# ADDENDUM TO BRIDGE DESIGN GROUP CHAIRMAN FACTUAL REPORT

(72 pages)

**NATIONAL TRANSPORTATION SAFETY BOARD**
**OFFICE OF HIGHWAY SAFETY**
**WASHINGTON, DC 20594**

# ADDENDUM TO BRIDGE DESIGN GROUP CHAIRMAN FACTUAL REPORT

## A. ACCIDENT

| | |
|---|---|
| Type of Accident: | Bridge Collapse |
| Date and Time: | August 1, 2007 at 6:05 pm CDT |
| Location: | Interstate Highway 35W Bridge over the Mississippi River, Minneapolis, Hennepin County, MN |
| Fatalities: | 13 |
| Injuries: | 145 |
| Case Number: | HWY07MH024 |

## B. BRIDGE DESIGN GROUP

| | | |
|---|---|---|
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## C. ACCIDENT SYNOPSIS

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

The Addendum to Bridge Design Group Chairman Factual Report is organized by the following topic areas and page numbers:

# 1. MINNESOTA DEPARTMENT OF TRANSPORTATION (Mn/DOT) PROCESS OF CHECKING CONSULTANT PREPARED BRIDGE PLANS

## 1.1 STATE OF MINNESOTA CLASSIFICATION QUESTIONNAIRE DATED FEBRUARY 24, 1960

Mn/DOT provided a copy of a State of Minnesota Classification Questionnaire dated February 24, 1960 (See Attachment 36 – Minnesota Classification Questionnaire dated February 24, 1960). The classification questionnaire indicated the following:

*"To review the preliminary bridge plans which have been prepared by Consulting Engineers for the purpose of ensuring that the plans conform to M.H.D. and AASHO Specifications.*

*The preliminary bridge plan and preliminary report is made for the purpose of determining the geometries, design and architectural features, all critical dimensions, and general layout of the bridge. The primary purposes served by the preliminary review are as follows:*

1. *Economic study of various types of bridge construction.*
2. *The geometric study to show the actual adoption of the bridge to the bridge site.*
3. *Aesthetic considerations.*
4. *Determination of materials to be used in the structure.*
5. *Analysis of soil conditions involved at the bridge site to determine proper footing and pile requirements.*
6. *Consideration of actual design requirements.*

*The details of this work involve checking alignment from available surveying data. Horizontal and vertical clearances are checked against standard specifications. Stations and elevations on the plan are recalculated to check for* *errors in the Consultants computations. Any irregularities of design, layout, or standard details, and errors in computations are noted on the plan."*

## 1.2 MINNESOTA HIGHWAY DEPARTMENT BRIDGE DESIGN MANUAL DATED APRIL 12, 1972

Mn/DOT provided a copy of the Minnesota Highway Department Bridge Design Manual[1] dated April 12, 1972 (See Attachment 37 - Minnesota Highway Department Bridge Design Manual dated April 12, 1972). The manual indicated the following:

*"CHECKING CONSULTANT PLANS*

*Consultant prepared plans are to be reviewed and checked for the following major items to insure adequate layout control and coordination with roadway plans.*

1. *Control Points – Horizontal control dimensions and vertical control elevations and dimensions are to be checked for correct alignment and grade. The horizontal and vertical clearances are to be checked for compliance with all clearance requirements of M.H.D., railroad or others. Cross check elevations and stations of each substructure unit with those on staking plan.*

2. *Strength – The following should be reviewed for adequacy in design and conformance with M.H.D. requirements and standards.*

   a. *Railing – Conformance with standard and proper post spacing.*

   b. *Slab – Conformance with M.H.D. slab tables.*

   c. *Beams and Girders – Design check for strength, shear connector spacing, and diaphragm spacing.*

   d. *Bearings – Check selection for proper sizes.*

   e. *Piers and Abutments – Design check for strength. Geometric check.*

   f. *Piling – Review for type, length, and loading.*

   g. *Railroad underpasses will not be checked for strength.*

3. *Miscellaneous*

   a. *Locate floor drains, when used, to avoid endangering traffic below.*

[1] Bridge Design Manual, Minnesota Highway Department Bridge Division and Standards, Office of Engineering Standards, Transmittal Letter No. 5-392 (72-1), April 12, 1972, page 10.

*b. Checking of individual sheet quantities in bridge plan will not be required. Check that consultant has made 2 independent computations for each quantity, and that the results agree with that shown in the plans.*

*c. Check the addition of each sheet's quantities with those of the summary of quantities.*

*d. Check notes and pay items for conformance with M.H.D. specifications and practices."*

1.3 CONSULTANT AGREEMENT BETWEEN Mn/DOT AND SVERDRUP AND PARCEL AND ASSOCIATES, INC. DATED NOVEMBER 5, 1962

Mn/DOT provided a copy of the consultant agreement between Mn/DOT and Sverdrup and Parcel and Associates, Inc. dated November 5, 1962 (See Attachment 38 - Consultant agreement between Mn/DOT and Sverdrup and Parcel and Associates, Inc. dated November 5, 1962). The consultant agreement was for engineering services on T.H. No. 35W Bridge No. 9340 over the Mississippi River in Minneapolis. The consultant agreement[2] indicated the following:

*"Section 10. Checking Prints.*

*When detail plans have been completed and checked by the Consultant, he shall furnish to the State one set of paper transparencies of the final plans and four copies of the special construction requirements and of a complete estimated construction cost analysis of the Bridge Project, plus an equal number of revised copies if the State's review discloses that revisions are necessary. The Consultant shall also furnish to the State two copies of checked design computations and quantity computation (except four copies as noted in (a) of Section 4 for concrete quantities) and computations for moment influence line diagrams for all parts of the entire structure. Computations shall be submitted on 8 ½" x 11" sheets insofar as practicable."*

1.4 Mn/DOT'S CONSULTANT SERVICES WORK TYPE DEFINITION DATED MARCH 26, 2003

Mn/DOT provided a copy of the consultant services work type definition dated March 26, 2003 (See Attachment 39 – Mn/DOT consultant services work type definition dated March 26, 2003). Specific examples and quality attributes of output that consultant engineering firms are required to furnish Mn/DOT include the following:

*"Specific Examples of Output*

[2]Agreement between the State of Minnesota, Department of Highways, and Sverdrup & Parcel and Associates, Inc. Consulting Engineers for T.H. 35W Bridge (No. 9340) over Mississippi River in Minneapolis, page 10.

- *Certified final bridge construction plans, including non-standard special provisions, 100% complete and ready for construction contract bidding, that meet all project specific requirements.*
- *Final reports, which may require certification, that meet all project specific requirements.*
- *Bridge preliminary plans, 100% complete, as the basis for final bridge plan design and preparation.*
- *All design services, a set of computations and electronic design files in a format compatible with Mn/DOT's Microstation (latest version).*
- *Cost estimates and construction documents, including special provisions.*

*Quality Attributes of Output*

*Consultant to check/verify bridge plans in conformance with Mn/DOT Bridge Design Manual and their documented QA/QC Plan. In some cases this requires a complete, independent analysis. Consultant's QA/QC plan must address their methods of verifying their work, including review submittals, comments from previous submittals, and final deliverables."*

Consultant engineering firms perform four (4) different levels of work for the Office of Bridges and Structures. The four (4) different levels of work include the following:

***"Level 1 Average Bridge Design –*** *Examples include bridges with multiple spans and some aesthetic treatments, structural steel beam bridges with moderate skews, pre-stressed concrete beam bridges with moderate to high skews, substructures supported on pile or spread footings, high or low parapet type abutments, long wingwalls supported on footings, includes designs for both new construction and bridge renovation, moderate staging may be required, may include preliminary and final design services, and may include attached cantilever retaining walls.*

***Level 2 Complex Bridge Design*** *– Examples include curved structural steel girder bridges, straight structural steel girder bridges with skews greater than 20 degrees, post tensioned concrete box girders supported on falsework during construction, rigid frames with balanced lateral loads and/or moderate skew, bridges with extensive aesthetic treatments or complex geometry, river crossings, railroad bridges, includes designs for both new construction and bridge renovation, significant staging may be required, may include special provisions, may include preliminary and final design services, and may include attached cantilever retaining walls or earthen walls.*

***Level 3 Specialty Bridge Design*** *– Examples include segmental post tensioned concrete box girder bridges, steel box girder bridges, truss bridges, concrete or steel arch bridges, major river crossings with unique geotechnical conditions, rigid frames with unbalanced lateral loads and/or high skew, includes designs for both new construction and bridge renovation, includes development of* *construction specifications, may include preliminary and final design services, and may include attached cantilever retaining walls or earthen walls.*

***Level 4 Bridges & Structure Studies*** *– This work involves evaluation of new or in place structures (includes bridges, retaining walls, earthen walls, culverts, other miscellaneous structures) and the preparation of studies & reports relating to the structures' design, construction, and/or maintenance issues. Studies include but are not necessarily limited to filed investigations; structural, mechanical, electrical analysis; bridge ratings; repair cost estimates; bridge life expectancy estimates; and development of design and construction specifications for non-standard projects."*

The I-35W Bridge over the Mississippi River would be considered a Level 3 Specialty Bridge Design because it was a truss bridge that spanned over a major river crossing.

