

# Transportation Literature Search



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## Pre-Cast Bridge Substructure Elements

Prepared for  
Division of Transportation System Development  
WHRP Structures Technical Oversight Committee

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*Transportation Literature Searches are prepared for WisDOT technical staff in highway development, construction and operations. The bibliography below is representative, rather than exhaustive, of available studies on the topic. Primary online resources for the literature searches are the Transportation Libraries Catalog ([TLCat](#)), the Transportation Research Information Service ([TRIS Online](#)), and various academic and scientific databases. Online copies of publications are noted when available. **Hard copies of all cited literature may be obtained through the WisDOT Library.***

### **KEYWORDS**

Our search of academic and industry databases employed the following terms: precast, prefabricated, bridge, pier, column, substructure, cast-in-place, stay-in-place, element, rapid construction.

### **CITATIONS**

**Title: NCHRP Synthesis 324: Prefabricated Bridge Elements and Systems to Limit Traffic Disruption**

Author(s): Mohsen A. Shahawy

Date: 2003

Doc ID/URL: NCHRP Synthesis 324: Prefabricated Bridge Elements and Systems to Limit Traffic Disruption During Construction. TRB, Washington, D.C., 2004. [http://trb.org/publications/nchrp/nchrp\\_syn\\_324.pdf](http://trb.org/publications/nchrp/nchrp_syn_324.pdf).

Description: 48 pages

Contents: From the literature review and analysis of the survey responses, it is clear that the use of innovative prefabricated elements and systems has generally increased during the last few years. New systems have been developed to prefabricate the decks, the superstructures, and the substructures. The current interest is toward the development of totally prefabricated systems that could accelerate construction time and further minimize traffic disruption. The synthesis report also looks into the use of fiber-reinforced polymers and other advanced materials and new technologies that are gaining in popularity, but still in the experimental stages. The major problems that inhibit the widespread use of innovative systems and elements are identified. To overcome the problems raised in the survey, sustaining research should be pursued to develop better-performing and cost-effective systems. Also, a more efficient collaboration between departments of transportation, consulting engineers, researchers, and contractors is required to share concerns, to orient the research projects, and to generalize the successful aspects leading to standardization and design guidelines for practicing engineers.

**Title: Fiber-Element Model for Cyclic Analysis of Concrete-Filled Fiber Reinforced Polymer Tubes**

Author(s): Yutian Shao, Seyyed Aval, and Amir Mirmiran

Date: Feb. 2005

Doc ID/URL: *Journal of Structural Engineering*, vol. 131, no. 2: pp. 292-303.

Description: 12 pages

Contents: In recent years, concrete-filled fiber reinforced polymer (FRP) tube (CFFT) has been used as precast piles, girders, and pier columns in federally funded innovative bridge projects around the country. While the monotonic behavior of CFFT columns is studied rather extensively, their cyclic response is not yet fully understood. This paper presents a comprehensive composite beam-column fiber element for large displacement nonlinear inelastic analysis of CFFT beam columns. A two-dimensional three-node combined element is used with 13 degrees of freedom, including five for each end node and three for the middle node. The constitutive models for cyclic loading of FRP and concrete are described. The model is verified against the available cyclic test data of an earlier study on six CFFTs with and without internal steel reinforcement. A study is carried out to evaluate the effect of CFFT

parameters on its hysteretic response, and to compare the response with reinforced concrete (RC) and concrete-filled steel tubes (CFSTs). The study shows the feasibility of designing CFFT columns with comparable hysteretic performance to RC columns. However, hysteretic response of CFFT columns cannot measure up to their CFST counterparts, unless their superior durability is considered in the selection process.

**Title: State-of-the-Art Report on Precast Concrete Systems for Rapid Construction of Bridges**

Author(s): David Hieber

Date: 2005

Doc ID/URL: NTIS: Springfield, Virg., 2005. (Report No. WA-RD 594.1. Washington State Department of Transportation: Olympia, 2005.) GovDoc: WA 388 T68sta a2 2005; LC: [TG335](#)

Description: Final technical report, 92 pages

Contents: n/a

**Title: Cyclic Response of Unbonded Posttensioned Precast Columns with Ductile Fiber-Reinforced Concrete**

Author(s): S.L. Billington and J.K. Yoon

Date: July 2004

Doc ID/URL: *Journal of Bridge Engineering*, vol. 9, no. 4 (July/August 2004): 353-363. (10.1061/(ASCE)1084-0702(2004)9:4(353))

