PREFABRICATED BENT CAPS ON THE LAKE BELTON BRIDGE

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ABSTRACT

The Texas Department of Transportation (TxDOT) is implementing innovative design and construction techniques for bridges to reduce traffic disruption and construction project duration while enhancing safety for the motoring public and constructability for the contractor. This initiative is being accomplished through research, new design techniques, and partnering with contractors during construction.

TxDOT is currently constructing a new bridge over Lake Belton near Temple, Texas using precast concrete bent caps. Lake Belton's water surface elevation varies widely and the anticipated difficulties of cast-in-place concrete 40 feet above the lake level, as well as environmental considerations, warranted the use of precast bent cap construction. Utilizing precast components helps mitigate both of these construction challenges.

Keywords: Prefabricated, Concrete, Bridge, Construction.

INTRODUCTION

The Texas Department of Transportation (TxDOT) is implementing innovative design and construction techniques for bridges to reduce traffic disruption and construction duration while enhancing safety for the motoring public as well as construction personnel and constructability for the contractor. This initiative is being accomplished through a multifaceted approach involving completed and ongoing research projects, new design techniques resulting from research findings for precast element connections, partnering with contractors and suppliers to develop construction techniques and field performance data for precast/ prefabricated systems in service. The Lake Belton Bridge project and its use of precast bent caps is the latest effort of the Texas Department of Transportation to implement innovative design to meet current and future needs for rapid bridge construction.

THE NEED FOR RAPID BRIDGE CONSTRUCTION TECHNIQUES

Texas is experiencing one of the highest population growth rates of any state in the country. The need to move people and goods around the state is crucial in serving the increasing demands of the growing population. Road capacities must be increased to meet this need, but the construction of these larger facilities can severely impact the motoring public. The impact and costs associated with disrupted traffic flow have increased significantly in recent years. Traffic delays impair mobility and motorist and worker safety is compromised. Goods and services may not reach the people requiring them. Direct and indirect costs related to traffic disruption are a major concern. One of the many ways TxDOT is responding to the challenge is by devising ways to construct bridges with less impact to the motoring public and greater safety for the workers who build them.

THE NEED FOR A PRECAST BENT CAP SYSTEM

Four previous construction projects that successfully used precast bent caps motivated TxDOT to initiate the formal development of a precast bent cap system. These were the Redfish Bay and Morris & Cummings Cut Bridges along the Gulf Intracoastal Waterway on SH 361 near Port Aransas, the Pierce Street Elevated section of IH 45 in the Houston central business district, US290 West in Austin, and the Lake Ray Hubbard Bridge near Dallas. These projects proved the practicality of precast bent systems and continue to guide the effort for improvement. The Lake Belton Project is a bridge replacement project for a geometrically and structurally deficient structure that carries State Highway 36 over a flood control and water supply reservoir in central Texas. The original bridge was built in the early 1950's and its two narrow lanes, substandard shoulders, and dated design, including pin and hanger details, destined it for replacement. The existing bridge had to remain open during construction and its designed capacity precluded delivery of new bridge materials via the existing roadway. The new bridge will span 3840 feet and will ultimately have two 40-foot wide roadways. The superstructure will be comprised of