The minimum technical qualifications that a consultant engineering firm must have for a Level 3 Specialty Bridge Design include the following:

*"**Minimum Number of Staff –***

- *At least two professionals are required for Level 3 and Level 4 Projects. One of the professionals is required to perform independent checks of data, calculations and reports of the other.*
- *Number of professional and technical support personnel must be recorded and updated.*

***Professional Certification/Licensure*** *–*

- *The qualified engineering personnel shall have engineering training, experience, knowledge, and expertise in the appropriate areas necessary to do the project in accordance with AASHTO, FHWA, Mn/DOT, and all other applicable design policies, procedures, practices and standards.*
- *At least one of the engineers shall be a Minnesota Board Registered Professional Civil Engineer as specified under Minimum Number of Staff.*

***Qualifying Experience*** *–*

- *Level 3*
  - *Satisfactory experience must be demonstrated on at least two Level 3 projects in the last ten years (these projects may be from Minnesota or other states); and*
  - *Staff from firm's out-of-state offices with project specific expertise may provide the majority of services; however, local office must be capable of providing project management as a minimum.*

*Note: A professional qualification of Level 3 includes automatic qualification for Level 4.*

*Note: Professional qualifications of Level 3 will be qualified for Levels 1 and/or 2 if they are staffed locally to do the work and meet all other pre-qualification criteria.*

***Past Record & Experience of Firm***

- *Level 3 and 4: Out-of-state personnel may substantially complete the project; however, the firm must have a local Minnesota office capable of project management as a minimum extent of participation.*
- *Firm must be capable of delivering bridge plans in Microstation (current Mn/DOT version) and special provisions and reports in Microsoft Word (current Mn/DOT version).*

*Level 3 and 4*

- *Firms qualifying for Levels 3 and 4 must list all programs specific to the work type they are applying.*

*Level 1, 2, 3 and 4*

- *Firm's Quality Assurance Plan must certify that they independently validate the accuracy of their bridge analysis and design software programs and program updates. The QA Plan must provide the methodology for the independent validation.*
- *Firm's QA Plan must certify their methodology for checking/verifying the accuracy of their work (i.e. designs, drawings, report preparation).*
- *Note: Mn/DOT currently follows Load Factor Design (LFD) criteria for bridge design. Load Resistance Design Factor (LRFD) will be adopted in Calendar Year 2003. All LRFD software must also be validated against design examples illustrated in Mn/DOT's LRFD Manual. The Manual will be made available prior to adoption of LRFD criteria.*

***Requirements of Professional Staff***

- *Qualifying experience of key personnel for each category/level of work applied for shall be documented by resumes and personal experience histories.*
- *Other professional and technical personnel used to support pre-qualification shall also be documented.*

***Requirements of Firm***

- *Satisfactory experience of the firm in the category shall be documented by reference to completed projects.*
- *Levels 1, 2, and 3: Submit no more than three hard copies of relevant work samples (consisting of General Plan and Elevation sheets and no more than five additional representative sheets, on 11" x 17" bond) that meet the qualifications for each category.*

*Note: If the samples were not produced for Minnesota's State, County State Aid, or equivalent systems, then also submit no more than three work samples that do.*

- *Work samples of current key personnel may be submitted in lieu of work samples of the firm. To qualify as relevant work sample plans of key personnel that personnel must have been either the registered engineer who certified the plan as the Engineer of Record or a registered engineer with significant participation in plan preparation (i.e. plan sheets initialed for design and/or checking).*
- *Submit copy of pertinent sections of Firm's Quality Assurance (QA) Plan that addresses Levels of work being applied for. It is not required to submit the entire QA Plan. The QA submittal must include the firm's procedures for checking designs and plan drawings, for updating and validating design software, and verifying information and data contained in special reports. Mn/DOT reserves the right to request additional QA information.*

***Project Documentation***

- *Project examples may be submitted electronically on CD's or you can submit project examples in hard copy (i.e. reports, plans, etc.)."*

## 1.5 Mn/DOT'S QUALITY ASSURANCE PEER REVIEW OF DESIGN PROJECTS

### 1.5.1 CROSSTOWN PROJECT AND I-35W EMERGENCY REPLACEMENT

Mn/DOT sent a letter to the NTSB dated March 6, 2008 indicating that Mn/DOT had implemented a peer review process on complex bridge projects designed by consultants (See Attachment 40 – Letter to the National Transportation Safety Board from the Minnesota Department of Transportation dated March 6, 2008). The letter indicated the following:

*"For complex structures that are designed by consultants we have implemented a peer review process on recent projects. We will be utilizing peer reviews for similar projects in the future. Examples of complex bridges include segmental concrete structures, cable supported structures, and other bridge types that are less frequently used on our system.*

*You requested a description of the peer review process we employed on the Crosstown Project designed in 2005-2006, and the I35W emergency replacement bridge currently under design. Those descriptions are provided below:*

***Crosstown Project***

*The Crosstown Project on I35W and Trunk Highway 62 on the southern border of Minneapolis included twenty-four bridges. Six of those structures are precast segmental concrete box girders. These are the first precast segmental used in Minnesota. We employed three firms to each design two of the segmental bridges. It was important that the designs were consistent in details for constructability and fabrication economy. We also chose to include a peer process for design reviews rather than perform with our staff. Our in house designers were fully booked on their own design projects at the time.*

*To achieve those goals, we took three steps. First, one firm Parsons Brinckerhoff, was designated as lead firm to establish standard details, design criteria, and coordinate with the other two firms to ensure consistent application. URS Corporation and Parson Transportation were the other two firms. Secondly, for quality assurance, each firm was required to complete an independent design and analysis check for the segmental box girders with personnel completely independent from the main design team. Finally, Parsons Brinckerhoff performed a "quality assurance peer review" of the plans prepared by URS and Parson Transportation. This peer review was not a complete plans check. They reviewed the design for post-tensioned requirements, erection sequence, and conformance with the intent of the segmental design standards.*

*These bridges have since gone to contract and are under construction. The substructures are being built and segments are being cast at an offsite facility.*

***I35W Emergency Replacement***

*The I35W Bridge is a fast tracked Design Build Project. The bridge type selected by the contractor, Flatiron Construction, is a concrete box girder with portions cast-in-place on false work and the main span precast segmental. Figg Engineering is the designer for the Design Build contractor. As part of the design process, Figg is conducting an independent check of their design. This is commonly done in the industry.*

*Mn/DOT retained Parsons Transportation to assist in performing the owner's review of the Figg Engineering design. To facilitate coordination and communication, Mn/DOT's project specifications required the Design Build team be co-housed with Mn/DOT and our peer review consultant. The peer review process by Parson's and Mn/DOT is occurring concurrently with the Figg design. As portions of the design are completed, Figg submits the plans and calculations for review and comment. Design assumptions and decisions are discussed and resolved between Figg, Parsons and Mn/DOT on a daily basis."*

## 1.6 WAKOTA BRIDGE

Mn/DOT sent a letter to the NTSB dated March 24, 2008 indicating the problems Mn/DOT encountered during construction of the Wakota Bridge over the Mississippi River (See Attachment 41 – Letter to the National Transportation Safety Board from the Minnesota Department of Transportation dated March 24, 2008). The letter indicated the following:

> *"Mn/DOT retained a consultant firm to design the bridges in early 2001. The river bridges are twin structures but vary slightly since the westbound bridge includes extra width for a bike trail. The design consultant completed the design in 2002 and the bidding took place in December of 2002. Lunda Construction was the contractor and began work in early 2003. The two bridges together accounted for $59 million of a larger contract that included roadway and interchange bridges. Of the bridges, the westbound bridge cost was approximately $34 million and the eastbound bridge was about $25 million.*
>
> *In September of 2004, hairline cracks were discovered in the webs of the box girders. The westbound bridge was about 40% complete at the time. Construction inspection was being conducted by Mn/DOT construction staff and Parsons Transportation retained by Mn/DOT to assist. Parsons Transportation was not the bridge designer. Construction continued through the fall of 2004 as we investigated materials, methods and other issues to determine the cause of the cracking. In December of 2004, we began adding vertical post tensioning to the webs of the remaining segments being cast to prevent additional cracking. Early in 2005 we directed Parsons Transportation to conduct a peer review of the box girder superstructure design. Parsons determined the original designer assumed a simplified distribution of load to the exterior and interior webs whereby each web carried 1/3 of the load. In reality, the center web carries over 40% of the load.*
>
> *We further directed Parson Transportation to undertake a complete review of the design plans for both the westbound bridge under construction and the eastbound bridge which had not yet begun. This included foundations, piers and superstructure. That peer review was completed in the summer of 2005 and detailed the design deficiencies.*
>
> *During the spring and summer of 2005, the original designer was also preparing retrofit plans to add external post-tensioning to the westbound bridge to relieve the overstresses in the portion of the bridge built prior to the discovery of the cracks. Parsons Transportation conducted an over the shoulder peer review of the retrofit design as it progressed...*
>
> *The retrofit and construction delays of the westbound bridge added approximately $19 million to the construction cost and it was completed one year behind schedule...We subsequently advertised the eastbound bridge for competitive*

*bidding in February of 2008 and the bridge portion of the project cost was approximately $56 million…The eastbound bridge is now scheduled for completion in 2010, three years after the original planned date of 2007."*

## 1.7 Mn/DOT'S CURRENT PROCESS OF CHECKING CONSULTANT PREPARED BRIDGE PLANS

Mn/DOT provided a copy of the Load and Resistance Factor Design (LRFD) Bridge Design Manual[3] (See Attachment 42 – Mn/DOT Load and Resistance Factor Design (LRFD) Bridge Design Manual). The manual indicated the following regarding checking of consultant prepared bridge plans:

