Memorandum

To Julie Meredith, SR 520 Program Director

From John Reilly, Chair SR 520 Pontoon Expert Panel

cc: Panel Members: Neil Hawkins, Tom Sherman, John Clark,
SR520 Larry Kyle, Mike Cotten, Tom Horkan, Dave Ziegler

Date: August 17, 2012

Re: SR520, Expert Panel Recommendations

Dear Julie:

Thank you for the opportunity to convene the SR 520 Pontoon Expert Panel in order to offer an independent opinion on the most likely cause of the concrete cracking and spalling in the SR 520 floating bridge pontoons, discovered May 11, 2012 in one of the Cycle 1 pontoons being constructed in Aberdeen, WA.

The Panel members - Dr. Neil Hawkins, Mr. Tom Sherman, and Dr. John Clark - have worked closely and consistently since their appointment in June to investigate the cracking, determine probable causes and to recommend changes which could better limit the extent of future cracking.

Background:

On May 11, 2012, unexpected spalling and cracking of concrete occurred inside Pontoon V, one of the longitudinal pontoons constructed in Cycle 1. The cracking was discovered after the pontoon's longitudinal post-tensioning was complete. WSDOT, working with the contractor, Kiewit-General, immediately developed a repair and modification procedure to apply to all three longitudinal Type 1 pontoons in Cycle 1. The Panel considered the additional concrete and steel reinforcement specified by the WSDOT Bridge and Structures Office and concluded: "…the added bars were adequate to effectively fulfill the AASHTO requirements as demonstrated by their successful performance when the pontoons were subsequently again post-tensioned."

The following document lists the essential recommendations of the Panel which, we understand, are being addressed by WSDOT. We understand that WSDOT and the contractor are working to identify and implement specific changes related to these recommendations, and are addressing those construction, materials, processes and procedures necessary to minimize cracking of the pontoons for construction Cycle 2 (currently in preparation). More refinements are anticipated for Cycle 3 and beyond. Changes for Cycle 2 and subsequent cycles are the subject of a design analysis that is under way, as recommended by the Panel, including an independent review of the current design to identify and evaluate potential design changes.

Please call to discuss the specifics of the Panel recommendations if and as necessary. The Panel is currently monitoring the design analysis work in process and will review changes for Cycle 2 and beyond. They stand ready to assist as possible within their remit.

Yours sincerely,

John Reilly, Chair

Panel Members:

Dr. Neil Hawkins Mr. Tom Sherman Dr. John Clark

SR 520 PONTOON CONSTRUCTION PROJECT, SUMMARY OF EXPERT PANEL RESULTS

The SR 520 Bridge Replacement and HOV Program requires large concrete pontoons built to withstand the loadings of launch, transport, assembly and to support the SR 520 Evergreen Point Floating Bridge on Lake Washington. During construction of the pontoons in the casting basin in Aberdeen, WA, unexpected cracking and spalling of concrete was observed in one of the Cycle 1 pontoons. As a result, a panel of concrete and construction experts was convened to conduct an expert review of the design and construction process for the pontoons – related to the observed cracking and spalling.

Panel Member's - Background

The Expert Panel members were selected for their expertise in the design and construction of complex concrete and pre-stressed/post-tensioned[1] concrete structures. More than one member was required to have experience in floating bridges. An understanding of concrete materials and technologies was required.

Panel members are Neil M. Hawkins, Ph.D., Dist. M. ASCE, Professor Emeritus, University of Illinois, and former chair of the Civil Engineering Department, University of Washington; Tom Sherman, specialist in floating bridge design and construction, TES Enterprises; and John H. Clark, P.E., Ph. D., a consultant in long-span bridges and heavy structures. The panel is chaired by John Reilly, P.E., C.P. Eng., with experience in management, risk assessment and pre-stressed concrete.

Scope of the Panel's work

Determine, as feasible:

1. The most likely cause of concrete cracking and spalling in the SR 520 floating bridge pontoons being constructed at the casting basin in Aberdeen, WA.
2. The need for, and character of, potential changes to pontoon design, details, and/or construction methods to avoid similar concrete cracking and/or spalling in future concrete pontoon construction cycles. Design and construction changes are the responsibility of WSDOT and/or the contractor.
3. In coordination with WSDOT, identify and present considerations regarding the ability of the as-constructed pontoons to be repaired to a condition that will maximize their service life as an integral part of the completed new SR 520 floating bridge.