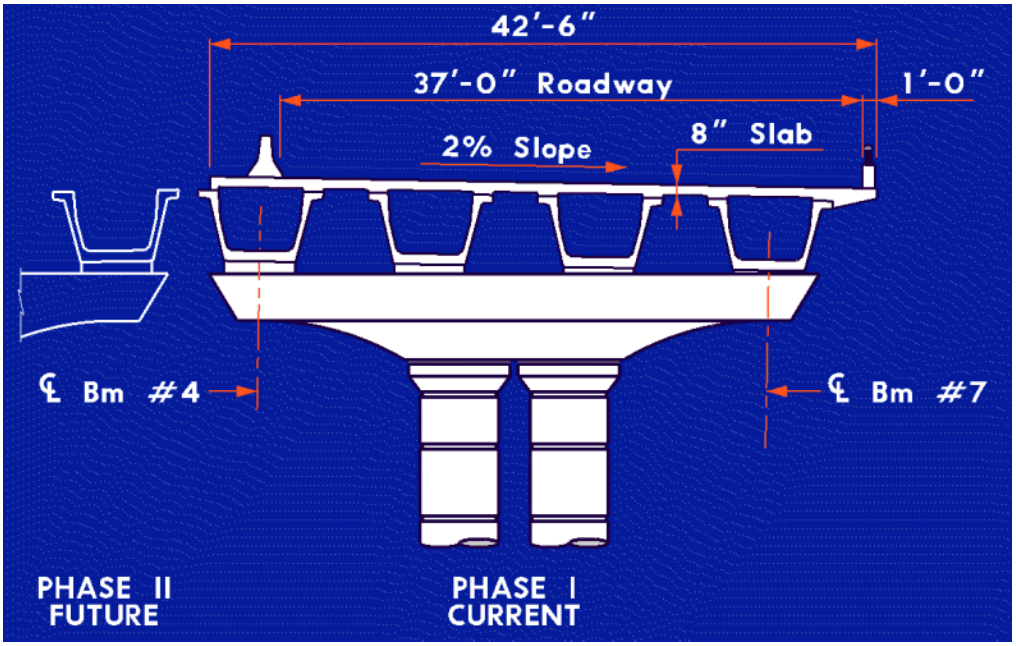
thirty-two 120-foot long prestressed concrete U-beam spans, supported by a twin bent substructure. The U-beams are also a Texas precast innovation. They have an aesthetic appeal of a wider-spaced beam system and a form that emulates that of conventional box-girders with sloping webs. They are also readily produced by Texas' well-established precast industry. The bent caps on this project were designed to enhance the overall aesthetics balanced with structural efficiency.

Arial View of Project

The bridge is being constructed in two phases and will ultimately include 62 precast caps. Precast bent caps offered four key advantages on this project:

- Time: Time is saved by removing formwork construction and removal, reinforcing steel and concrete placement, and concrete cure time from the critical path of on-site construction sequencing. The on-site construction activities were reduced from an estimate of one week to just a few hours per bent cap.
- Cost: Overall costs are reduced by making the bent caps easier to build and streamlining the labor effort both at the precasting yard as well as the project site. Assembly-line techniques are used at the precasting yard and the reliable repeatability of operations make construction crews faster and more efficient.
- Quality: The quality of the finished product is enhanced by building the bent caps in the controlled environment of the precasting yard. All construction and inspection work for fabricating the bent caps is done on the ground, instead of 40 feet in the air over water. The quality of the precast concrete is superior and easier to control in a plant environment instead of in the remote location of the bridge. Fabricators tend to have access to higher quality materials and usually have more experience and knowledge of concrete chemistry and admixtures. Curing is also more consistent in the controlled environment of the precasting yard.

- Safety: Safety is improved for the workers and inspectors by reducing the amount of construction work performed at significant heights over water. Motorists' exposure to an active work zone is also reduced.



Planned Cross-Section

Formwork, reinforcing and completed caps in casting yard

TXDOT-SPONSORED PECAST BENT CAP RESEARCH

TxDOT sponsored Project 0-1748, "Development of a Precast Bent Cap System", which was carried out by the Center for Transportation Research at The University of Texas at Austin. Under this study, completed in January 2001, a project panel was assembled consisting of TxDOT bridge engineers, DOT engineers in other states that have developed precast substructure systems, and precast and construction industry representatives. With the panel input, Project 0-1748 developed four categories of connection details. These are grout pockets, grouted vertical ducts, bolted connections and grout-sleeve couplers. Multiple details were developed for the connection categories to provide options to accommodate a wide range of applications and required connection capacities. Other criteria used in development of connection details were the capacity to resist unbalanced moments, avoiding conflicts between cap longitudinal reinforcement and connection features, confinement of the connection region to ensure development of full capacity of the connection and providing proper durability of the connection and protecting connectors from corrosion. The ease of setting the cap in final position and adjusting grade of the cap and bearing seats, completing the connection, and grout specifications were also considered.

