FACTUAL SUMMARY OF STATE DOT RESPONSES

TO BRIDGE DESIGN ERRORS

(9 pages including this cover sheet)

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF HIGHWAY SAFETY
WASHINGTON, D.C. 20594

FACTUAL SUMMARY OF STATE DOT RESPONSES TO BRIDGE DESIGN ERRORS

A. ACCIDENT

NTSB #: HWY-07-MH-024

Date and Time:	August 1, 2007 at 6:05 p.m.
Description:	Interstate 35W Bridge collapse
Location:	Interstate Highway 35W Bridge over the Mississippi River, Minneapolis, Hennepin County, MN.
Fatalities:	13
Injuries:	145

B. REPORT GROUP

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C. ACCIDENT SUMMARY

About 6:05 p.m. (CDT), on Wednesday, August 1, 2007, the 35W Interstate Highway Bridge over the Mississippi River, in Minneapolis, Minnesota experienced a catastrophic failure in the main span of the deck truss portion of the 1907-foot-long bridge. As a result, approximately 1,000 feet of the deck truss collapsed with about 456 feet of the main span falling into the river. An assessment of the gusset plates within the deck truss revealed that the connections at U10, U10 prime, L11 and L11 prime were under-designed. The bridge was comprised of eight traffic lanes, with four lanes in each direction. At the time of the collapse, a roadway construction project was underway that resulted in the closure of two northbound and two southbound traffic lanes causing traffic queues on the bridge. A total of 111 vehicles were documented as being on the portion of the bridge that collapsed. Of these, 17 vehicles were recovered from the water. As a result of the bridge collapse, 13 people died and 145 people were injured.

D. DETAILS OF THE REPORT

Between April 29, 2008, and July 23, 2008, investigators interviewed staff from 14 state departments of transportation. The primary purpose of these interviews was to gather information as to how each state performed their review and acceptance process when designs were prepared by private consultants. These interviews also looked at other aspects of each department in regard to their organizational configuration, staffing issues and bridge inventories. Additionally, issues of bridge design errors were discussed at the conclusion of each interview, and information was obtained from the department about any recent experience with such errors.

This report contains a summary of the bridge design errors provided by each state. In order to ensure a consistent reporting format, each department was sent a follow-up questionnaire about bridge design errors. Of the 14 states interviewed, all but four responded to the questionnaire. As such, only ten design error summaries are presented and no information is available from Oregon, Texas, Virginia, or Nebraska.

California:

1. Bridge Description:

Date of Construction - 2008
Type of Bridge - 2 Span, Cast-in Place, Pre-stressed (P/S) Box Girder Overcrossing
Length of Bridge - 195 Ft
Number of Traffic Lanes - Three lanes
Type of Crossing (Water or land) – Land, local street over freeway

2. Brief description of the design error:

The pre-stress cable path that was shown on the structure plans was incorrect.

3. Error discovered before or after the original construction was completed:

The error was found during construction during our review of the prestressing shop drawings that were submitted by the prestressing subcontractor. The cable path shown on the shop drawings was different than that shown on the plans.

4. Brief summary of action taken to resolve the issue:

The consultant designer went back to their bridge design calculations and found that the cable path on the shop drawings was indeed the correct one. (This coincidence is mostly likely explained by the probable scenario that the sub contractor noticed the error in the cable path while preparing the shop drawings and contacted the designer before submitting.)

Florida:

1. **Bridge Description:**

   Date of Construction - 2004 - 2006
   Type of Bridge - Span by Span Segmental superstructure on single column piers with single drilled shaft foundations
   Length of Bridge - Approx 5.8 miles
   Number of Traffic Lanes - Three lanes
   Type of Crossing (water or land) - land

2. **Brief description of the design error:**

   Aggressive drilled shaft design assumptions were used despite highly variable conditions in the SPT borings and advice against those assumptions from FDOT reviewers. During construction, drilled shaft embedment lengths were reduced further based on the results of eight Osterberg load tests, even though test borings were not performed at the load test locations for comparison with the design borings.

3. **Error discovered before or after the original construction was completed:**

   The error was found during the early stages of construction . Pier 97 rapidly settled eleven feet during erection of the span between Piers 97 & 98. In an unrelated event, Pier 99 settled 50% more than the tolerable limit set by the engineer of record.

