AMERICAN SEGMENTAL BRIDGE INSTITUTE

GROUTING COMMITTEE

INTERIM STATEMENT ON GROUTING PRACTICES

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INTRODUCTION

The American Segmental Bridge Institute (ASBI) Grouting Committee was formed in October 2000 to provide an industry response to recent problems reported with grouted tendons on four bridges in Florida. The Committee will also develop a comprehensive training program for personnel responsible for grouting or inspecting grouting practices. This program will be implemented not later than November 1, 2001. In conjunction with this activity, the committee will develop consensus recommendations on all aspects of grouting practice in the form of a proposed revision of the AASHTO grouting specifications. The committee will also explore development of a certification program for grouting technicians and inspectors. The first meeting of the committee was held November 13-14 in Austin, Texas. The initial committee membership roster is appended to this interim statement. Several additional members will be added to the committee prior to the next meeting scheduled to be held in Atlanta the week of January 15.

On a worldwide basis, experience with grouted tendons for half a century has proven that cementitious grout provides excellent protection to prestressing steel. Members of the ASBI Grouting Committee from the states of California, Georgia and Texas, all of which have used post-tensioned construction extensively over many years, are presently unaware of any problems with structures in those states related to the adequacy of grouting practices. On a national basis, no structurally deficient segmental bridges were disclosed in the ASBI "Durability Survey of Segmental Concrete Bridges," published in September 2000. This survey was based on a compilation of the latest available National Bridge Inventory Inspection reports. While there have been isolated and well-publicized problems with post-tensioned bridges in the U.S. related to grouting, such as the Walnut Lane Bridge in Philadelphia, which have impacted the service life of bridges, there have been no structural failures of bridges in the U.S. attributable to corrosion of post-tensioning tendons. Experience has shown that the quality of the grouting as well as use of appropriate design details are of primary importance for the long-term durability of prestressing tendons and post-tensioned structures.

Not withstanding the generally satisfactory performance of post-tensioned bridges in the U.S. and elsewhere, the discovery of any corrosion problem in post-tensioned bridges tends to generate general concern in reference to all post-tensioned construction. Response to this concern has sometimes been disproportionate to an objective evaluation of the problem. In England, the failure of the Bickton Meadows footbridge in 1967, and the collapse of the Ynys-Y-Gwas Bridge in 1985, the latter of which was predictable from a technical perspective, led to a ban on the use of post-tensioned bridges in the United Kingdom from 1992 to 1996. This ban was removed on the basis of recommendations published in Concrete Society Technical Report No. 47 "Durable Bonded Post-Tensioned Bridges." [(1)*] A 1999 publication co-authored by six transportation officials from England, and five transportation officials from France,[(2)] begins Chapter 7, "Problems in Great Britain" with the sentence, "In general, post-tensioned bridges are giving good service and only a small number have had problems."

It is clear that the cost of repairing grouting deficiencies, when discovered, is disproportionately high in comparison with the small incremental costs that may be associated with implementation of improvements in grouting technology. Recent materials technology research [(3)] has demonstrated the means of achieving a very high level of assurance of satisfactory grouting of

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***** *Numbers in raised parenthesis refer to references listed at the end of this paper.*

post-tensioning tendons. It is essential that appropriate grouting technology be used, and that grouting be given attention in the construction process commensurate with its importance in ensuring long-term durability. The ASBI Grouting Committee will be working in the year ahead to provide training resources to assist owners in achieving this goal.

RECENT GROUTING RELATED PROBLEMS IN FLORIDA

During the spring of 1999, a corrosion-related failure of an external tendon was found in the Niles Channel Bridge, one of a series of low-level segmental bridges over seawater on the highway to Key West. The Niles Channel Bridge is 4,557 ft. long and was completed in 1983. Further inspection revealed two corroded strands in the middle (second from the top) tendon anchorage in the opposite web of the bridge in this same span. These anchorages were located at an expansion joint. It was concluded that the initial corrosion resulted from the absence of grout due to accumulated bleed water that separates from the grout leaving voids at the tendon anchorages. It appears that additional corrosion resulted when the voids were recharged with water leaking through the concrete cover at the anchorages.

In August 2000, one failed external tendon and one partially failed external tendon (5 failed strands out of 19) were found in the Mid-Bay Bridge near Destin, Florida. The Mid-Bay Bridge is 19,265 feet long with 140 spans and it contains 840 tendons (six tendons per span). Subsequent inspections resulted in removal and replacement of nine additional tendons due to Florida DOT evaluation of corrosion damage at grouting voids near anchorages. Ten of the eleven tendons replaced were at expansion joints. The investigation also disclosed numerous grout voids at anchorages that need to be filled. The subsidence of grout material, bleed water, and potential recharge of voids during construction before pour-back casting may have contributed to the observed tendon corrosion. It is understood that the Florida DOT expects to release a draft report on the problems observed on the Mid-Bay Bridge in the near future.

In September 2000, corrosion damage was found in two of the four legs of vertical looped tendons of Pier 22N of the Sunshine Skyway Bridge. Inspection of the Sunshine Skyway Bridge superstructure did not reveal evidence of any problems such as corrosion.

The I-75/I-595 Sawgrass Interchange located in Broward County, Florida, is composed of nine precast box girder segmental bridges built between 1986 and 1989. The bridges all have bonded internal tendons and were erected in balanced cantilever with epoxy joints. Since 1992 the Florida DOT has conducted routine inspections of the bridges and has found efflorescence at some of the anchor blocks, leakage at some joints, and visible water leakage at a few closure joints. During the repair process of some of these tendon ducts, it was found that some ducts did not contain any grout. The last routine inspection conducted in February 2000 found some joints with visible water leaking and efflorescence.