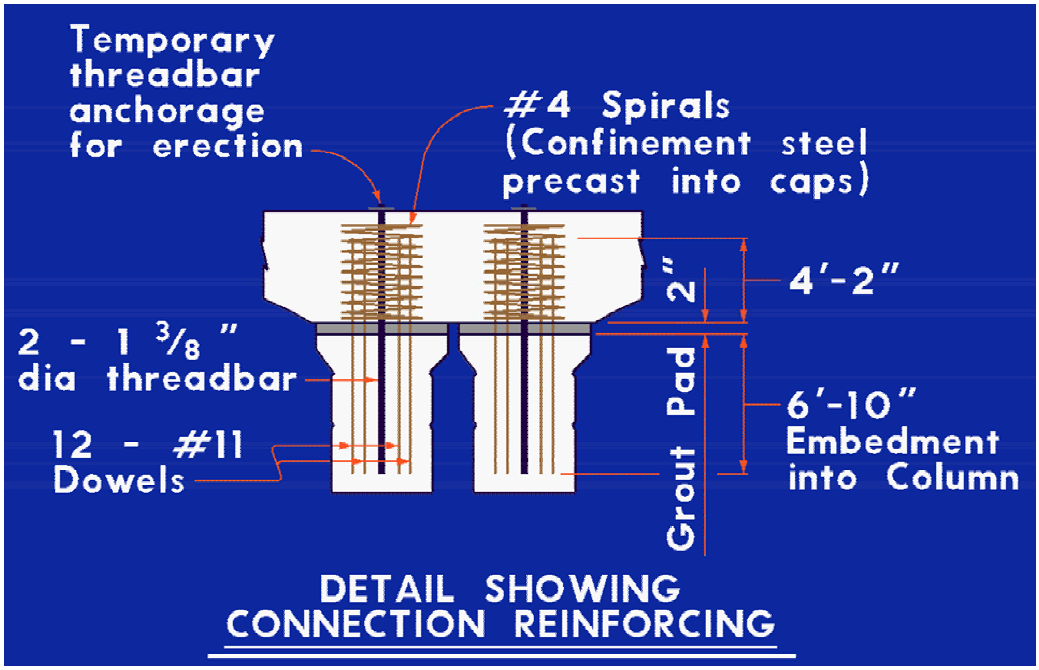
TxDOT Research Report 1748-2 presents a full description of the research, testing and connection design recommendations. This report should be carefully reviewed before applying the design procedures. Some of the highlights of the connection design procedure are:

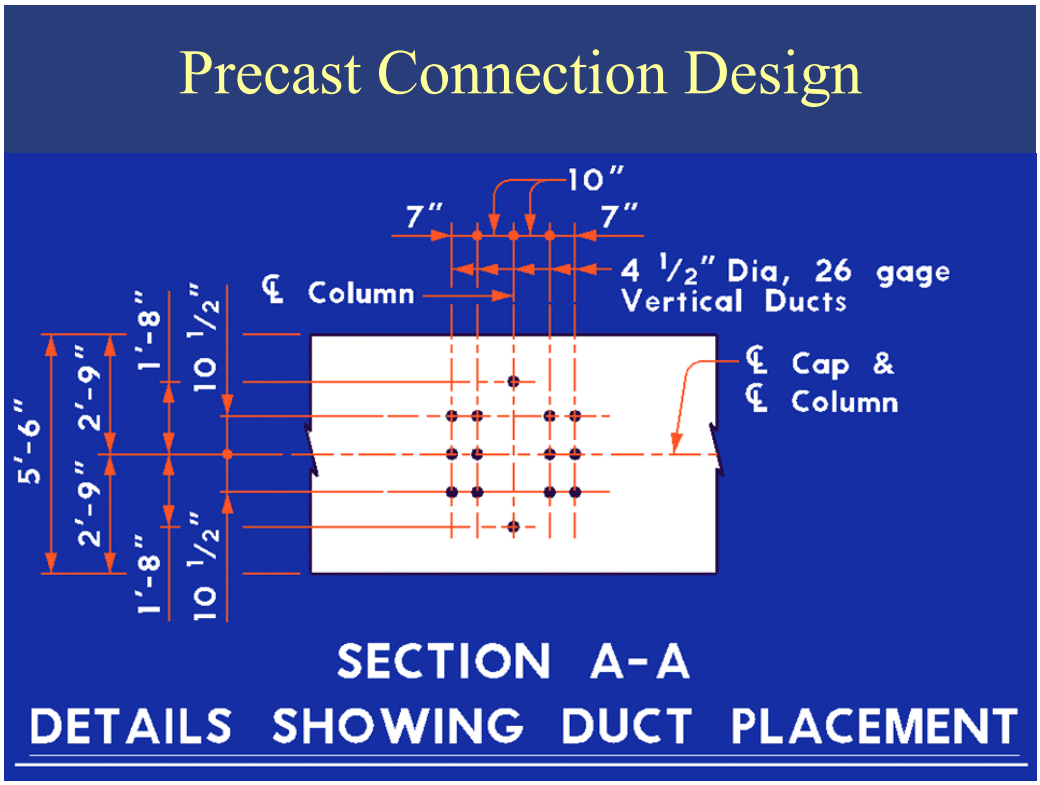
- All loads and load combinations and load directions should be considered in connection design.
- Bent caps should be designed with pin connections at support points. Columns or piles should consider the governing case of pinned or fixed connection at column or pile top. Engineering judgment should be used in determining degree of fixity.
- Precast connections should be designed as a rigid connection.
- Connector embedment length and connector spacing should be carefully considered in evaluating the capacity of the connection. Durability and constructability should be considered when devising connector details.
- The area of the connector steel should not be less than 0.7 percent of the gross cross-sectional area of the conventionally reinforced column or less than 1.0 percent of the gross cross-sectional area of the prestressed pile.
- Confining reinforcement is an important component of the connection system. It significantly decreased required embedment length for a given connector capacity in the laboratory tests.
- Grout mix and grout placement is crucial to adequate connection strength, durability, and constructability. Long term durability of the grout mix must be carefully considered. Grout specification and placing procedures must be carefully considered. Plans for inspection during and after grouting should be established and documented prior to grouting. Connection mock-up and grout mixing and placing tests should be done before precasting any caps or grouting any connections in the bridge structure.