4. **Brief summary of action taken to resolve the issue:**

   An intensive soil investigation was conducted along with a re-evaluation of the drilled shaft design methods. Each foundation was reviewed and specific repair details were developed to strengthen foundations already constructed or to modify foundations yet to be constructed. No further problems have been reported since this work was accomplished.

Iowa:

1. **Bridge Description:**

   Date of Construction - 2002
   Type of Bridge - Continuous Welded Plate Girder
   Length of Bridge - 435 Feet
   Number of Traffic Lanes - Two
   Type of Crossing (water or land) - Water

2. **Brief description of the design error:**

   Spacing of the intermediate stiffeners on the girder web resulted in an inventory shear rating less than the desired design rating.

3. **Error discovered before or after the original construction was completed:**

   The error was discovered after construction was completed, during our initial rating review.

4. **Brief summary of action taken to resolve the issue:**

   The issue was resolved by installing additional intermediate web stiffeners in the field. Installation was completed using DOT forces. The consultant was charged for the cost of the new material.

Kansas:

1. **Bridge Description:**

   Date of Construction - February 2007
   Type of Bridge - PBMC-6 Continuous Pre-stressed Concrete Beam Spans-6 Beam Lines
   Length of Bridge - 109 Feet
   Number of Traffic Lanes - Two
   Type of Crossing (water or land) - Water

2. **Brief description of the design error:**

   The girders had fewer stirrups than the plans called for in approximately 25% of the beams (12% on either end of the beam). The shop details did not reflect the plan details. The engineer who checked the shop details did not catch that they were incorrect. Thirty four of 66 girders were fabricated with too few stirrups.

3. **Error discovered before or after the original construction was completed:**

   The error was not discovered by inspection staff in the fabrication plant until 34 girders were fabricated.

4. **Brief summary of action taken to resolve the issue:**

   The DOT's standard practice is to add extra stirrups near the ends of the girders to accommodate bursting forces. The extra stirrups also act as a reserve for high shear during super-load situations. The girders as fabricated just met the current LRFD Specification, but did not have the reserve capacity that is normally present in a new prestress I-girder bridge. The girders were used and the fabricator and the consultant were penalized monetarily. The design short-coming is noted in the DOT's data-base for future super-load routing needs.

Maryland:

1. **Bridge Description:**

   Date of Construction - 1977
   Type of Bridge - Steel Girder
   Length of Bridge - 7,207 feet
   Number of Traffic Lanes - Two
   Type of Crossing (water or land) - Predominantly water, some land

2. **Brief description of the design error:**

   Inadequate reinforcing in certain pier caps. Error was contested by the designer and the issue was ultimately left unresolved. No liability was established, so it may not be entirely accurate to classify this as a design error.

3. **Error discovered before or after the original construction was completed:**

   After construction, about 12 years.

4. **Brief summary of action taken to resolve the issue:**

   External post-tensioning was applied to the pier caps found to be in distress.

Minnesota:

1. **Bridge Description:**

   Date of Construction - 2003 to 2006
   Type of Bridge - Segmental cast-in-place box girder (Twin structures)
   Length of Bridge - 1890 feet
   Number of Traffic Lanes - Five lanes on each bridge
   Type of Crossing (water or land) - Water

2. **Brief description of the design error:**

   The original analysis of the load distribution within the twin cell box superstructure made an improper assumption that each web would carry one third (33 percent) of the structure's dead load. However, the center web was found to carry over 40 percent of the dead load.

3. **Error discovered before or after the original construction was completed:**

   The error was discovered prior to completion. Stress cracks in the webs were found by construction inspectors during construction.

4. **Brief summary of action taken to resolve the issue:**

   Vertical post tensioning was added to the webs of segments cast after discovering the web cracking. Portions already cast were retrofitted with external post-tensioning to relieve the overstresses.

New York:

1. **Bridge Description:**

   Date of Construction - 1997
   Type of Bridge - Continuous span steel multi girder
   Length of Bridge - 595 Feet
   Number of Traffic Lanes - Four lanes plus one turning lane
   Type of Crossing (water or land) - Water--non navigable stream

2. **Brief description of the design error:**

   Error in sizing the girder section. Some sections of the girders had inadequate structural cross section to resist the full design loadings. Error was attributed to an improper interpretation of the design specifications.