*"**1.3.2 Checking of Consultant Prepared Bridge Plans***

*Consultant prepared bridge plans are created by private engineering firms through contracts with the Department. The finished plans are complete to the extent that they can be used for construction.*

*Since these plans receive final approval of the State Bridge Engineer, there must be assurance that the plans are geometrically accurate and buildable; structural design is adequate and design codes have been correctly applied; proper direction is given to the construction contractor; and all construction costs are accounted for. Plan errors may cause costly construction delays or safety may be compromised by an inadequate design.*

*To keep consultant plan reviews consistent and timely, a procedure was developed as a guide that assigns priority to specific items in the plans. The overall review includes "a Thorough Check" and "Cursory Review" of various items. The distinction between "Thorough Check" and "Cursory Review" is as follows:*

*<u>Thorough Check</u> refers to performing complete mathematical computations in order to identify discrepancies in the plans, or conducting careful comparisons of known data and standards of the Project with values given in the plan.*

*<u>Cursory Review</u> refers to a comparative analysis for agreement with standard practice and consistency with similar structures, all with application of engineering judgment. Mathematical analysis is not required, but may be deemed necessary to identify the extent of a discrepancy.*

*The review procedure is listed on the CONSULTANT BRIDGE PLAN REVIEW form following this section. Headings on this list are defined as follows:*

*PARTIAL PLAN: In order to assure that the consultant is proceeding in the right direction, an early submittal of the plan is required. This submittal usually*

[3] LRFD Bridge Design Manual, Minnesota Department of Transportation Bridge Office, pages 1-12 through 1-14.

*consists of the General Plan and Elevation sheet showing the overall geometry of the structure and the proposed beam type and spacing; the Bridge Layout Sheet; the Framing Plan Sheet; and the Bridge Survey sheets. Errors and inconsistencies found in this phase can be corrected before the entire plan is completed. For example, a framing plan, including the proposed beams, must be assured as workable on the partial plan before the consultant gets deep into the design of the remainder of the bridge.*

*FINAL PLAN: A final plan should be complete in all areas to the extent that it can be certified by the designer, although a certification signature is not required for this phase.*

*THOROUGH CHECK: Items indicated for checking on the consultant's partial plan must be correct. Given geometry must fit the roadway layout. Most of this information can be checked using data from the approved preliminary plan. Approval of the partial plan will indicate that Mn/DOT is satisfied with the geometry and proposed structure, and the consultant may proceed with further development of the plan. For the final plan, obvious drafting and numerical errors should be marked to point out the errors to the consultant, however, the reviewer should not provide corrections to errors in the consultant's numerical computations.*

*Checking on the final plan should be thorough to eliminate possible errors that may occur, such as the pay items in the Schedule of Quantities. Plan notes and pay items can be difficult for a consultant to anticipate because of frequent changes by Mn/DOT. Pay items must be correct because these are carried throughout the entire accounting system for the Project. Plan (P) quantities must also be correctly indicated.*

*CURSORY REVIEW: Normally, a cursory review would not require numerical calculations. This type of review can be conducted by reading and observing the contents of the plan in order to assure the completeness of the work. The reviewer should be observant to recognize what looks right and what doesn't look right. Obvious errors or inconsistencies on any parts of the plan should be marked for correction.*

*Although structural design is usually the major focus of any plan, most consultants are well versed in design procedures and should need only minimal assistance from our office. A comparison of the consultant's calculations with the plan details should be performed to assure that the plans reflect their design and that the applicable codes are followed. An independent design by our office is time consuming and is not recommended unless there is a reasonable doubt as to the adequacy of the consultant's design.*

*NO REVIEW: A thorough review of these items would be time-consuming and may not produce corrections that are vital to construction; therefore, it is* *recommended that little or not time be spent on the listed items. Numerous errors can occur in the Bills of Reinforcement and quantity values. However, checking this information is also time-consuming, hence the burden of providing correct data should be placed on the consultant."*

## 1.8 PERCENTAGE OF Mn/DOT BRIDGE PROJECTS DESIGNED BY CONSULTANTS

Mn/DOT provided information to NTSB investigators regarding the percentage of bridge projects designed by consultants for fiscal years 2002 through 2006. Table 1 shows the percentage of bridge projects designed by consultants, Mn/DOT in-house personnel, or design-build projects for fiscal years 2002 through 2006.

**Table 1 – Percentage of bridge projects designed by consultants, Mn/DOT in-house personnel, or design-build projects for fiscal years 2002 through 2006**

| Fiscal Year | Consultants | Mn/DOT In-House Personnel | Design-Build Projects | Total Expenditure |
|---|---|---|---|---|
| FY 2002 | 41% | 58% | 1% | $129,000,000 |
| FY 2003 | 60% | 22% | 18% | $168,000,000 |
| FY 2004 | 6% | 72% | 22% | $65,000,000 |
| FY 2005 | 11% | 65% | 24% | $116,000,000 |
| FY 2006 | 5% | 78% | 17% | $64,000,000 |

## 2. FEDERAL HIGHWAY ADMINISTRATION (FHWA) MINNESOTA DIVISION OFFICE PROCESS OF CHECKING CONSULTANT PREPARED BRIDGE PLANS

### 2.1 DIFFERENCES IN REVIEWING CONSULTANT ENGINEERING BRIDGE PLANS IN THE EARLY 1960's VERSUS TODAY

FHWA's Minnesota Division Office explained in a March 7, 2008 email to NTSB investigators the differences in reviewing consultant engineering bridge plans in the early 1960's versus today (See Attachment 43 – Email to the National Transportation Safety Board from the Federal Highway Administration – Minnesota Division Office dated March 7, 2008):

> *"In general, the administration of the Federal-aid program is less hands-on today than it was in the 1960's. In the 1960's FHWA engineers were more likely to be involved with the detailed engineering of projects during design and be active participants during construction. In addition, the workforce of the 1960's and 1970's included many engineers who grew up in the organization during the Interstate era when many State DOT's lacked technical expertise and were just starting to evolve. Thus, many of those employees would assume a professional responsibility in filling technical gaps in knowledge and experience and be more involved in project level activities. Today, our workforce is much different and we have a lesser number of employees who grew up in the organization having "touched" actual projects in detail. In addition, State DOT's are very mature. Thus, current employees focus on broader program delivery activities in carrying out their day-to-day responsibilities. This approach is consistent with current agency direction that has been shaped through years by various transportation bills.*
>
> *Having said the above, it appears that the FHWA review practices related to bridge plan review have really not changed much over the years. This is based on our inherent knowledge of such practices and discussions with retired FHWA bridge engineers who worked in the 1960's. We spoke with two individuals who were able to shed some light on this discussion: a retired Minnesota Division Bridge Engineer, and a retired Region One Bridge Engineer.*
>
> *According to the retired Minnesota Division Bridge Engineer, the practice of today is the same as the practice from the 1960's. The practice being that all reviews do not generally get into any great detail unless some design feature appears to be out of place (under-sized or over-designed). The retired Region One Bridge Engineer provided similar feedback.*
>
> *The following additional thoughts concerning the level of bridge plan review at the Division Office level are provided:*

*a. Review effort is dictated by the level of interest of the particular Engineer performing the review. Additionally, the review effort varies from bridge to bridge.*

*b. Compared to the 1960's there are little or no non-redundant structures being designed these days. Most structures designed these days are very redundant structures.*

*c. The review effort at both the Regional and Washington Office is probably not much different compared to the reviews that are performed by the Division Office, both now and historically. Major and unusual structures receive reviews by more than one Engineer (Regional and Washington Office) whereas other structures receive reviews by only one Engineer (the Division Bridge Engineer). Again the review effort is dictated by the level of interest of the particular Engineer performing the review. Additionally, there is no requirement for the Washington Office to be involved in the review of major and unusual structures beyond the preliminary plan stage. Note: Regional Offices no longer exist, so any supplementary reviews are being performed by the Washington Office."*

## 2.2 FHWA AND Mn/DOT STEWARDSHIP PLAN

FHWA and Mn/DOT signed a Stewardship Plan in December 2007 that sets forth the respective roles and responsibilities of each party in the administration and oversight of the Federal-aid Highway Program in the State of Minnesota. The Stewardship Plan covered two functional areas, project oversight and program oversight.