The presence of voids in the grout in some longitudinal post-tensioning tendons of the segmental bridges in the Sawgrass Interchange has created a concern about durability and structural performance. As a result, the Florida DOT is conducting a three-phase program to assess and repair these defective longitudinal tendon ducts. Phase 1 of the program is now completed. This consisted of identifying a nondestructive technique to assist in the location of voids within the post-tensioning tendon ducts in a reliable, noninvasive, safe and inexpensive manner. The impact-echo testing method was recommended to accomplish the required task (the impact-echo testing method is only applicable to tendons in metal ducts). Phase 2 is currently underway and encompasses two mock-up specimens of segmental bridges. The last phase of the program will be comprised of field prototype testing of five spans of the Sawgrass Interchange segmental bridges with the purpose of gathering information about the nature and extent of grouting voids.

In summary, it is our understanding that the more significant grouting problems associated with segmental bridge construction in Florida to date may be summarized as follows:

- Voids associated with accumulation of bleed water at tendon anchorages of span-by-span bridges.
- Recharge of ungrouted tendon anchorages with salt water or surface drainage during construction. Temporary capping and sealing of tendons is highly recommended over salt water.
- Leakage through end anchorage protection details at the expansion joints of span-by-span bridges.
- Quality of the grout installation and grout material (subsidence and excessive bleed water).
- Splitting of polyethylene ducts. Attention should be given to wall thickness and Environmental Stress Crack rating of duct material to insure that a durable installation is provided (the need for a revised specification for polyethylene ducts was recognized in the 1990's and a revised Florida DOT specification was issued about 1996).
- Deficiencies in implementation and inspection of grouting procedures (ducts without grout in the I-75/I-595 Interchange).

INTERIM RECOMMENDATIONS FOR IMPROVEMENTS TO GROUTING PRACTICE

On the basis of research in recent years and the experience in Florida described above, the following interim recommendations are offered as a basis for elimination of the observed grouting related problems:

1. Implement administrative requirements in specifications to ensure that all grouting operations are supervised, inspected and documented by technicians and/or engineers who have experience and training in grouting operations and who understand the importance of grouting to long-term structural performance.
2. Conduct a pre-grouting air pressure test of ducts and take measures to eliminate or reduce the consequences of identified leakage. [(1)]
3. Provide effective sealing of tendons from ingress of water in the interval between stressing and grouting.

4. Use an anti-bleed or low-bleed grout. [3] This type of grout may require the use of a colloidal mixer. Prepackaged grout may be used in lieu of special mix design and testing.

5. Physically probe or visually inspect **all** anchorages 48 hours after grouting until the inspection agency is assured that there are no bleed water or subsidence voids. Subsequent spot inspections may be conducted of one or more selected anchorages per span as long as no voids are found. Any voids discovered should be filled immediately with a cementitious grout.

6. End anchorage protection at expansion joints to incorporate a permanent non-metallic grout cap fastened to the anchor plate, and dense concrete pour-backs mechanically anchored to the segment concrete with reinforcement ties. All end anchorage protection details to be shown on design drawings and implemented during construction without exception. See Concrete Society Technical Report 47, "Durable Bonded Post-Tensioned Concrete Bridges" [1] for sample details.

7. Grouting from low points is preferred, with vents provided at high points. Grouting of span-by-span bridges is recommended to be accomplished through a grout inlet at midspan. In addition to the grout vents at the anchorages, grout vents in span-by-span bridges to be provided as near the inside face of the diaphragm as practicable, located at the top of the polyethylene duct. These requirements also apply to any external tendons utilized in balanced cantilever construction.

8. For internal tendons of structures in a salt-water environment or exposed to de-icer chemicals, robust plastic ducts with a minimum wall thickness of 2mm are recommended complying with the *fib* technical report "Corrugated Plastic Ducts for Internal Bonded Post-Tensioning." [4] These ducts are commercially available to all post-tensioning materials suppliers in the U.S. External polyethylene ducts to conform to the requirements of the AASHTO "Guide Specifications for Design and Construction of Segmental Concrete Bridges," Second Edition, Section 16.1.2.

9. Attention needs to be given to the shelf life of admixtures and prepackaged grout in accordance with the type and source recommendations.

10. Variations in cement chemical and physical properties may adversely affect grout characteristics. Freshness of cement should be in accordance with AASHTO M 85. Water demand, bleed water test, setting time test, and strength test should be performed with materials to be used in the proposed grout. The cement manufacturer utilized in laboratory trial batches of the proposed grout should not be changed during construction without retesting.

IMPLEMENTATION PLAN

The grouting related problems discovered in several bridges in Florida indicate the need for utilizing currently available technology for improving the quality of grouting materials and the quality of grouting procedures. Supervisors and inspectors of grouting operations must have the necessary training and experience to ensure compliance with grouting specifications. To this end, the ASBI Grouting Committee will implement a training or certification program for grouting supervisors and inspectors on or before November 1, 2001, and will concurrently develop consensus grouting specifications for submission to the AASHTO Subcommittee on Bridges and Structures.

REFERENCES

(1) "Durable Bonded Post-Tensioned Concrete Bridges" Concrete Society Technical Report, No. 47, Berkshire, England, 1996.

(2) "Post-Tensioned Concrete Bridges," Anglo-French Liaison Report, Thomas Telford Publishing, London, 1999.

(3) Schokker, A. J., Koester, B. D., Breen, J. E., and Kreger, M. E., "Development of High Performance Grouts for Bonded Post-Tensioned Structures". Research Report 1405-2, Center for Transportation Research, October 1999.

(4) "Corrugated Plastic Ducts for Internal Bonded Post-Tensioning," *fib* Technical Report, International Federation for Structural Concrete (*fib*), Lausanne, Switzerland, 2000.

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