3. **Error discovered before or after the original construction was completed:**

   Discovered during construction. During the time of construction, the bridge structural information from the plans was entered and processed into our statewide load rating system. This load rating analysis indicated a substandard load capacity of some of the girder sections.

4. **Brief summary of action taken to resolve the issue:**

   The design was reviewed which confirmed the error in the design calculations. Cover plates and additional web stiffeners were retrofitted to portions of the girders to and new bearings were installed provide the required design capacity. The design consultant assumed the cost of the remedial work that was attributable to the design error.

Pennsylvania:

1. **Bridge Description:**

   Date of Construction - April 2008
   Type of Bridge - Steel multi-girder, three-span overpass bridges.
   Length of Bridge - Less than 300 feet total length of each bridge.
   Number of Traffic Lanes - Two lanes
   Type of Crossing (water or land) - Grade Separation - Bridge carries the mainline traffic

2. **Brief description of the design error:**

   Reinforcing detailing/design error in a reinforced concrete pier cap. The primary flexural reinforcement in the top of the hammerhead pier cap had inadequate anchorage and development length. The shear design of the cap was based on deep beam theory, but the detailing of the confinement reinforcement did not meet the AASHTO ratio of 0.003 in each direction in each face of the cap. The cap reinforcement did not meet the AASHTO requirements for temperature and shrinkage.

3. **Error discovered before or after the original construction was completed:**

   The error was discovered after the cap concrete was placed. The cap exhibited excessive cracking which lead to the discovery of the reinforcing detailing/design error.

4. **Brief summary of action taken to resolve the issue:**

   The caps of the concrete hammerhead piers were removed, redesigned and reconstructed with proper reinforcing detailing. As the design and detailing errors pertain to basic bridge engineering principles, a written design advisory was not warranted, but was discussed and shared with Department staff engineers.

<u>Tennessee:</u>

1. **Bridge Description:**

   Date of Construction - 2004 to 2005
   Type of Bridge - Chorded Welded Steel Plate Girder
   Length of Bridge - 740 feet
   Number of Traffic Lanes - Four lanes (two lanes in each direction)
   Type of Crossing (water or land) - Land (Grade Crossing)

2. **Brief description of the design error:**

   Differential deflection of the girders during slab pour due to effect of extreme skew, un-predicted thermal movement of the girders due to stiff sub-structures, not accounting for the thrust force at the Bents due to kinked girders, and other un-foreseen forces acting on the structure.

3. **Error discovered before or after the original construction was completed:**

   After original bridge construction

4. **Brief summary of action taken to resolve the issue:**

   Add expansion bearing at Bents, tilted girders were jacked to near plumb position, thrust blocks were installed at heavily kinked girders at Bent no. 2 to redirect thermal movement, fractured bolts in the cross-frames were replaced, heavier cross-frames were install near the bents, and other miscellaneous repairs.

Washington:

1. **Bridge Description:**

   Date of Construction - The ramp was constructed in 2007.
   Type of Bridge - Cast-in-place concrete retaining walls that retain soil supporting an on grade cast-in-place post-tensioned cantilevered slab (Original design was cast-in-place reinforced concrete slab).
   Length of Bridge - 356 feet along the length of the retaining walls.
   Number of Traffic Lanes - Three lanes
   Type of Crossing (water or land) - Land

2. **Brief description of the design error:**

   The north ramp consists of cast-in-place concrete retaining walls placed back to back approximately 52 feet apart. The retained soil between the retaining walls support an on grade cast-in-place post-tensioned cantilevered slab that overhangs the walls on both sides by about 13 feet (original design was cast-in-place reinforced concrete slab). The original slab design did not fully account for the soil support condition which effectively results in a larger overhang for design.

3. **Error discovered before or after the original construction was completed:**

   After the original slab was constructed.

4. **Brief summary of action taken to resolve the issue:**

   The cracked slab was shored with timber posts and demolished in a controlled manner. The redesign was completed incorporating the soil support condition. Transverse post-tensioning of the slab was used to eliminate longitudinal cracking. Internal checking as well as an external design check was performed and revised plans were issued. The slab was constructed according to the revised plan set. This particular portion of the project had inadvertently been missed during the process of checking the design. However, all other portions were adequately checked.

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