The Stewardship Plan defined project oversight as activities that would be undertaken as part of the project development process. The activities listed under project oversight included the following:

- Environmental Process
- Right-of-Way (ROW) Process
- Design Monitoring Process
- Local public agency Delegation Process
- Programming Process and Project Authorization/Agreement Process
- Intelligent Transportation System (ITS) Process
- Construction and Contract Administration Process

The Stewardship Plan defined program oversight as activities that would be undertaken as part of the administration of programs of mutual benefit to Mn/DOT and FHWA. The activities listed under program oversight included the following:

- Bridge Program
- Civil Rights Program
- Financial Management Program
- Maintenance Monitoring Program

- Material Acceptance Program
- Pavement Management and Design Program
- Planning Program
- Research, Development, and Technology Program
- Safety and Traffic Program
- Miscellaneous Programs and Activities

The following excerpts were taken from the Stewardship Plan[4] as it relates to project oversight of the design monitoring process:

*"**General Guidelines***

*In Minnesota, oversight determinations are made depending on the type and cost of projects.*

! *All Design/Build Projects under 23 CFR 636 will have full Federal oversight.*

! *All Major Bridges on the NHS over $10 million will have full FHWA oversight.*

! *Interstate construction or reconstruction projects over $1 million will have full Federal oversight. Highway construction projects on the Interstate System under $1 million will be administered by Mn/DOT.*

! *Projects on the Interstate System regardless of funding source require concurrence by FHWA that the system is not being degraded. The Interstate System includes all interchanges to the control of access limits.*

! *Full oversight projects will require FHWA approval of design exceptions.*

! *FHWA will review and approve all changes in access control to the Interstate System.*

! *FHWA will review and approve all exceptions to the Mn/DOT Utility Accommodation Policy on the NHS.*

*State administered projects on the NHS will be administered by Mn/DOT but will be subject to joint FHWA-Mn/DOT process reviews and inspections and must comply with all Federal requirements. Projects off the NHS will be except from FHWA design oversight as provided under Title 23 U.S.C. unless specifically*

[4]Federal Highway Administration and Minnesota Department of Transportation Stewardship Plan, December 2007, pages 23 and 24.

*requested. Projects off the NHS that are administered through Mn/DOT by local agencies will not be subject to FHWA design oversight as provided under Title 23 U.S.C., unless specifically requested, but will be subject to Mn/DOT oversight in accordance with state laws for State Aid projects.*

***FHWA Review of Bridge Preliminary and Final Plans***

*The following apply to Bridge Projects that Require Full Oversight by FHWA, Bridge Projects that Require Partial Oversight by FHWA, and Bridge Projects for which Mn/DOT Maintains Oversight. This is outlined under FAPG G6012.1 Preliminary Plan Review and Approval.*

*Along with the general guidelines listed above for FHWA project review, following are some specific guidelines for bridges:*

- *Sets of prints of the preliminary plans are distributed to the various offices of Mn/DOT and outside agencies for information, review, and approval, as the case may be.*

- *Approval by all concerned of the proposed structure dimensions, type of construction, and geometrics before the start of final design is one of the most important functions of the preliminary plans. This is particularly true of stream crossings, railroad crossings (over and under) and structures requiring special aesthetic treatment.*

***Bridge Projects that Require Full Oversight by FHWA:***

- *New or reconstruction (rehabilitation and improvement) bridge projects on the Interstate system (bridges that carry interstate traffic and interchange bridges). Preliminary bridge plans (if prepared) as well as final plans, specifications and estimates (PS&E) will be submitted to FHWA for approval. Final Preliminary plans or substantially complete preliminary plans will be submitted to FHWA as soon as they are developed and prior to proceeding with final design. Final plans at 85 to 90% completion will also be submitted to FHWA for concurrent review. Please note that preliminary plans normally not prepared for bridge improvement type projects.*

- *On the non-Interstate NHS in which the bridge structure estimated cost is equal to or over $10 million. Preliminary bridge plans and PS&E will be submitted to FHWA for approval. Final Preliminary plans or substantially complete preliminary plans will be submitted to FHWA as soon as they are developed and prior to proceeding with final design. Final plans at 85 to 90% completion will also be submitted to FHWA for concurrent review.*

***Bridge Projects that Require Partial Oversight by FHWA***

- ! *<u>New or reconstruction (rehabilitation and improvement) bridge projects that carry traffic over the Interstate Highway regardless of funding source</u>. Preliminary bridge plans (if prepared) will be submitted to FHWA for approval. Final Preliminary plans or substantially complete preliminary plans will be submitted to FHWA as soon as they are developed and prior to proceeding with final design. This submission is generally for the purpose of evaluating horizontal and vertical clearances on the Interstate system.*

***Bridge Projects for which Mn/DOT Maintains Oversight***

- ! *<u>Any bridge project not included in the above full and partial oversight categories</u>. Preliminary plans will be submitted to FHWA with a transmittal letter. FHWA will not require a preliminary cost estimate but would be reviewing the preliminary plan, elevation and the transverse section. It is very important that final preliminary or substantially complete plans be submitted to FHWA as soon as they are developed and prior to proceeding with final design. Note that funding source(s) does not change the above processes. For Mn/DOT oversight projects, a courtesy copy of the letter transmitting preliminary plans for the proposed bridge project will be sent to FHWA (without the plans) for informational purposes.*

*FHWA Headquarters Bridge Division shall be responsible for the approval of preliminary plans for unusual bridges and structures on the Interstate System. FHWA Headquarters Bridge Division will be available for technical assistance on other Federal-aid and non-Federal-aid highways when requested.*

*For the purpose of this guidance, unusual bridges are generally those bridges that have: (1) difficult or unique foundation problems, (2) new or complex designs with unique operational or design features, (3) exceptionally long spans, or (4) been designed with procedures that depart from currently recognized acceptable practices.*

*Examples of unusual bridges include cable-stayed, extradose, suspension, arch, segmental concrete, movable, or truss bridges. Other examples are bridge types that deviate from AASHTO bridge design standards, or AASHTO guide specifications for highway bridges; bridge types without adopted standards; bridges requiring abnormal dynamic analysis for seismic design; bridges with spans exceeding 152 m (500 feet); and bridges with major supporting elements of "ultra" high strength concrete or steel."*

The following excerpts were taken from the Stewardship Plan[5] as it relates to program oversight of the bridge program:

> ***"OVERSIGHT ACTIVITIES***
>
> *A NBIS compliance review will be conducted with at least one Mn/DOT District each year. The reviews include the following major NBIS elements: inspection procedures, frequency of inspection, qualifications of personnel, quality of the reports and the inventory. The Division Bridge Engineer will also review the District's underwater inspections, their program to deal with scour, quality assurance and procedures established to review, prioritize and track recommendations for repairs. The review includes a random sampling of bridge inspection reports and records and field reviews of selected bridges.*
>
> *Mn/DOT's Office of Bridges and Structures (OBS) is responsible for managing its bridge inspector certification program and for monitoring Local Public Agency compliance with NBIS requirements. The OBS also maintains a statewide bridge management system, and the statewide bridge inventory. The Division Bridge Engineer will annually review OBS quality assurance processes and will participate with the OBS in at least two NBIS compliance review of selected Counties, Cities or other Local Agencies each year. Mn/DOT will submit a status report every spring on progress towards developing POA's for scour critical bridges. Supplemental information will be provided as necessary to comply with FHWA policy provisions.*
>
> *A report is prepared annually of the NBIS review by the Division Bridge Engineer. A report is prepared by the OBS of the NBIS review for each County or bridge owner for the non-Mn/DOT bridges. FHWA will furnish comments to be included in the OBS report."*

### 2.3 FHWA AND Mn/DOT RISK MANAGEMENT PARTNERING INITIATIVE

FHWA used risk management as a partnering initiative with Mn/DOT to assist program managers in identifying and directing where program needs are to be focused both today and in the future. The December 2007 Stewardship Plan[6] defined risk management and the vision for risk management in Minnesota:

> ***"2. What is Risk Management?***
>
> *Risk management involves the identification and analysis of opportunities and threats in Minnesota's Federal-aid Program. Risk Management is not an audit, but a partnering opportunity to jointly identify Risk events and assess Minnesota's Federal-aid highway program. Risk Management provides structure and mutual understanding of high-risk program areas. Additionally, the formal structure*

[5]ibid, page 50.
[6]ibid, Appendix B, page 1 of 4.

*supplements program managers' ability to identify, assess, manage, and communicate opportunities and threats involved in the FHWA and Mn/DOT mission. The Risk Management Process and the identification of potential Risk events should happen in a cyclical fashion (Every Year) to ensure response strategy performance. It is envisioned that Risk Management will garner more information about the health and future of Minnesota's Federal-aid program areas than an audit ever could!*

***3. What is the Vision for Risk Management in Minnesota?***

*The Risk Management is a partnering initiative that will complement program manager's ability to communicate effectively and confidently about the future of their program. Risk identification and analysis meetings will help clarify the links between Risks and program impacts. Program Managers will be empowered to contribute their expertise and to determine program area priorities. Following the Risk identification and analysis step within your program area, Division leadership will challenge program managers to identify effective response strategies to the identified Risks. Division leadership will focus and communicate State-wide risk areas and promote confident allocation of FHWA resources to effective risk response strategies.*

FHWA had approximately 360 risk assessments related to their program functional areas. One of the risk assessments was related to bridge load ratings and postings. The FHWA – Washington Office sent a memorandum to Division Administrators dated February 22, 2007 asking the field offices to address bridge load ratings and postings in their next program risk assessment (See Attachment 44 – FHWA Memorandum to Division Administrators dated February 22, 2007). The following is an excerpt from the memorandum:

*"First, as part of the 2007 risk assessment cycle, field offices are to address bridge load rating and posting practices in their next individual program risk assessment. The second action item depends on the outcome of the risk assessment. If the risk is evaluated high, field offices should conduct a focused in-depth review of bridge load rating and posting practices within 1 year as a response strategy. If the risk associated with bridge load ratings and postings is not evaluated high, a focused in-depth review does not have to be completed with 1 year; however a focused in-depth review should be accomplished within the next 3 years as a supplement to the annual review of the National Bridge Inspection Standards (NBIS) compliance. Upon completion of the initial in-depth review, field offices should continue to monitor the bridge load rating and posting program areas during annual reviews of the NBIS compliance, annually reassess the risk, and implement response strategies if warranted by the risk assessment."*

