td>
<td>11</td>
<td>9</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.65 f'_{ci}$</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>$0.68 f'_{ci}$</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>$0.70 f'_{ci}$</td>
<td>15</td>
<td>4</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>$0.75 f'_{ci}$</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The numbers in the table represent the number of respondents that reported in each category.
Recommendations in the sixth edition of the PCI Design Handbook should be reviewed for calculation of prestress losses and camber and revised as needed to reflect the greater transfer stress. Recommendations in the handbook should be provided for the sequence of cutting strands to transfer the prestress.

**REFERENCES**


**Table 2. Performance of Prestressed Members with Compression Transfer Stresses Above 0.60 f’ci**

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Respondents Reporting Difficulties</th>
<th>Respondents Reporting No Difficulties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive camber</td>
<td>7</td>
<td>36</td>
</tr>
<tr>
<td>Concrete splitting around strand end</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Excessive strand end slip</td>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>Other problems observed</td>
<td>4</td>
<td>35</td>
</tr>
</tbody>
</table>

The length of time that producers have used greater compression transfer stresses varied widely. Respondents reported using greater values for between three and ten years. A higher compression transfer stress recommendation first appeared in the 1999 edition of the PCI Design Handbook. One respondent noted that in the 1970s when the compression transfer stress was raised to 1000 psi (6.9 MPa) above the ACI 318 recommendation, there were no difficulties to report.

A final question asked for recommendations for compression transfer stress. These responses are summarized in Table 3. The survey respondents are primarily those that use compression transfer stresses that are greater than those allowed by ACI 318 and, hence, would like to see it codified.

**CONCLUSIONS**

Several conclusions can be drawn from these data:

- Producers have several years of experience using compression transfer stresses in excess of 0.60 f’ci.
- Few production problems have resulted from increased compression transfer stresses.
- The wide variety of product types designed with compression transfer stresses greater than 0.60 f’ci indicates acceptable performance across the industry.
- Issues associated with cracking in the tensile zone have historically been addressed by placement of ordinary reinforcement in that zone to control the crack opening.
- Detailed independent research programs have determined that raising the compression transfer stress to 0.70 f’ci still allows for prediction of camber and prestress losses. Additional camber and prestress loss computational effort may be required, and greater variation between predicted and actual behavior may result. However, neither results in life safety issues.

**RECOMMENDATIONS**

Based on the results of the PCI survey and the assessment of independent research reports, the authors recommend the following:

- ACI 318 should raise the allowable compression transfer stress to 0.70 f’ci.
- Producers with tension cracking problems could either use a lower compression transfer stress or provide supplemental tensile reinforcement.

**Table 3. Respondent Recommendations for Transfer Stress**

<table>
<thead>
<tr>
<th>Recommended Transfer Stress</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.60 f’ci (no change recommended)</td>
<td>11</td>
</tr>
<tr>
<td>0.70 f’ci</td>
<td>29</td>
</tr>
<tr>
<td>0.75 f’ci</td>
<td>5</td>
</tr>
<tr>
<td>0.80 f’ci</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
</tr>
</tbody>
</table>

Recommendations in the sixth edition of the PCI Design Handbook should be reviewed for calculation of prestress losses and camber and revised as needed to reflect the greater transfer stress.

Recommendations in the handbook should be provided for the sequence of cutting strands to transfer the prestress.