Project Summary Report 1748-S
Development of a Precast Bent Cap System

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PROJECT SUMMARY REPORT

Summary: Development of a Precast Bent Cap System

The impact and costs associated with traffic control and disrupted traffic flow have increased significantly in recent years as the Texas Department of Transportation (TxDOT) continues to build bridges in increasingly congested urban environments. Concerns about traffic delays as well as public and worker safety in construction zones have heightened as traffic volume has increased. Moreover, direct and indirect costs related to traffic control, disruption, and environmental impact are also concerns.

To address these concerns, TxDOT has gradually introduced precast concrete components in bridge systems. For example, TxDOT already uses a number of precast superstructure elements, such as pretensioned girders with precast concrete deck panels. Even greater potential for economy and speed of construction is anticipated through the development of precast concrete bridge substructures. This is particularly true for large, repetitive bridge projects in urban areas or over water crossings, which have been shown to be slow and costly due to the large volume of cast-in-place concrete, associated formwork, and considerable field operations.

The development of a precast bent-cap system is expected to be an important step in the advancement of precast substructures. Not only will such a system reap the benefits of reduced construction time and traffic disruption, but it will also allow the controlled conditions of precast plants to be exploited, enabling efficient production of high-quality caps and facilitating the use of high-performance concrete.

Two recent TxDOT projects that successfully used precast bent caps, the Pierce Street Elevated section of IH-45 in the Houston central business district, and the Red Fish Bay and Morris & Cummings Cut Bridges along the Gulf Intracoastal Waterway on State Highway 361 near Port Aransas, motivated TxDOT to initiate the formal development of a precast bent-cap system. The Pierce Street Elevated project involved replacement of 113 spans of bridge superstructure and bent caps that were damaged by reinforcement corrosion. Use of precast bent caps allowed the project, which would normally require more than 1.5 years for completion, to be finished in 95 days. The Red Fish Bay and Morris & Cummings Cut Bridges were designed and constructed as replacement structures for the original bridges because of severe salt water-induced deterioration. The original substructure design was for cast-in-place bent caps on precast piles, but the contractor requested to use precast bent caps to minimize concrete operations over water. Use of more than 60 precast bent caps greatly expedited construction, enabling work to be completed six months ahead of schedule.

Realizing the potential benefits as well as the uncertainties associated with the use of precast bent-cap systems, the Texas Department of Transportation, through The University of Texas at Austin's Center for Transportation Research, funded Project 0-1748, "Design and Detailing of a Precast Concrete Bent-Cap System." The primary objectives of the research project were to: 1) develop practical, cost-effective candidate details for connecting precast bent caps to cast-in-place columns and precast concrete trestle piles; 2) test select candidate connection details to examine connection constructability and behavior under loading; and 3) develop a design procedure, example details, and construction guidelines for connecting precast bent caps to cast-in-place columns or precast trestle piles. A major emphasis of the research project was to obtain implementable results.

What We Did...

Overview of Research Project

Following a thorough literature review of precast connection technology, as well as extensive communication with officials in states that have developed precast substructure systems, the research team set out to develop several candidate details for connecting precast bent caps to cast-in-place columns or trestle piles. To ensure that the details would be economical and satisfy requirements for constructability, durability, and force transfer, the

research team developed connection details with the help of an advisory panel that included representatives of the precast and construction industries as well as TxDOT engineers. The advisory panel included: Chairman, Randy Rogers, McCarthy Brothers; Charlie Burnett, Champagne-Webber; Paul Guthrie, Texas Concrete; Fred Heldenfels IV, Heldenfels Enter-prises; Carl Thompson, Dalworth Concrete; Roger Welsh, Association of General Contractors; TxDOT Project Director, John Vogel; and TxDOT Project Advisors, Robert Sarcinella and Lloyd Wolf.

Four different categories of connection details were developed with the assistance of the advisory panel. The connection categories included: 1) grout pockets, 2) grouted vertical ducts, 3) bolted connections, and 4) grout-sleeve couplers. Multiple details were developed for most of the connection categories to provide designers and constructors with options to accommodate a wide range of applications and required connection forces. An example of a grouted-vertical-duct connection is shown in Figure 1. This connection is capable of resisting large unbalanced moments associated with the use of inverted-T caps and disparate span lengths on each side of the cap, is detailed to avoid interference between the top longitudinal cap reinforcement and the connection reinforcement, and is detailed to provide protection against corrosion of the connection reinforcement. A detailed summary of the connection development program is presented in Report 1748-1, "Development of Precast Bent Cap Systems and Testing Program."