- Bedding layer thickness must be within the 1 ½ to 4-inch limits outlined in the report and must be fully grouted.
- Allowance must be made for construction and fit-up tolerances in detailing the precast connections.

IMPLEMENTATION OF RESEARCH RESULTS

The design procedure developed under Project 0-1748 was extended for use on the Lake Belton Bridge hammerhead bents. These bents have higher moments than the multi-column bents previously constructed with this technology. Due to the hammerhead bent design there are two layers of main reinforcing bars in the top of the cap to provide sufficient moment capacity for the superimposed loads. This necessitated the use of a four-line grouted duct connection that did not extended the full height of the cap, except for four threaded bars in ducts used to temporarily hold the cap in place during connection grouting. While not extending the ducts through the cap challenges the grouting effort, it does enhance durability by not exposing grouted ducts on the top surface of the cap. Grout is pumped into the bottom of the galvanized metal ducts via a ¾-inch inlet tube just above the bedding layer and vented out of the top of each sealed duct by a ½-inch diameter tube. Different inlet and outlet tube sizes positively identify inlet tubes; the grout must be pumped in from the bottom and up to the top to drive air out of the connection. Due to aesthetic considerations in design, the limits of the bedding layer are oval in shape. This complicated sealing of the bedding layer before pressure grouting and necessitated the use of peripheral dry-pack grouting to seal the bedding layer. Aesthetics also made the use of friction collars difficult and dictated the use of shims to set bedding layer thickness and adjust cap elevation.



