Precast Concrete Pier Caps Aid Construction of Jacksonville Flyover Bridge with Tight Site Conditions

by Andrew Mish, Summit Engineering Group (a Modjeski and Masters company)

In September 2017, the Southbound Interstate 95 (I-95) to Eastbound State Road 202 (SR 202; also known as J. Turner Butler Boulevard) Flyover Bridge was opened to traffic in Jacksonville, Fla. The structure allows for a continuous flow of traffic through the interchange and provides a significant upgrade to the previous configuration of an off ramp with a traffic light, which led to traffic backups of a mile or more on I-95 during peak travel times.

Among the many challenges faced during the design-build process were the constrained jobsite conditions due to the heavy traffic volume on each roadway at the interchange. In just seven spans, this bridge has three major traffic crossings in an interchange that carries more than 200,000 vehicles per day. The Florida Department of Transportation (FDOT) required that all lanes remain open for the duration of construction and permitted only nighttime traffic closures, which limited construction operations to a maximum of 8 hours per day. A Project Profile article, "Southbound Interstate 95 to Eastbound State Road 202 (J. Turner Butler Boulevard) Flyover," appears in this issue of *ASPIRE*® on page 26; this article focuses on the precast concrete pier caps.

Precast Concrete Pier Caps Provide Construction Solution

With all lanes open to traffic during construction, four of the six interior piers were adjacent to active traffic as the bridge was built. This situation eliminated the possibility of the typical cast-in-place (CIP) pier caps because the shoring would interfere with traffic. Additionally, any solution needed to provide at least 16 ft 6 in. of vertical clearance. Precast concrete pier caps ultimately provided the best solution.

The contractor chose to fabricate the pier caps on site, but away from traffic. The minimum clearance was easily maintained, with the bottom of the precast concrete cap at least 17 ft 6 in. above the roadway. Additionally, the precast concrete caps were used to support girders during construction, minimizing the amount of temporary falsework required for the project.

Steel channels with welded studs form shear keys as part of the column-to-cap connection. Photo: Modjeski and Masters.

Precast Concrete Pier Cap Design

The design of the precast concrete pier caps focused on a time-dependent, staged-construction analysis. This approach allowed the designer to ensure that the caps would perform as intended and meet all FDOT and American Association of State Highway and Transportation Officials' design criteria through each stage of construction and the full life of the structure. Loadings at each stage were considered, and time-dependent effects over the life of the structure were analyzed and included in the design.

The precast concrete caps were designed to be handled and erected as mildly reinforced components prior to the application of any post-tensioning. Designing the caps this way allowed the contractor flexibility in scheduling the erection of the caps and their phased post-tensioning.

Column-to-Cap Connection

The column-to-cap connection is one of the most important and interesting aspects of the design. The connection needed to transmit out-of-balance loadings during girder erection and work in concert with the CIP diaphragms to transfer all composite loads to the column. Each interior pier was designed with a single 7-ft by 4-ft column. The precast concrete cap was constructed with a full-depth vertical blockout that is 1 in. larger than the column cross-section dimensions. All the reinforcement from the column projected through the blockout and was developed into the CIP diaphragm.

Within the blockout, four rows of steel channels (C6) were installed to create four continuous shear keys around the perimeter of the blockout. The pier cap was erected by threading it over the column reinforcement and bearing on temporary support brackets. Once it was in place, 10-in.-long shear studs were welded to the C6 channels and the blockout was cast with concrete that was the same class as the column concrete. The governing design condition during construction was the out-of-balance loading that occurred when the first girder was erected onto the pier cap.

Multiphase Post-Tensioning

The staged post-tensioning is another important aspect of the design. Each precast concrete cap was designed with four post-tensioning tendons with twelve 0.6-in.-diameter, 270-ksi strands each. All four tendons are located at the top of the section to provide negative moment reinforcement and control stresses. The tendons in the caps were tensioned in two phases to accommodate multiple loading conditions through several stages of construction. After the column-to-cap connection concrete was cast and cured, the first two tendons were tensioned and grouted. Next, the precast concrete girders were erected and the final two tendons in the precast concrete cap were tensioned and grouted.

During the design review process, the design team and FDOT discussed whether the CIP column-to-cap connection would behave in a fully composite fashion with the cap. To account for the range of various possible behaviors, the designer bounded the solution by considering both fully composite action and zero-composite action at the connection. This approach gave the owner confidence in the construction method. The phased post-tensioning was designed to work with both solutions.

Diaphragm Composite Action

After erecting the pier girders, the integral diaphragm was cast. The CIP diaphragm was designed to act compositely with the precast concrete pier cap. To ensure composite action, the tops of the precast concrete caps were roughened to ¼-in. amplitude and reinforcement projected from the cap into the diaphragm. Both post-tensioning tendons and the reinforcing bar projected through sleeves in the girder webs to tie the diaphragm and girder together, developing integral action for the final design loadings. The diaphragm was designed with conventional reinforcement and three post-tensioning tendons with twelve 0.6-in.-diameter, 270-ksi strands each, which were tensioned prior to casting the deck and would resist the noncomposite dead load of the wet concrete deck as well as the composite dead and live loads of the final structure.