Description: 11 pages

Contents: A precast segmental concrete bridge pier system is being investigated for use in seismic regions. The proposed system uses unbonded posttensioning (UBPT) to join the precast segments and has the option of using a ductile fiber-reinforced cement-based composite (DRFCC) in the precast segments at potential plastic hinging regions. The UBPT is expected to cause minimal residual displacements and a low amount of hysteretic energy dissipation. The DRFCC material is expected to add hysteretic energy dissipation and damage tolerance to the system. Small-scale experiments on cantilever columns using the proposed system were conducted. The two main variables were the material used in the plastic hinging region segment and the depth at which that segment was embedded in the column foundation. It was found that using DRFCC allowed the system to dissipate more hysteretic energy than traditional concrete up to drift levels of 3–6%. Furthermore, DRFCC maintained its integrity better than reinforced concrete under high cyclic tensile-compressive loads. The embedment depth of the bottom segment affected the extent of microcracking and hysteretic energy dissipation in the DRFCC. This research suggests that the proposed system may be promising for damage-tolerant structures in seismic regions.

**Title: Application and Design of Segmental Precast Arches**

Author(s): David Hutchinson

Date: July 2004

Doc ID/URL: *GeoTrans 2004: Geotechnical Engineering for Transportation Projects*, Mishac K. Yegian and Edward Kavazanjian, eds.; July 27-31, 2004, Los Angeles, Calif. (10.1061/40744(154)30)

Description: n/a

Contents: The development of the arch was one of the most significant events in the history of structural design. Its value is apparent in the ability of the arch to transfer vertical loading into manageable compression loading. In the highway and industrial markets, arches have been developed as both precast and cast-in-place concrete structures used for bridges, tunnels, culverts and material containment igloos. A new technology called TechSpan™ consists of segmental precast units forming a three-hinged arch structure. TechSpan utilizes the concept of a funicular curve. The term funicular is defined as "imitating a rope and its tension". This concept is used for the TechSpan design. This paper will discuss the analysis, design, and construction of TechSpan. The analysis involves use of a finite element soil-structural model, which allows flexibility in fitting various precast arch shapes to the needs of a project. Specific TechSpan projects will be discussed to demonstrate the relationship of analysis and design to the final construction of the arches.

**Title: Repair of Failing MSE Railroad Bridge Abutment**

Author(s): Tom A. Armour, John Bickford, and Tom Pfister

Date: Jan. 2004

Doc ID/URL: *GeoSupport 2004: Drilled Shafts, Micropiling, Deep Mixing, Remedial (sic) Methods, and Specialty Foundation Systems*, John P. Turner and Paul W. Mayne, eds; Jan. 29-31, 2004, Orlando, Flor. (10.1061/40713(2004)53)

Description: n/a

Contents: In 1978, Idaho Transportation Department (ITD) designed and constructed the first U.S. "true" MSE bridge abutment over the Union Pacific Railroad (UPRR) tracks in Soda Springs. This project was one of the six original FHWA Demonstration Projects introducing reinforced earth technology to the U.S. transportation industry. In the summer of 2002, approximately six of the precast concrete facing panels "popped out" in a localized area of one of the MSE earth retaining walls supporting the bridge approaches. It was determined that the galvanized steel

soil reinforcing strips had corroded at the panel connection to a point where the lateral earth pressures exceeded the connection's remaining capacity. Concerned, ITD and UPRR officials immediately prepared the contract documents for the repair of approximately 3,700 m<sup>2</sup> of MSE walls and bridge abutments. The scope of work in the ITD contract documents included installing horizontal drilled and grouted cross-tie ground anchors in the approach walls, anchored soldier piles at the abutments and a reinforced shotcrete facing structurally attached to the existing MSE facing panels. The cross-tie anchors connected the "back-to-back" MSE approach walls located approximately 25 m from panel to panel. Challenges included traffic control and rail traffic sequencing, winter construction, monitoring the condition of the existing structures, drilling ground anchors (from panel to panel) horizontally through a compacted fill with thousands of steel soil reinforcing elements and installing the soldier pile and rock anchor elements from the existing bridge deck.