The development program revealed numerous uncertainties associated with transfer of connection forces between bent caps and cast-in-place columns or precast trestle piles, such as bar anchorage within grout pockets or grouted vertical ducts, interlock of grout pockets and ducts in precast caps, failure modes,

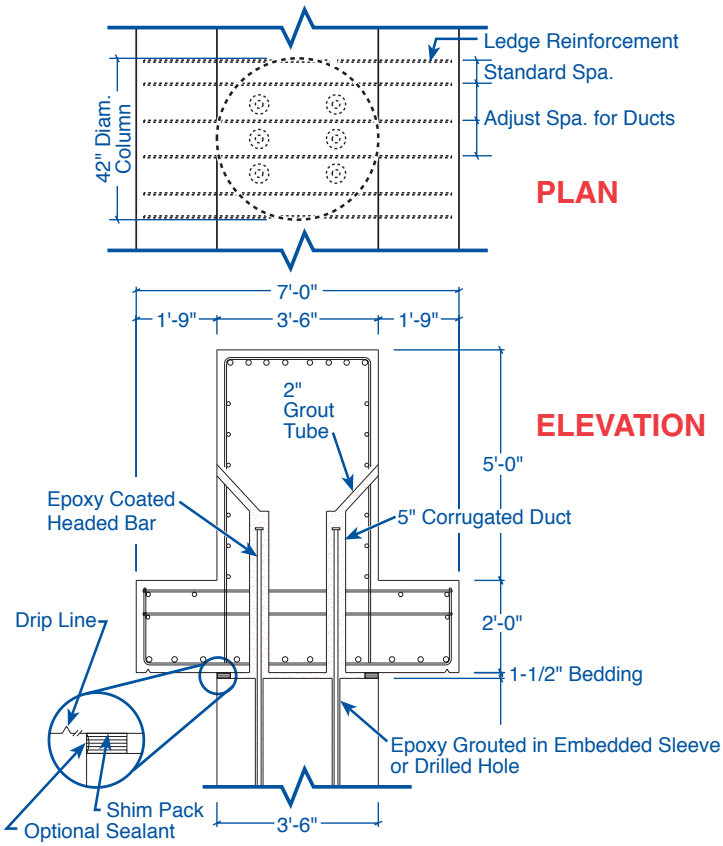

Figure 1 - Grouted Vertical Duct Connection (Inverted-Tee Cap)

and the influence of confinement on connection behavior.

To address these concerns, a three-phase testing program was conducted. In the first phase, 32 pullout tests were conducted on single-line and double-line grout pockets as well as grouted vertical duct specimens to investigate uncertainties associated with connector anchorage. A photograph of the test setup used for a typical bar pullout test is presented in Figure 2. Initial tests were conducted to examine grout types and to determine the depth at which failure transitioned from a concrete breakout to yield of the connector steel. Several tests were conducted to examine the effects of straight versus headed bars, two bars loaded simultaneously, multiple grout pockets, and confining effects on anchorage behavior. Results of the Phase 1 tests were used to proportion and detail four full-scale precast bent cap-to-column connections for the Phase 2 testing program. Connections included a single-line grout pocket, double-line grout pocket, grouted vertical duct, and bolted connection. Specimens in Phase 2 were fabricated and loaded to service-level, factored-load level, and failure to verify design provisions and specifications that were developed through the Phase 1 testing program, and to investigate constructability of full-scale connections in the laboratory environment. Phase 3 utilized a trestle-pile bent and column bent that included seven different connection configurations to examine not only constructability issues similar to those in Phase 2, but also issues associated with the use of a grout specification (developed primarily by John Vogel of TxDOT), construction tolerances for multiple connections, assembly and grouting of multiple connections in realistic field conditions, including adverse weather conditions, and contractor/engineer interaction. The Phase 3

Figure 2 - Setup for Phase 1 Pullout Test

specimens were designed and detailed by the research team and TxDOT bridge design engineers. Fabrication and testing was carried out by Champagne-Webber at its construction facility in Houston, Texas.

What We Found...