Responsibility for pontoon design, construction, towing and assembly:

The design of all SR 520 pontoons, in terms of their final configuration and performance in-service on the lake, is the responsibility of WSDOT. The Contractor is responsible for specific design elements of the pontoons including but not limited to, the design of the post tensioning systems, pontoon access and walkway systems. Design and construction of the casting basin and the physical construction of the pontoons in the Aberdeen facility are the responsibility of the Contractor, Kiewit-General. The Contractor is responsible for Quality Control (QC) and Quality Assurance (QA) for the entire project.

Other related contracts, such as the Floating Bridge and Landings (FB&L) contract affect decisions related to towing, construction and assembly of the SR 520 floating bridge. Design of elements such as the road deck superstructure – including construction and integration with the pontoons – is the responsibility of the FB&L contractor (Kiewit/General/Manson, A Joint Venture) which also has responsibility for construction of anchors, the remaining pontoons at the Tacoma facility, and towing and assembly of all pontoons on Lake Washington.

[1] Prestressing refers to beneficial stressing of the concrete structures before application of in-service loads. Post-tensioning is the process of applying that prestressing after the concrete has been placed and hardened.

SUMMARY - CAUSES OF CRACKING AND SPALLING

The Panel found the following basic causes for the cracking and spalling of the Cycle 1 pontoons:

1. The placement and location of the longitudinal post-tensioning ducts and tendons for the Type 1 pontoons deviated from the contract drawings to such an extent that the tendon forces caused cracking and spalling of the slabs adjacent to the end bolt beam.
2. Resistance to longitudinal post-tensioning from the interior precast concrete walls caused vertical cracking of the bolt beam, adjacent to these precast walls.
3. End walls experienced a combination of thermal and autogenous[2] concrete shrinkage, radial tension stresses from the post-tensioning end anchorages and forces from the longitudinal post-tensioning which led to cracking of these walls. Additionally, construction access block-outs in these end walls contributed to the cracking.
4. Contract requirements for concrete curing and thermal control were not rigorously followed resulting in more extensive thermal and shrinkage cracking.
5. For some concrete, water/cementatious (w/c) ratios were lower than those recommended following the ACME project. The ACME project was a test project developed prior to pontoon construction that allowed WSDOT to test mix designs for strength and durability, test form methods for efficiency and to expedite pontoon construction. Procedures for control of the w/c ratio on site (e.g. moisture measurements of aggregates, water added at the site) did not appear to be sufficient.
6. The long pour length for some longitudinal walls (133.9 feet in some cases) was a major cause of the extent of shrinkage and associated vertical cracking in these walls. Adverse cement and concrete properties, curing and thermal control issues potentially added to this cracking.

[2] Autogenous shrinkage is a volume change when there is no moisture transfer to the external environment. It is therefore different than drying shrinkage and most prevalent in high performance concrete where the water-cement ratio (w/c) is under approximately 0.32. The w/c ratio for the Aberdeen pontoons was as low as 0.28.

SUMMARY - RECOMMENDATIONS

CYCLE 1 PONTOON REPAIRS (COMPLETED)

1. **Longitudinal Pontoons T, U and V:**
   a. The Panel concurs with the WSDOT Bridge and Structures Office that repairs made to the bolt-beam/slab spalling and pulled-out post-tensioning ducts are adequate for structural capacity. Pontoons T, U and V were successfully re-tensioned longitudinally after this repair.
2. **Cross Pontoon W**

Future work noted in this section applies to the design and construction of the second cross-pontoon (A).

   a. Longitudinal tendon re-tensioning was completed. Some additional cracking was observed at four locations and was repaired. The cause of this cracking needs to be understood and measures taken.
   b. Repairs to spalling at the bolt-beam transverse post-tensioning were completed. The spalling in this area appears to have occurred even where the post-tension tendons were reported to be in the correct location although significant local deviations were noted. The cause of this cracking needs to be understood and measures taken.
   c. External wall cracking (at the bolt beam location) is a cause for concern. Cracking is also evident at the end wall which will be exposed to the lake in the in-service condition. The cause of this cracking needs to be understood and measures taken.
   d. Issues relating to the bolt-beam and associated transverse prestressing, plus the effect of deck hatch locations, need to be understood and measures taken.