**Title: Constructability Considerations for Balanced Cantilever Construction**

Author(s): Gunnar Lucko and Jesús M. de la Garza

Date: Feb. 2003

Doc ID/URL: Practical Periodical on Structure Design and Construction, vol. 8, no. 1 (February 2003): 47-56.  
(10.1061/(ASCE)1084-0680(2003)8:1(47))

Description: 10 pages

Contents: Constructability considerations are of importance in segmental bridge construction as the occurrence of failures of bridge superstructures under construction has highlighted. For a safe and economical construction process, the interactions between construction loads and the permanent structural system, depending on the chosen erection method, need to be evaluated. Segmental bridges can be constructed with methods like balanced cantilever construction, where individual spans are counterweighted about their substructure support. Time-dependent material properties like strength of the newly cast concrete, as well as shrinkage, creep, and relaxation influence the structural system resistance. Resulting stresses in the unfinished bridge structure during construction can even exceed the final stresses during service. This paper makes an educational contribution by illustrating these concepts with the case study of the Wilson Creek Bridge in Virginia. This five-span, cast-in-place bridge was constructed using balanced cantilever construction. Two form travelers were used to construct cantilever arms about the pier tables until the full span was finally connected at midspan; casting cycle duration for a single segment was 7 days. The contractor implemented major constructability changes in both the design and the construction of the bridge to facilitate a more economical construction process.

**Title: Stay-In-Place FRP Form for Concrete Columns**

Author(s): A. Mirmiran

Date: August 2003

Doc ID/URL: Advances in Structural Engineering, vol. 6, no. 3 (August 1, 2003): 231-241  
(10.1260/136943303322419241)

Description: 11 pages

Contents: Advanced fibre reinforced polymer (FRP) composites can be used in combination with traditional materials in a number of different applications such as slabs, beams, columns and piles. The advantages of combined construction include the cost-effectiveness and the ability to optimize the cross section based on material properties of each component. The most efficient use of FRP stay-in-place form is for concrete columns, as it eliminates the need for internal reinforcement and protects concrete against environmental effects. This paper provides a thorough review of the basic principles and research findings to date on the stay-in-place FRP forms for concrete columns. The various design issues including confinement modelling, axial-flexural behaviour, time-dependent behaviour, buckling and slenderness, pile driving, seismic behaviour, connections and modular construction, shear behaviour, fatigue performance, and nondestructive testing and inspection of stay-in-place FRP-concrete columns are discussed. The study to date shows the feasibility and effectiveness of the system for civil engineering applications.

**Title: Precast Piles for Route 40 Bridge in Virginia Using Concrete Filled FRP Tubes**

Author(s): Amir Fam, Miguel Pando, George Filz and Sami Rizkalla

Date: May 2003

Doc ID/URL: *PCI Journal*, May 2003: 2-15.

[http://www4.ncsu.edu:8030/~srizkal/TechPapers2003/PrecastCompositePilesForRoute40BridgeInVirginia\\_AmirFam\\_PandoCSCCE\\_Feb2003.pdf](http://www4.ncsu.edu:8030/~srizkal/TechPapers2003/PrecastCompositePilesForRoute40BridgeInVirginia_AmirFam_PandoCSCCE_Feb2003.pdf).

Description: 14 pages

Contents: This paper summarizes the construction details and findings of laboratory and field tests of a new generation of precast composite piles used for the first time in the construction of the Route 40 highway bridge over the Nottoway River in Virginia. The piles consisted of 24.6 in. (625 mm) diameter concrete-filled glass fiber reinforced polymer (GFRP) circular tubes, with a 0.21 in. (5.3 mm) wall thickness. The composite piles extended above the ground level and were directly embedded into the reinforced concrete cap beam supporting the superstructure. Laboratory tests included two full-scale composite piles loaded to failure using four-point bending

configuration. Field testing included a full-scale precast composite pile and a conventional 20 in. (508 mm) square concrete pile prestressed with fourteen 1/2 in. (12.7 mm) diameter strands. This paper presents details of the construction and driving of the piles, comparisons between the behavior of the composite and prestressed concrete piles under axial and lateral loading, the observed failure modes, and the details of the connection between the piles and the reinforced concrete cap beam.

**Title: Moorebank Ave Interchange – A Tribute to the Versatility of Precast Concrete in Fast Track Infrastructure Construction**

Author(s): corporate author, National Precast Concrete Association Australia

Date: October 2003

Doc ID/URL: *National Precaster*, no. 32 (October 2003): 1-2.

<http://www.npcaa.com.au/html/NationalPrecaster/BackIssues/Prec32.pdf>

Description: 2 pages

Contents: Precast concrete construction appeared a natural outcome to the designers combining both the ease and speed of construction with the durability and low maintenance requirements inherent in high-class, high-strength precast concrete.