Conclusion

By using precast concrete pier caps in the design of the Southbound I-95 to Eastbound SR 202 Flyover Bridge, the designer and contractor overcame significant issues during construction. The caps were designed as a complementary piece of the structure that helped enhance the aesthetics of the bridge, and they were an integral part of the collaborative process that made this project a success.

EDITOR'S NOTE

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Design Stages of the Precast Concrete Pier Caps

The design stages of the precast concrete pier cap were:

- Stage 1: Handling and erection of the cap as a mildly reinforced component
- Stage 2: Installing and casting of the cast-in-place (CIP) column-to-cap connection
- Stage 3: Phase 1 post-tensioning of the pier cap including tendon grouting
- Stage 4: Erection of precast concrete curved, spliced pier girders considering out-of-balance loading with only the first girder erected
- Stage 5: Phase 2 post-tensioning of the pier cap including tendon grouting
- Stage 6: Casting of the CIP diaphragm for composite action with the precast concrete pier cap
- Stage 7: Applying post-tensioning to the CIP diaphragm/cap for composite action
- Stage 8: Erection of drop-in girders and completion of longitudinal post-tensioning of the structure
- Stage 9: Casting of the CIP deck
- Stage 10: Applying composite dead loads
- Stage 11: Aging of the structure to 30 years to account for time-dependent effects
- Stage 12: Applying vehicle live loads

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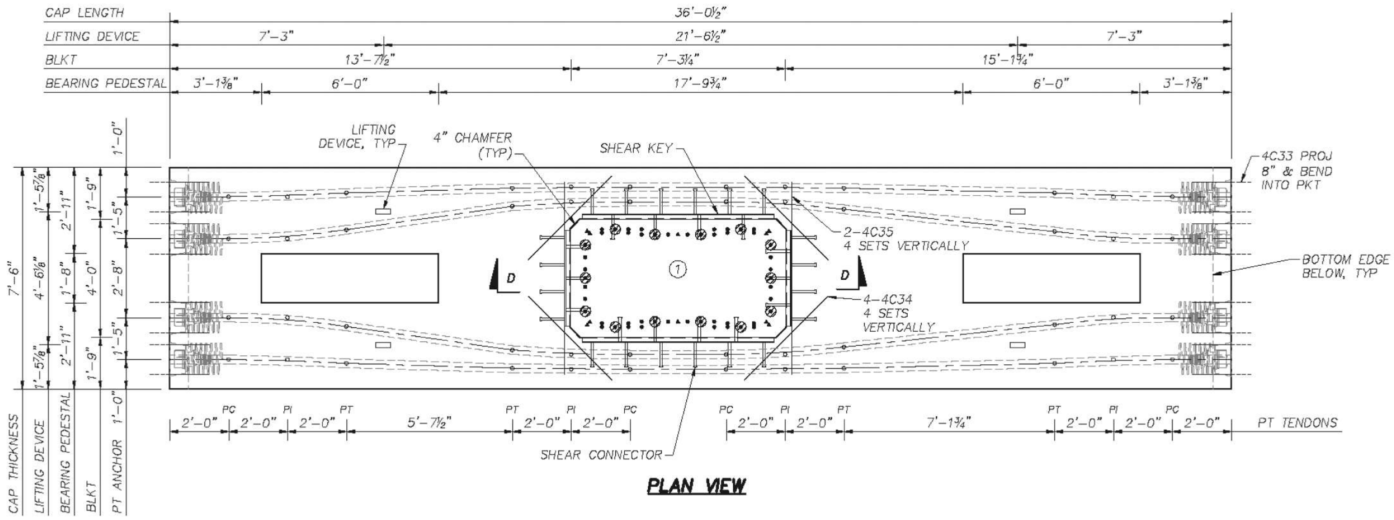


Plan view of the precast concrete pier cap showing the column blockout, horizontal post-tensioning tendon layout, and shear key. Figure: Modjeski and Masters.

A PROFESSOR'S PERSPECTIVE

Educating Students

about the Proper Use and Interpretation of Design Aids and Software

by Dr. Andrea Schokker, University of Minnesota Duluth

As engineering professors, we are responsible for giving students the background and theory they need as well as acquainting them with the design aids and tools of the profession. Design aids and software are critical to a practicing engineer, but, as with any tool, they must be used for the applications for which they were designed.

I want my students to be ready to step into their first engineering jobs with as much practical understanding as possible. However, I also want to make sure we have done a good job building a base of knowledge, including critical and innovative thinking, so they can go beyond the "cookbook" approach (or, as one of my professors used to say, “So you can design more than a one-bay chicken coop”!).