The Phase 1 testing program provided critical data needed for the development of anchorage provisions for single and multiple epoxy-coated, headed bars embedded in grout pockets. An example of the type of data collected during pullout tests for an epoxy-coated, headed No. 8 reinforcing bar embedded 12 inches in a grout pocket (Test SL03) is shown in Figure 3. Instrumentation utilized during testing allowed the researchers to determine the load versus slip response along the length of the embedded bar as well as determine the distribution of resistance provided by various parts of the bar. The Phase 1 testing program also provided preliminary information about grout mixes and placement of grout, which aided in the development of a grouting specification.

Phase 2 tests confirmed the adequacy of the anchorage provisions that were developed following the Phase 1 testing program and were used to design the connections between the precast cap elements and trestle-pile or column elements. Tests indicated that the anchorage provisions were somewhat conservative. However, because embedment depths in precast bent-cap elements were not prohibitively long, no modifications were made to the anchorage provisions. The testing program also provided further information about grout behavior and placement procedures that was used in the refinement of the grout specification.

Phase 3 once again confirmed the adequacy of the anchorage provisions and demonstrated that precast bent caps could be constructed under adverse field conditions if the proposed specifications were followed.

Following completion of the three phases of the testing program, a formal procedure for design of precast bent-caps was developed. Included in that formal procedure are design provisions for individual bars anchored in grouted ducts, provisions for individual bars or groups of bars embedded in grout pockets, and numerous other detailing provisions. In addition, a connection specification for precast bent-cap systems that addresses material properties, a detailed plan for placement of the bent caps, and grouting procedures were also developed.

Details of the complete testing program, test results, and development of the connection specification and grout specification are provided in Report 1748-2, "Development of a Precast Bent Cap System."

The Researchers Recommend...

The research team developed design and construction recommendations and a precast connection specification for typical multi-column and trestle-pile bents based on a three-phase testing program and analysis of results from that testing program. Recommendations are not intended to be comprehensive, but instead focus on differences between the design of a precast bent-cap system and that of a cast-in-place system. Preliminary drafts of these recommendations have already been used by TxDOT bridge design engineers to design and detail precast concrete bent caps and their connections for the East Fork Trinity River Bridges.

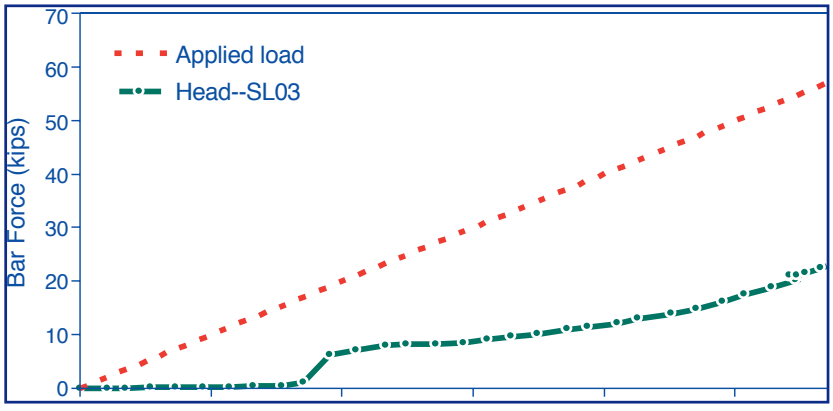

Figure 3 - Distribution of Bar Force

For More Details...

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TxDOT Project Director: John Vogel, P.E., (713) 802-5235, jvogel1@dot.state.tx.us

The research is documented in the following reports:

Report 1748-1, *Development of Precast Bent Cap Systems and Testing Program*. Unpublished.
Report 1748-2, *Development of a Precast Bent Cap System*. October 2001.

To obtain copies of the report, contact: CTR Library, Center for Transportation Research, phone: (512) 232-3138, email: ctrlib@uts.cc.utexas.edu

TxDOT Implementation Status April 2001

The results from this research project have been incorporated into the construction drawings for the East Fork Trinity River Bridges (SH 66) in the Dallas District. Construction is presently underway on these structures. The Bridge Division has translated the results from this project into standard detail sheets for the connection of precast bent caps to square pilings or round columns. The Houston District is using these details on FM 528 over IH 45, to be built soon, and the Harris County Toll Road Authority used this research to develop details for a direct connector on the Westpark Tollway, currently under design in Houston. Further implementation will be realized through utilization of precast bent caps during reconstruction of 94 miles of IH 35 through the Waco District, which will include replacement of approximately 200 bridges.

For more information, please contact Tom Yarbrough, P.E., RTI Research Engineer, (512) 465-7685, tyarbro@dot.state.tx.us

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