## 2.4 FHWA BRIDGE PROGRAM MANUAL

FHWA provided a copy of the FHWA Bridge Program Manual (See Attachment 45 – FHWA Bridge Program Manual dated August 2004). The Manual was intended to collect in one location all of the basic program information needed for bridge engineers to deliver the FHWA Bridge Program in an efficient and effective manner. The Manual does not establish any new policies, but contains existing guidance and sources for regulations and administrative rules. The FHWA Bridge Program Manual[7] indicated the following regarding design review:

*"**Preliminary Plan Review***

*Preliminary Plan Review is often referred to as Type, Size and Location review (commonly known as TS&L) for new and replacement structures. It refers to the type of structure selected, general size of the bridge, geometry and clearances, length and width, horizontal and vertical alignment, and the actual location of the bridge itself.*

*The preliminary plan reviews provide the opportunity for the Division Bridge Engineers to have major input on the type of structure being designed. Major items to be addressed include: use of high performance materials, use of new technologies, new innovative materials, opportunities for accelerated construction, unique/creative new uses of known materials, constructability, appropriateness of construction techniques, maintainability, inspectibility, cost-effectiveness, aesthetic requirements, corrosion protection strategy, improved details to eliminate existing problem areas on bridges (i.e., bridge expansion joints, fatigue prone details, bearings, etc.) hydraulic/scour analysis and deck drainage, geotechnical requirements and types of foundations. Preliminary design studies should consider the bridge location, length, width, span arrangement and superstructure system considering traffic requirements, safety measures, channel configuration, stream flow, etcetera. Feasible alternatives for a proposed bridge crossing, along with their merits and shortcomings, should be identified and discussed.*

*Emphasis should be placed on design considerations for a 100-year service life with minimum future maintenance requirements. Life cycle cost analysis should be used for major and unusual structures to determine the appropriate type of materials to be used. For major and unusual structures and major interchanges, so-called Bridge Preliminary Reports should be considered to formulate the decision for the type or types of structures to advance to final design. To address accelerated bridge construction, prefabricated elements and systems should be considered at this time…*

---

[7]FHWA Bridge Program Manual, Bridge Leadership Council and the Federal Highway Administration, August 2004, Chapter 3 Design Review, pages 86 through 94.

### *Final Design*
### *(And/Or Advanced Detail Plan Review)*

*Final Design plans are generally prepared to provide a formal review of the structure as it progresses. This is to review the design before it gets too far along, and to ensure that the design is within the scope of the project. There is no Federal requirement that Final Design plans be developed or submitted to the FHWA; however, the State generally prepares them. There may be a formal agreement between the State and the FHWA Division, regarding their development and submittal at specific stages of completion (e.g. 60% plans)…*

### *Plans, Specifications and Estimate Review*

*At this stage of project development, the Plan, Specifications, and Estimate (PS&E) package for a project is submitted for review and approval. A typical PS&E package will include a set of the completely detailed project plan sheets, the project contract proposal, and a copy of the design engineer's construction cost estimate. The package may include other items such as right-of-way certificates, environmental permit applications, or other documentation specific to the project. The PS&E review consists of examining the submitted package for consistency with the project's scope of work, conformity to acceptable engineering design and construction practices, Federal-aid eligibility, environmental compliance, and adherence to all appropriate Federal rules and regulation. The review also ensures that all previous comments, such as those made at the Advanced Detail Plan (ADP) review have been satisfactorily resolved. In some instances, ADP's may not have been submitted, thus the PS&E review represents the initial evaluation of project plans. Once PS&E approval has been granted, the project can be authorized to proceed to construction. If outstanding issues arise during the PS&E review, a request can be made to resolve the issues prior to granting PS&E approval, or the PS&E can be approved with conditions placed on the project authorization, which must be satisfactorily addressed prior to the award of the contract. Sometimes, the State needs to issue addenda to resolve certain aspects of the contract package. The State Highway Agency shall provide assurance that all bidders have received all issued addenda. Addenda for projects that require FHWA oversight must be approved by FHWA because they represent a change to the approved PS&E.*

### *Design Exceptions for the NHS*

*For projects on the NHS, formal approval is required for 13 controlling criteria: design speed, lane and shoulder width, bridge width, structural capacity, horizontal and vertical alignment, grade, stopping sight distance, cross slope, superelevation, and vertical and horizontal clearance. On FHWA-oversight projects, FHWA approves design exceptions. On State-oversight projects, the*

*State approves design exceptions. Design features are generally improved upon as much as is feasible, when considering the approval of the design exceptions.*

*For bridges, the most applicable criteria are bridge width, structural capacity, and vertical clearance.*

*Bridge width – The criteria contained in 23 CFR 625 apply in determining the width of all bridges to be constructed, reconstructed, or rehabilitated on the NHS. For rehabilitated bridges on non-freeway NHS, the provisions in 23 CFR 625 dealing with 3R projects (i.e. Resurfacing, Restoration, and Rehabilitation) may be applied (in other words, State DOT design criteria as approved by FHWA).*

*Structural Capacity – All new bridges on the Interstate system shall have at least an HS-20 structural capacity (A Policy on Design Standards – Interstate System). Rehabilitated bridges on the Interstate System should have an HS-20 structural capacity (23 CFR 625, Non-regulatory supplement). For all other projects on the NHS, refer to the AASHTO standards.*

*Vertical Clearance – Interstate System: 4.9 meters for rural interstates; 4.3 meters is allowed in urban areas when a 4.9-meter single route is provided (A Policy on Design Standards – Interstate System, July 1991). For all other NHS, 4.3 meters is the minimum vertical clearance (2001 AASHTO "Green Book"). The vertical clearance to sign trusses, pedestrian overpasses and to cross bracing of through-truss structures should be 5.1 meters.*

*For horizontal clearance, consult the AASHTO Green Book for guidance and the various cases provided for what would be the appropriate design based on the particular situation involved.*

*For projects on the NHS, bridge railing must be successfully crash-tested in accordance with NCHRP Report 350. The bridge railing must meet Test Level 3 (TL3) or greater. For more information, see the last paragraph in the Preliminary Plan Review section.*

### ***Reviews by Washington Office and Resource Center***

*The Office of Bridge Technology and the Resource Center will assist in the review of projects at the request of the Division office. The Office of Bridge Technology has retained responsibility and approval authority of preliminary plans for unusual bridges and structures on the Interstate System. This is by policy memorandum dated November 13, 1998. Specific definitions for what is meant by unusual bridges and unusual structures are found in that memorandum. Early and complete submissions are requested in order to facilitate more meaningful and expeditious reviews and approvals. This generally is not a problem, but on occasion, projects may come into the Division Office at a late date due to* *unforeseen circumstances, such as when a State Highway Agency (SHA) decides to change to Federal-aid funds during the plan development stage.*

*This policy on Headquarters review pertains to rehabilitation projects as well as new structures. The policy provides for delegation, upon consultation with Headquarters, when substantial and adequate experience in the Division office or Resource Center is available.*

*Oversight of Federal-aid projects in the Division Office is determined based on the stewardship agreement between the SHA and the Division. So, for example, projects estimated to cost below a certain dollar value on the Interstate System might not be subject to the Division office's detailed review of plans."*

## 3. <u>JACOBS ENGINEERING QUALITY ASSURANCE / QUALITY CONTROL (QA/QC) PROCESS OF CHECKING PREPARED BRIDGE PLANS</u>

The I-35W Bridge (Bridge #9340) was designed by the engineering consultant firm of Sverdrup & Parcel and Associates, Inc. Sverdrup & Parcel and Associates, Inc. was a predecessor company of Sverdrup Corporation, a company acquired by Jacobs Engineering Group Inc. in 1999.

### 3.1 SVERDRUP & PARCEL AND ASSOCIATES, INC. DOCUMENT ENTITLED PROCEDURE FOR CHECKING DESIGN NOTES AND COORDINATING SAME WITH DETAIL CHECKER DATED SEPTEMBER 1953

Jacobs Engineering Group Inc. provided a copy of a Sverdrup & Parcel and Associates, Inc. document entitled <u>Procedure for Checking Design Notes and Coordinating Same with Detail Checker</u> dated September 1953 (See Attachment 46 - Sverdrup & Parcel and Associates, Inc. document dated September 1953). The following excerpts are taken from the Sverdrup & Parcel and Associates, Inc. document:

> *"The design notes shall be checked on the original computation sheets, <u>not prints</u>. The checker shall make all check marks and all change notations in blue pencil. `Where a design sheet is entirely or nearly void due to the amount of changes, the checker shall mark the original sheet void and originate a new sheet, or sheets, to replace it. He shall fill out the heading of this new sheet as though he were the original designer since in fact he is. Where additional sheets of design are required the design checker shall proceed as in the case of void original design sheets described above.*
>
> *When the original designer is returned the checked design sheets, he shall backcheck the checker's work. This in effect amounts to the original designer checking the checker. Any disagreement with the checker's blue marks shall be noted by the designer in green pencil on the computation sheets. In checking any new sheets of computations that the checker has added to the computations the designer shall use a blue pencil since he is then acting as a design checker.*
>
> *When the design checker receives the design from the designer after it is backchecked he shall see that all his blue marks have been agreed to and the corrections made. If so, he shall erase the blue marks from the design sheets. Where green marks occur he shall see that a final figure is put in the original space and the green marks removed. He shall also backcheck any new design sheets he has added to the set, and the same procedure as noted above followed to clear these marks from the design sheets.*
>
> *Since the checking of detail drawings may have been done at anytime during the checking of the design notes it is <u>most important</u> that the detail checker be allowed to examine the design notes <u>before</u> any checking or backchecking*