Teaching engineering judgment alongside the design process ensures that our students never just accept an answer blindly. I remember sitting in a Master’s thesis defense early in my career where a colleague’s student presented his findings on a purely computational project. He showed results that were consistently huge (several feet thick) for a fairly short-span concrete slab. I asked him if that seemed reasonable, and he said, “It’s right because I got it from the computer.” I knew then and there that I could not allow any student that came through one of my classes or my research groups to have that kind of dangerous view.

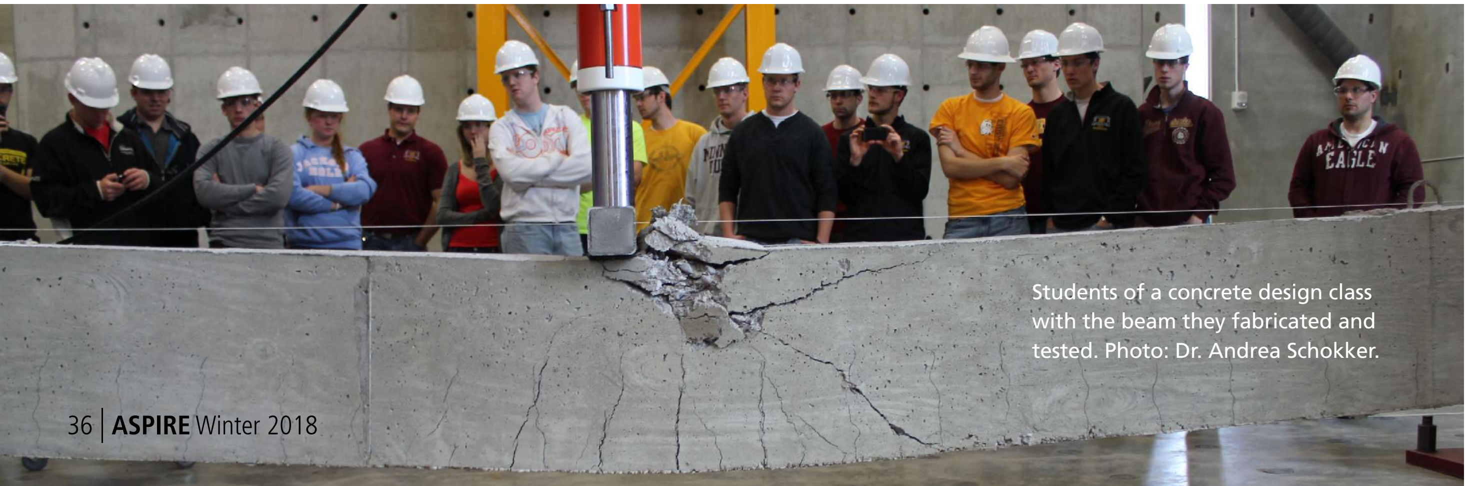
My approach is to move students into the use of design tools early in their design classes, while simultaneously challenging them with questions about the assumptions used in the process. We often use design aids and software to work on problems, and then I ask for a hand calculation for comparison. My students always know my next questions will be, “Does your hand calculation match the value from the table or computer output? Why or why not? What assumptions were made?”

Likewise, I spend time showing them the steps I use when looking at computer output. Today’s programs can show results in a highly visible format, which enables the engineer to catch potential problems more quickly than when scrolling through a list of numerical output on the screen (as I remember doing with the early programs). Today’s students have an inherent trust in computers, which means it is important to help them understand that “junk in equals junk out” is a major source of errors and that the way to check the input is to be able to judge the reasonableness of the output.

I tell them that I always start with a plot of the input (are the loads in the right direction and where I want them?) and then go to a deflection diagram rather than other output (does the shape and magnitude make sense?). I also teach them to consider the bounds or extremes on a solution by reducing it to a basic problem that they can do quickly by hand or in their heads to see whether the order of magnitude is reasonable. In our curriculum, we have also incorporated both small- and large-scale demonstrations to help students visualize structural behavior and to compare laboratory results to hand calculations and design aids.

Engineering judgment comes from years of experience, but its development can also be jump-started by ensuring that students realize that no design table or software is magic. When engineers use a tool, they must understand how it was developed or, at the very least, the assumptions that are built into it. They also need a way to do some basic checks of magnitude of the solution. I emphasize that design aids and software are a great starting point, but one’s education as an engineer is vital for true problem solving and final design. In our field of structural engineering, the point of life safety is often one I use to drive home the significance of critical-thinking skills. In class, blindly accepting results may affect a student’s grade but, in the profession, that approach might mean significant economic loss or, much worse, loss of life.

Our students will have much to learn on their first jobs, but I think a good professor understands that the educator’s duty is to ensure a strong base of knowledge and an understanding of both how to use tools as well as their limitations.



Students of a concrete design class with the beam they fabricated and tested. Photo: Dr. Andrea Schokker.