**Title: Innovative Prefabrication in Texas Bridges**

Author(s): Ronnie Medlock, Michael Hyzak and Lloyd Wolf

Date: 2002 or later

Doc ID/URL: [http://www.txdot.state.tx.us/brg/Publications/Innovative\\_1.pdf](http://www.txdot.state.tx.us/brg/Publications/Innovative_1.pdf)

Description: 6 pages

Contents: Texas has used prefabricated bridge elements for decades, but prefabrication's potential to reduce traffic disruption and improve constructibility has stimulated increasing bridge design innovation within TxDOT in recent years. TxDOT is developing new ways to incorporate prefabrication into bridge design as it responds to growing public demand for improved traffic flow in urban areas with minimal traffic disruption during construction.

**Title: Applications of Self-Compacting Concrete in Japan, Europe and the United States**

Author(s): Masahiro Ouchi, Sada-aki Nakamura, Thomas Osterberg, Sven-Erik Hallberg and Myint Lwin

Date: 2002 or later

Doc ID/URL: <http://www.fhwa.dot.gov/bridge/scc.htm>

Description: FHWA web document

Contents: Japan has used self-compacting concrete (SCC) in bridge, building and tunnel construction since the early 1990's. In the last five years, a number of SCC bridges have been constructed in Europe. In the United States, the application of SCC in highway bridge construction is very limited at this time. However, the U.S. precast concrete industry is beginning to apply the technology to architectural concrete. SCC has high potential for wider structural applications in highway bridge construction. This paper covers the applications of SCC in Japan and Europe. It discusses the potential for structural applications in the U.S. and the needs for research and development to make SCC technology available to the bridge engineers.

**Title: Alternate Substructure Systems for Standard Highway Bridges**

Author(s): S.L. Billington, R.W. Barnes and J.E. Breen

Date: March, 2001

Doc ID/URL: *Journal of Bridge Engineering*, vol. 6, no. 2 (March/April 2001): 87-94. (10.1061/(ASCE)1084-0702(2001)6:2(87))

Description: 8 pages

Contents: This paper focuses on improving bridge substructures by developing attractive and rapidly constructed substructure systems for short- and moderate-span bridges. The importance of improved substructure design is discussed. A review of current cast-in-place and precast concrete substructure systems is presented. A specific proposal for a precast segmental substructure system is described including methods of fabrication and erection. The goal of this system is to improve aesthetics and reduce construction time for standard bridges. Reduced construction time leads to important safety and economic advantages when traffic disruption or rerouting is necessary. Precasting would result in an increased use of high performance concrete and will bring improved substructure durability. Recommendations are made for standardization of precast substructure systems.

**Title: A Precast Substructure Design for Standard Bridge Systems**

Author(s): Sarah L. Billington, Robert W. Barnes, J.E. Breen

Date: Jan. 1999 revision

Doc ID/URL: The Center: Austin, Tex., 1999. (OCLC: 45410498)

Description: 170 pages

Contents: n/a

**Title: Interim Conclusions, Recommendations, and Design Guidelines for Durability of Post-Tensioned Bridge Substructures**

Author(s): A.J. Schokker, J.S. West, J.E. Breen and M.E. Kreger

Date: October 1999

Doc ID/URL: *Interim Conclusions, Recommendations, and Design Guidelines for Durability of Post-Tensioned Bridge Substructures*. Center for Transportation Research: Austin, 1999.

[http://www.utexas.edu/research/ctr/pdf\\_reports/1405\\_5.pdf](http://www.utexas.edu/research/ctr/pdf_reports/1405_5.pdf).

Description: 48 pages

Contents: The research program involves exposure testing of twenty-seven large-scale beam specimens and ten large-scale column specimens to investigate numerous combinations of variables for durable post-tensioned substructure design. Beam variables include prestress level, loading, grout type, duct splices, concrete type, strand type, duct type, and end anchorage protection. Column variables include foundation connection, post-tensioning protection, concrete type, and loading. In addition, a testing program with small-scale macrocell corrosion specimens was used to investigate corrosion protection for internal tendons in precast segmental construction. A comprehensive study concerning grouts for bonded post-tensioning included fluidity testing, accelerated corrosion testing, and field testing in a large-scale clear parabolic duct. Preliminary durability design guidelines were developed for durability design of post-tensioned bridge substructures. Many of the experimental programs are ongoing, and final design guidelines will be developed at the completion of the project.