*correction marks are removed, or voided sheets of calculations are removed from the set of design notes. If this is not done, the details will either not conform to the latest design requirements, or the completed details affected by any design revision will have to be rechecked. Either result cannot be tolerated for obvious reasons."*

### 3.2 SVERDRUP & PARCEL AND ASSOCIATES, INC. DOCUMENT ENTITLED QUALITY CONTROL COORDINATION AND CHECKING PROCEDURES DATED APRIL 1975

Jacobs Engineering Group Inc. provided a copy of a Sverdrup & Parcel and Associates, Inc. document entitled Quality Control Coordination and Checking Procedures dated April 1975 (See Attachment 47 - Sverdrup & Parcel and Associates, Inc. document dated April 1975). The following excerpts are taken from the Sverdrup & Parcel and Associates, Inc. document:

*"4.2 GROUP LEADER An Engineer or Designer Technician assigned by the Section Head to be in charge of work done by the section on a particular project. The Group Leader outlines the work for a design; supervises and coordinates all work by his group; reviews the design problems, conditions, assumptions, and completed design; and reviews selected important calculations to confirm the adequacy of the design and checking work. He also sees that all Design Engineers and Design Checkers within the section coordinate their work, and that their work is coordinated with that of other sections. He maintains an index of the calculations made by his group and stores them in labeled loose-leaf binders.*

*4.3 DESIGN ENGINEERS AND DESIGN CHECKERS*

*4.3.1 DESIGN ENGINEER An Engineer or Designer Technician who is technically qualified to compile and perform the assigned task, and is assigned to design all or part of a project under the direction of a Group Leader.*

*4.4 QUALITY ASSURANCE MANAGER (where applicable) The QA Manager provides surveillance to see that S&P QA objectives are followed by all project personnel. He reports adverse conditions affecting quality to all responsible parties including the Executive Vice President, St. Louis...*

*5.1.4 CHECK, BACKCHECK, AND RECHECK*

*5.1.4.1 CHECK Upon completion of the design calculations they shall be checked by an engineer technically competent for the assigned task. Because of the progressive nature of design calculations, the checker, during his design check, shall consult with the Design Engineer on any differences which are found. If agreement between the checker and the Design Engineer cannot be reached, the matter shall be resolved as outlined in the paragraph below entitled "Backcheck". In the interest of efficiency and accuracy, as few checkers as practicable shall be used in checking the design on any one project.*

*5.1.4.2 BACKCHECK Upon completion of his check the checker shall return the design material to the Design Engineer for backcheck and correction. If the Design Engineer does not agree with the checker's notations and the differences cannot readily be resolved between the two, the matter shall be referred to the Group Leader (and Section Head if necessary) for decision. The Design Engineer shall then make all necessary corrections to the design.*

*5.1.4.3 RECHECK Upon completion of the backcheck and corrections, the Design Checker shall recheck pertinent portions of the design to determine that all proper corrections have been made. Only when he is satisfied that all corrections have been made and the design is suitable and adequate shall the Design Checker sign the original design calculations...*

*5.1.7 COMPUTER CALCULATIONS*

*5.1.7.1 PROGRAM VERIFICATION All computer programs shall be checked for accuracy prior to their use. Programs shall be checked initially for accuracy of model, technique, equations and constants by an experienced engineer technically qualified to do the work. Computer results of test problems shall then be checked by manual methods or by a previously verified program to check computer performance with the program being verified...*

*5.2.4 DRAWING CHECK Upon completion of the drawings they shall be checked by a checker who is technically competent for the assigned task. They shall be checked for adherence to design, accuracy and adequacy of delineation and notation, and for interference with work designed both within the section and by other sections. In the interest of efficiency and accuracy, as few checkers as practicable shall be used to check the drawings on any one project."*

## 3.3 JACOBS ENGINEERING GROUP, INC. QUALITY ASSURANCE / QUALITY CONTROL (QA/QC) PROCESS

Jacobs Engineering Group, Inc. provided an overview and application of the Quality Assurance / Quality Control (QA/QC) process that is in place today for checking prepared bridge plans:

- Mandatory for all employees.
- All employees are responsible for quality.
- Project Manager is ultimately responsible for verifying that procedures are followed.
- Any deviations from the Manual must be:
    - Customer directed
    - Completely defined in a Job Specific Quality Plan (JSQP)
    - Approved in writing by the Designated Project Executive (DPE) or Manager of Projects (MOP)

- QA/QC is required on all services to clients.
- Not all levels of QA/QC apply to all disciplines or services.
- Discipline Matrix describes which levels apply to what services.
- All jobs require a Job Specific Quality Plan (JSQP) to describe how the matrix is applied to that project.
- The QA/QC Procedures document is on the Jacobs Engineering Group, Inc. website (JNet).

Jacobs Engineering Group, Inc. also provided the levels and other items covered under a Quality Assurance / Quality Control (QA/QC) process:

- Level 1: Checking Process (applied to calculations, plans, drawings, reports and software input). Typically involved a 100% document check, 100% input check, spot check (or partial check), originate and check, backcheck, update, and recheck.
- Level 2: Review Process (applied to concepts, intent, and processes). Typically involved a concept review, spot review, reasonableness review, prepared action plan, and formal peer review report or less formal memorandum.
- Level 3: Authorization Process (applied to documents that require signature and/or review by management). Typically involved signature by management on a matrix giving checking and review requirements or on a Job Specific Quality Plan.
- Development of a Project Procedures Manual (PPM) and Project Criteria Document (PCD). The PPM is an administrative document that defined the scope of work, project approach, tasks and hours, client contacts, work break down structure, in-house staff listing, quality specific plan, etc. The PCD is a technical document that defined the actual design criteria governing loads, design codes, material properties, and client standards. The PPM and PCD must be:
    - Completed within 30 days after receipt of a signed contract or signed notice to proceed.
    - Signed by the Manager of Projects (MOP) under Level 3 authorization.
    - Distributed to team members.
    - Audited by the Quality Manager within 10 working days of receipt of the PPM/PCD.
    - Updated as changes occur.
    - Used by team members.
- Development of a Job Specific Quality Plan (JSQP). The JSQP would include:
    - Identifying how to apply the requirements set forth in the QA/QC manual to a specific project.
    - Identifying the name of individuals, or at a minimum, the level of experience for specific QA/QC roles.
    - Detailing how support services would interface.
- Development of a Quality Audit Process. The Quality Audit Process would involve Quality Managers who conduct preliminary, secondary, and final audits.
- Development of an Electronic QA/QC Process.

## 3.4 JACOBS ENGINEERING GROUP, INC. STEP-BY-STEP APPROACH TO OVERALL DESIGN OF TRUSS BRIDGES AND CONNECTIONS

Jacobs Engineering Group, Inc. provided a step-by-step approach to the overall design of truss bridges and connections:

1. Span arrangements and cross section (design roadway deck, stringers and floorbeams).
2. Design upper and lower lateral systems.
3. Design portals and sway frames.
4. Design posts and hangers with small stress.
5. Compute primary moments, shears and stresses in the truss members.
6. Design upper chord members.
7. Design lower chord members.
8. Design web members.
9. Recalculate the dead load of the truss and compute final moments, shears and stresses.
10. Design joints, connections, and details.
11. Compute dead and live load deflections.
12. Check secondary stresses in members carrying direct loads and loads due to wind.
13. Review design for structural integrity, aesthetics, erection, and future maintenance and inspection requirements.

## 3.5 JACOBS ENGINEERING GROUP, INC. HISTORICAL PERSPECTIVE OF GUSSET PLATE DESIGN

Jacobs Engineering Group, Inc. provided a historical perspective of the design of gusset plates contained in a 1920 document entitled The Design of Highway Bridges of Steel, Timber and Concrete[8]:

> *"The gusset plates will be made at least thick enough to develop in bearing, the strength of the rivets in single shear……The plates must be of sufficient size to contain the necessary rivets and to carry the stresses transmitted from the members."*

Jacobs Engineering Group, Inc. cited some of the key guidelines for gusset plate design contained in various AASHTO publications:

- Minimum plate thickness is 5/16 inches.
- Connections shall be designed for the average of the calculated stress and the strength of the member but not less than 75% of the strength of the member.
- The strength of the member shall be determined by the gross section for compression members and by the net section for tension members.

[8] Milo S. Ketchum, C.E., The Design of Highway Bridges of Steel, Timber and Concrete, Second Edition Rewritten, 1920, page 223.

- Ample thickness to resist shear, direct shear, and flexure on the weakest section or critical section of maximum stress.
- Stiffening requirements.

Jacobs Engineering Group, Inc. cited the three methods recommended by AASHTO to design bridges:

- Allowable Stress Design (ASD) – primarily used in the 1960's and 1970's
  - Simple; empirical safety factors
  - No consideration to uncertainty in loads
  - Consistent measures of risk not available
- Load Factor Design (LFD) – primarily used in the 1980's and 1990's
  - More complex
  - Uncertainty considered
  - Still no risk assessment based on reliability theory
- Load and Resistance Factor Design (LRFD) – used today
  - Variability accounted for
  - Risk assessment based on reliability theory
  - Uniform levels of safety
  - Requires extensive statistical data

## 4. INTERVIEW OF STATE DEPARTMENT OF TRANSPORTATION (DOT) AGENCIES

NTSB investigators interviewed 15 State Department of Transportation (DOT) agencies from across the country to understand the procedures used by State DOT's in reviewing consultant engineering bridge plans. The 15 states included California, Florida, Iowa, Kansas, Maryland, Minnesota, Nebraska, New York, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Virginia, and Washington. The criteria used to select the states was based on geographic area, state demographics (area and population), and number of bridges in the NBIS inventory.