3. **Repair of all cracks** per contract procedures is reported to have been completed. These repairs follow WSDOT's practice for floating bridges, which have been successfully implemented on previous floating bridge applications.
4. **Issues related to the Pontoon's service life:** The repair areas should be inspected throughout the towing and assembly on Lake Washington. Special consideration and attention should be given to these areas according to normal WSDOT maintenance and operation procedures throughout the life of the SR 520 floating bridge. Under these circumstances, it is expected that the service life of the bridge can be met.

CYCLE 2 AND FUTURE PONTOONS:

1. **Verify that contract requirements are adhered to with special emphasis on the following elements:**
   a. Maintain the water/concrete (w/c) ratio in the range of 0.33 - 0.36. This requires control of water at the batch plant, water added at the site and moisture control of the aggregates. (The contract did not specify a lower limit for the w/c ratio).
   b. Thermal control plan must be followed per contract requirements.
   c. Concrete curing requirements must be followed per contract requirements.
   d. Released for Construction (RFC) drawings are to be issued by the contractor and reviewed by WSDOT before construction in the subject areas commences. In this regard, given the number of changes experienced in Cycle 1 and which are also expected for Cycle 2 and subsequent cycles, a reliable process to allow the required Quality Control (QC) and Quality Assurance (QA) by the contractor and the associated Quality Verification (QV) by WSDOT must be in place and enforced. The Panel was advised that a process with this intent was used but the specifics of this process have not been communicated to the Panel. This process needs to be verified in terms of adequacy and effectiveness.

e. Reduce length of wall pours to 100 feet or less. This is possible without increasing the number of construction joints and still considering the anchor chamber configuration. WSDOT construction managers have reported that a 75-foot length may be feasible. Similar considerations apply to the top and base slabs.

f. Test cement for C_3A C_4AF and Fineness. Levels of these elements can affect shrinkage.

g. The post-tensioning sequence designed by the Contractor is to be followed absolutely.

h. Increased WSDOT site and Quality Verification (QV) staff are needed to verify that Quality Control/Quality Assurance (QC/QA) is being performed correctly by the Contractor.

i. A review of batch plant and its operations, inputs and controls should be made in order to determine the adequacy of the procedures, inputs and controls that are essential for consistent production of concrete that meets the requirements of the contract. The ACME pilot program was able to achieve satisfactory results for concrete placement and limitation of cracking and should be a guideline in this and other aspects, as was specified in the contract.

2. Bolt beam and end wall design, Type 1 Pontoons[3]

a. Analyze the bolt beam longitudinally and transversely (relative to the long axis of the Pontoon) using a sufficiently detailed finite element analysis and redesign if necessary.

b. Perform an independent external review of the design and recommended changes.

c. Rescind Request for Information (RFI) 111 (post-tension tendon location, tangent point and curvature inside bolt beam).

d. Add reinforcing to resist post-tension tendon pull-out for the bolt beam and slab (hat bars).

e. Add reinforcing to resist spalling and splitting stresses, for the bolt beam in the transverse direction at the face of the end wall.

f. Evaluate, add and/or revise the end wall reinforcing to better resist concrete shrinkage, thermal effects and post-tensioning forces.

g. Consider deletion of deck hatch openings or other measures to reduce their influence for the future Cross-Pontoon Type 3 (A at cross walls 7T/1L).

h. Add trim bars around wall openings (if such openings must be used) but, preferably, eliminate end wall construction openings. If absolutely necessary, locate near center of the end panels (horizontal and vertical).

i. Decouple end walls from interior precast walls until after prestressing is complete.

j. Investigate moving the PT anchorages closer to the exterior perimeter (Cycle 2 and subsequent cycles, if possible).

[3] Similar considerations will in all likelihood apply to the remaining Type 3 pontoon (A).