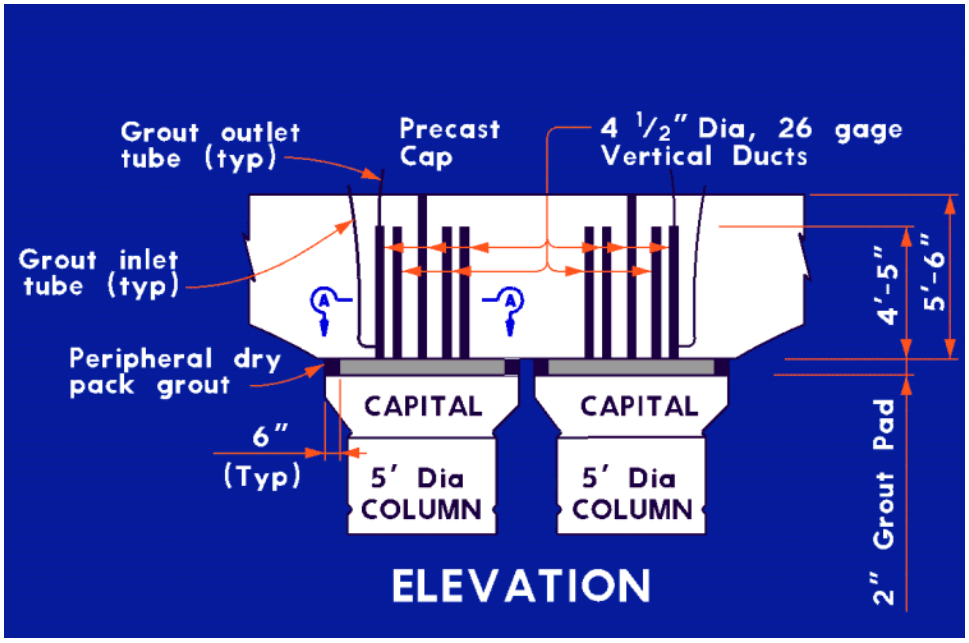


To ensure a good quality connection in the field and familiarity of field personnel with the necessary construction procedures, connection mock-up tests were done at the off-site precasting yard. A full-scale mock-up of the connection core in the cap and of the top of column with protruding connectors was cast. The connectors were smooth, however, to facilitate dismantling the specimen so that the connection integrity could be assessed. The cap core was set on shims, the edge of the bedding layer was formed with dry-pack grout and the connection was pressure grouted by contractor personnel. Dismantling of the specimen proved the dry pack and pressure grouting method was adequate, however excessive segregation and free water in the grout precipitated the use of another grout in the structure. The mock-up tests illustrated that the dry pack grout must be a very dry mix to place properly and develop a seal for pressure grouting.

CONSTRUCTION

The on-site construction is relatively straight-forward. As soon as the columns are fully cured, steel shims are used to support the cap, make final elevation adjustments, and create the space for the bedding layer of grout. Fourteen number 11 connection dowels extend 4 feet, 2 inches above the top of the columns. Templates are used to align the dowels and facilitate insertion into ducts in the precast bent cap. The cap is delivered to the site by truck. Once the cap reaches the site it takes approximately 45 minutes to place it on a barge, float it out to its location and lift it into place. The cap is immediately stable under construction loads as placed. The bedding layer is dry packed and allowed to cure overnight. Grouting is accomplished with a combination grout mixer and pressure pump apparatus. Each dowel is grouted inside a four and one-half inch diameter

galvanized metal corrugated vertical duct. The ducts and the bedding layer are interconnected and grouted simultaneously. Each complete bent cap connection, to both columns, requires approximately twenty cubic feet of grout and about 1 ½ hours to complete. In this structure there are two connections per cap to complete. As soon as the grout achieves a compressive strength of 3,000 pounds per square inch, the bridge superstructure can be placed. This strength can easily be achieved overnight.



Precast Bent Cap Connection Details


Setting a precast cap onto the connection dowel

SUMMARY

The Texas Department of Transportation is implementing innovative precast and prefabricated design and construction techniques for bridges to reduce traffic disruption and construction project duration while enhancing safety for the motoring public and constructability for the contractor. TxDOT sponsored research Project 0-1748, "Development of a Precast Bent Cap System" experimentally established precast bent cap to column connection behavior and developed a rational procedure for connection design. Design and construction details developed in Project 0-1748 were implemented in the Lake Belton Bridge.

Precast and prefabricated bridge components can shorten construction project duration and enhance safety. They are best implemented in the early phases of the design process so that other aspects of the total project package such as roadway and bridge geometry and bridge aesthetics are still fluid enough to be molded to enhance the benefits of precast / prefabricated bridge construction. Replication of similar precast elements enhances speed of construction and economy of scale. Other issues to be considered are where the precast components will be fabricated and how they will be transported to the site and lifted into position, and how this will affect traffic movements.

The inspection of the precast connections and necessary tests required for quality assurance are extremely important to the success of precast member connections. The use of component and connection mock-up tests can be a very important quality assurance tool. This gives all parties involved familiarity with the techniques of prefabricated construction and is a good test for grout material properties and pumping techniques. All parties must achieve complete confidence in the successful execution of precast connections before a connection is made on the bridge structure.

The total project package should be considered in maximizing the benefits of precast / prefabricated bridge technology. From project inception and schematic design through construction project completion, there may be many opportunities to benefit from precast / prefabricated construction if properly planned for in the project development process. Implementation of precast / prefabricated bent cap technology is one of the many tools that will help bridge engineers meet the challenges of building and maintaining a first class highway system under the ever increasing transportation demands of the 21st century.

Partially completed Phase 1 on left, existing bridge on right.

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