Each state was asked to fill out answers to a standard set of questions (See Attachments 48 through 62 - Answers to standard set of questions by State Department of Transportation (DOT) Agencies). The standard set of questions included the following:

1. What was your procedure in reviewing consultant engineering bridge plans in the early 1960's? What is your procedure in reviewing consultant engineering bridge plans today?

2. How do you ensure the QA/QC process of a consultant engineering firm is adequate? In the early 1960's and today? What procedures are in-place to ensure that the consultant does not submit an inadequate design?

3. What does the State DOT consider a red-flag item when reviewing consultant engineering bridge plans? What follow-up action is taken to address the red-flag item? Describe the level of detail the State DOT uses in reviewing consultant engineering bridge plans?

4. Does the State DOT review consultant engineering bridge plans concurrently with the FHWA Division Office? Does the State DOT review the consultant plans with the expectation that FHWA will be performing a similar type of review?

5. What are the qualifications of the State DOT personnel who conduct the review of consultant engineering bridge plans?

6. What is the percentage of bridge design work that is done in-house versus the percentage that is done by consultant engineering firms?

7. Describe the structure of the State DOT? Is the bridge office centrally organized? How many district bridge offices are located in the state? Are consultant engineering bridge plans reviewed at the central office or district bridge office?

In addition to the standard set of questions, NTSB investigators obtained basic information from each State DOT. Table 2 shows basic information on the total number of districts/regions in the state, the total number of state bridges and local bridges, the total percentage of consultant bridge designs and in-house bridge designs, and the types of bridge load rating programs and bridge management systems used in each state.

**Table 2 – Basic information obtained from each State DOT**

| State DOT | Total Number of Districts / Regions | Total Number of State Bridges[9] / Local Bridges | % Consultant / % In-House Bridge Designs | Bridge Load Rating Programs | Bridge Management System |
|---|---|---|---|---|---|
| California | 12 districts | 12,185 – state<br>11,782 – local | 50% - Consultant<br>50% - In-House | VIRTIS | Pontis with California modifications |
| Florida | 8 districts | 6,068 – state<br>5,532 – local | 95% - Consultant<br>5% - In-House | See Note 1 | Pontis with Florida modifications |
| Iowa | 6 districts | 4,064 – state<br>20,360 – local | 60% - Consultant<br>40% - In-House<br>(FY2008) | See Note 2 | See Note 3 |
| Kansas | 6 districts | 4,940 – state<br>20,524 – local | 70% - Consultant<br>30% - In-House | See Note 4 | Pontis with Kansas modifications |
| Maryland | 7 districts | 2,578 – state<br>2,233 – local | 50% - Consultant<br>50% - Local | See Note 5 | Inventory and appraisal information is entered and stored into an access database |
| Minnesota | 8 districts (including Metro) | 3,585 – state<br>9,344 – local | 50% - Consultant<br>50% - In-House | See Note 6 | Pontis with Minnesota modifications |
| Nebraska | 8 districts | 3,511 – state<br>11,828 – local | **Statewide**<br>5% - Consultant<br>95% - In-House<br>**Local**<br>95% - Consultant<br>5% - In-House | See Note 7 | Pontis and In-House Programs |
| New York | 11 regions | 7,632 – state<br>9,682 – local | 50% - Consultant<br>50% - In-House | See Note 8 | Pontis and In-House Analysis Tools |

[9]Tables 2 and 3 show bridges or culverts that carry vehicular traffic and are longer than 20 feet as defined by the National Bridge Inventory. Bridges on a toll authority system are included in the total number of local bridges.

| | | | | | |
|---|---|---|---|---|---|
| Ohio | 12 districts | 11,103 – state<br>17,974- local | 95% - Consultant<br>5% - In-House | PC BARS | Database monitored monthly using data mining software and spreadsheets |
| Oregon | 5 regions | 2,672 – state<br>3,974 – local | **Current**<br>20% - Consultant<br>80% - In-House<br>**Goal**<br>70% - Consultant<br>30% - In-House | BRASS | Pontis with Oregon modifications |
| Pennsylvania | 11 districts | 15,877 – state<br>6,416 – local | **Statewide**<br>60% - Consultant<br>40% - In-House<br>**Urban Districts**<br>95% - Consultant<br>5% - In-House | See Note 9 | Pontis with Pennsylvania modifications |
| Tennessee | 4 regions | 8,150 – state<br>11,419 – local | 5% - Consultant<br>95% - In-House | See Note 10 | Pontis and In-House Analysis Tools |
| Texas | 25 districts | 33,028 – state<br>17,448 – local | 40% - Consultant<br>60% - In-House | See Note 11 | Pontis with Texas modifications |
| Virginia | 9 districts | 11,721 – state<br>1,416 – local | 30% - Consultant<br>70% - In-House | See Note 12 | Pontis and HTRIS |
| Washington | 7 regions | 3,019 – state<br>3,878 – local | 10% - Consultant<br>90% - In-House | BRIDG FOR WINDOWS | Pontis with Washington modifications |

Note 1 - Florida bridge load rating programs include Leap Conspan, Smart Bridge, STAAD, BRUFEM, Merlin-Dash, GT STRUDEL, BAR7, MIDAS, BDAC, MDX, ADAPT, PC BARS, VIRTIS, and Smartbridge.
Note 2 – Iowa bridge load rating programs include LARS and VIRTIS.
Note 3 – The Iowa DOT is in the process of implementing PONTIS. The goal is to use it as an additional tool to help identify candidates for the Transportation Improvement Program.
Note 4 – Kansas bridge load rating programs include VIRTIS, STAAD, and BRASS.
Note 5 – Maryland bridge load rating programs include Merlin-Dash, BARS5, BARS7, STAAD, and in-house spreadsheets developed by staff.
Note 6 – Minnesota bridge load rating programs include BARS and VIRTIS.
Note 7 – Nebraska bridge load rating programs include BARS, LARS, VIRTIS, and in-house programs.
Note 8 – New York State bridge load rating programs include VIRTIS and BLRS (Bridge Load Rating System).
Note 9 – Pennsylvania bridge load rating programs include BAR7, STAAD, and BSDI-3D.

Note 10 – Tennessee bridge load rating programs include VIRTIS, BARS, Conspan, and Excel Spreadsheets.
Note 11 – Texas bridge load rating programs include BMCOL51, PSTRS14, RISA, STAAD, BRASS, and RATE.
Note 12 – Virginia bridge load rating programs include BARS, VIRTIS, DESCUS (Curved Girder Program), and STAAD.

Table 3 shows a breakdown of the total number of state bridges and local bridges by deck area.

**Table 3 – Breakdown of the total number of state bridges and local bridges by deck area**

| State DOT | Total Number of State Bridges / Local Bridges | Total Deck Area (square feet) |
|---|---|---|
| California | 12,185 – state<br>11,782 - local | 237,998,721 sq. ft. – state<br>64,494,529 sq. ft. – local |
| Florida | 6,068 – state<br>5,532 – local | 125,431,994 sq. ft. – state<br>38,257,764 sq. ft. – local |
| Iowa | 4,064 – state<br>20,360 – local | 35,434,725 sq. ft. – state<br>40,069,720 sq. ft. – local |
| Kansas | 4,940 – state<br>20,524 – local | 38,791,815 sq. ft. – state<br>45,469,949 sq. ft. – local |
| Maryland | 2,578 – state<br>2,233 – local | 28,441,714 sq. ft. – state<br>21,360,354 sq. ft. – local |
| Minnesota | 3,585 – state<br>9,344 – local | 47,027,471 sq. ft. – state<br>28,272,722 sq. ft. – local |
| Nebraska | 3,511 – state<br>11,828 – local | 22,090,847 sq. ft. – state<br>18,778,942 sq. ft. – local |
| New York | 7,632 – state<br>9,682 – local | 78,622,000 sq. ft. – state<br>57,345,000 sq. ft. – local |
| Ohio | 11,103 – state<br>17,974- local | 106,739,000 sq. ft. – state<br>34,778,100 sq. ft. – local |
| Oregon | 2,672 – state<br>3,974 - local | 35,125,249 sq. ft. – state<br>13,688,325 sq. ft. – local |
| Pennsylvania | 15,877 – state<br>6,416 – local | 106,503,300 sq. ft. – state<br>14,206,400 sq. ft. – local |
| Tennessee | 8,150 – state<br>11,419 – local | 78,203,975 sq. ft. – state<br>26,332,721 sq. ft. – local |
| Texas | 33,028 – state<br>17,448 - local | 366,973,079 sq. ft. – state<br>71,614,950 sq. ft. – local |
| Virginia | 11,721 – state<br>1,416 – local | 83,390,530 sq. ft. – state<br>20,051,368 sq. ft. – local |
| Washington | 3,019 – state<br>3,878 – local | 45,567,272 sq. ft. – state<br>14,187,731 sq. ft. – local |

Listed below is a summary of the interviews conducted with each State DOT.

**California DOT**

NTSB investigators interviewed staff from the California DOT (Caltrans) Structure Design Office on May 1, 2008.

The main Caltrans bridge design office is located in Sacramento with two smaller regional design groups located in Los Angeles County and in Oakland. The Caltrans has a total of 12 district offices. The majority of the consultant designed bridge plans are reviewed in the main office in Sacramento. The following percentages represent a 10-year timeframe for bridges built on the state highway system in California. These percentages are approximate based on costs obtained from bid openings or from engineer's estimates:

- 50% by in-house engineers
- 25% by consultants hired by Caltrans
- 25% by consultants hired by cities, counties, regional transportation authorities and developers.

The Structure Design Office has approximately 370 bridge design staff in-house. In the past, the Structure Design Office worked on 600 to 700 projects annually at a cost of approximately $2 billion. Today, the current annual expenditures are approximately $3-4 billion.

In California, the selection for professional services of private engineering firms is based on demonstrated competence and the professional qualifications of the firm. The Caltrans evaluates the firms statement of qualifications and performance data on file with the agency, together with those of other firms, and conducts discussions with no less than 3 firms regarding anticipated concepts and methods of approach for furnishing the required services. The Caltrans develops a short list and invites the firms for interviews. The Caltrans ranks and selects the firms, in order of preference, based upon the criteria established for the project. These firms are deemed to be the most highly qualified to provide the services required. Should Caltrans be unable to negotiate a satisfactory contract with the firm to be the most qualified, the agency shall undertake negotiations with the second most qualified firm.

Since the mid-1980's an office dedicated to the review of consultant engineered bridge plans has been in place. In the mid-1990's the office was split, with one office handling Caltrans sponsored projects the other office handling external agency sponsored projects.

Currently there is a comprehensive process for developing consultant prepared bridge projects. The comprehensive process begins at the planning stage and continues through preliminary design and final design stage, and through completion of construction. The comprehensive process includes the following:

- Project Study Reports
- Project Reports

- Preliminary Design (pre-type selection, type selection, and post-type selection)
- 65% Unchecked Details
- Initial Plans, Specifications, and Estimates (PS&E) submittal
- Intermediate Plans, Specifications, and Estimates (PS&E) submittal
- Final Plans, Specifications, and Estimates (PS&E) submittal
- Contract Advertisement
- Addenda
- Bidder Inquiries
- Contract Change Orders
- Cost Reduction Incentive Proposals
- As-Builts

The Caltrans offices, with functional support from groups with specialized expertise, review the items listed above against design specifications, Department policies, and design guidance materials. Consulting engineering firms are required to develop internal procedures and project specific QA/QC plans. The QA/QC plans are a required submittal and are reviewed in addition to the items listed above.

The Office of Special Funded Projects (OSFP), of the Division of Engineering Services, has oversight responsibility for the structures portion of special funded projects, designed by consultants and implemented by local agencies. The OSFP does independent quality assurance (IQA), from inception of the projects to the acceptance of projects on the state highway system. The following are some of the notable issues resolved with recent OSFP's oversight process:

**Project 1** – a 2-span CIP P/S box girder was proposed as a replacement of existing structure. The Seismic Design Criteria (SDC) requires superstructures to resist the demands created by plastic hinging of the columns during longitudinal seismic movement. The consultant did not calculate this demand and the drawings did not show any rebar to resist it. The OSFP review reminded the consultant of this requirement, and subsequent calculations showed that a significant amount of rebar was indeed required.

**Project 2** – the scope of the project included widening on both sides for a pair of 3-span box girder bridges. A spreadsheet that the designer was using to compute the maximum factored shears and moments did not capture the correct negative values. As a result the bridge would have been designed for negative moments at the bents as much as 12% less than the actual values. The maximum shear was likewise not properly identified. In addition, the widenings have variable widths and the designer did not specify the correct deck thickness and reinforcement. The result is that, for a significant portion of the bridge length, the deck would have been about 17% thinner and with about 17% less transverse reinforcement than required.

**Project 3** – the widening was proposed for a pair of existing box girder structures using P/C P/S girders. The OSFP reviewer performed calculations to spot-check the adequacy of the P/S girders. The results consistently showed that the P/S specified was about 25% less than that required.

**Project 4** – the widening was proposed on both sides of an existing slab bridge on a state route over a creek. These are "sliver" widenings requiring one new pile on each side at each abutment and bent. Load Factor Design requires that the factored loads applied to a pile be divided by a phi factor of 0.75 to obtain a required nominal resistance. The nominal resistance is multiplied by 2 to obtain a design loading and both values are placed on the drawings to indicate the pile capacity required for contract compliance. The designer did not divide the factored loads by the phi factor. The piles would have been driven to only 75% of the required load values.

**Project 5** – a 185-foot long tieback retaining wall constructed at the abutment of the existing bridge. Typically, these walls have a number of tiebacks to provide redundancy; that is, the loss of one or two tiebacks will not result in failure of the wall. This wall had only two tiebacks, one at each end. The loss of either one would have resulted in the collapse of the wall. The designer agreed to add more tiebacks.

**Project 6** – the proposal was to replace existing multi-span T-beam structure. During stage construction portions of the existing structure were removed and the existing 3-column bents temporarily became 2-column bents. When this occurred the moments in the bent cap shifted, specifically the positive moments in the bottom of the cap increased significantly. The consultant did not correctly calculate the amount of this increase and concluded that temporary shoring of the bent cap was not necessary. Review by OSFP showed that the increase in positive moment was indeed significant and that the existing bent cap was inadequately reinforced. As a result shoring was added under the bent cap.

**Project 7** – the scope of the project was to replace an existing multi-span T-beam structure with a CIP P/S box girder structure. The bent caps did not have the width required by SDC to resist transverse plastic hinging and joint shear. The seismic capacity of the columns was checked using an obsolete procedure (taking moments from the program YIELD and using a reduction factor) instead of the procedure currently required by the SDC (a push-over analysis).

The Caltrans has incorporated an independent peer review process on the following projects:

- Benicia Martinez
- Carquinez Bridge
- Devil's Slide Tunnel
- I-880 Reconstruction
- Richmond-San Rafael
- San Diego-Coronado
- San Mateo-Hayward
- Santa Monica Viaduct
- SeiRet Yerb Buena Tunnel
- Vincent Thomas Bridge
- Gerald Desmond Bridge
- I-210 Corridor LA &SBD Counties

- SR 84 @ Port of Long Beach

On other large and complex bridge design projects, it is typical for Caltrans to select a second consultant to perform an independent peer review of the plans and design calculations. For in-house design projects, an independent review is performed of the design and this review examines all load cases.

The Caltrans has a Seismic Advisory Board whose mission is to assist Caltrans in its role and obligation to provide seismic safety of California's transportation structures. The Seismic Advisory Board is an independent body that consists of leading experts in the fields of academia, design, and construction.

## Florida DOT

NTSB investigators interviewed staff from the Florida DOT (FDOT) Structures Design Office on May 8, 2008.

The FDOT was de-centralized in the late 1980's and has a total of 8 districts (including the Turnpike Authority). Prior to the de-centralization in the late 1980's, the percentage of bridge design work done in-house was 95% versus 5% done by consultant engineering firms. The combination of additional bridge design work and the de-centralization of the FDOT have resulted in out-sourcing of work to consultants. Today, the percentage of bridge design work done in-house is 5% versus 95% done by consultant engineering firms. All districts have a bridge design staff and most have a consultant on staff to assist in this work. The FDOT experienced a 25% reduction in staff a couple of years ago. A lot younger staff is in the Bridge Design Office than 20 to 30 years ago.

The FDOT pre-qualifies consultant engineering firms according to bridge design type. This group includes the following sub-categories of qualification:

**Miscellaneous Structures and Minor Bridge Design** – typically this includes design for the lengthening of box culverts, retaining walls, and simple span I-beam bridges.

**Major Bridge Design** – typically this includes design for bridges with spans estimated to be less than 400 feet. This type of work is subdivided into three categories that include concrete (ex. post-tensioned concrete beam bridges), steel (ex. steel box girders and curved steel girder bridges), and segmental bridge designs (ex. precast or cast-in-place concrete segmental superstructures).

**Complex Bridge Design** – typically this includes design for bridges with spans estimated to be longer than 400 feet. Examples of complex bridge designs include cable-stayed bridges, suspension bridges, truss spans, concrete arch bridges, and bridges requiring unique analytical methods or other design features not commonly addressed in AASHTO publications.

**Movable Span Bridge Design –** this type of work includes the design of bascule bridges, swing bridges, and vertical lift bridges.

Quality assurance and quality control are two distinct processes used by the FDOT to ensure that the public receives a quality product. Quality assurance is the responsibility of, and performed by, the Central Office. Quality control is a responsibility of the District Offices, and is performed by the districts and their agents (consultants), as appropriate. Each district has a quality control plan, at least for design.

Two important parts of any FDOT project manager's QC responsibility are to ensure that the consultant's QA/QC plan is being followed adequately and to review project deliverables to ensure that they are of an adequate and appropriate quality. The FDOT project manager meets with the consultant project manager early in the project to reach a common understanding of QA/QC methodologies to be used and submittal requirements. The FDOT project manager checks the QA/QC actions taken by the consultant by visiting the consultant's office and reviewing the quality control documentation. There should be a record of all QA/QC activities. Marked-up copies of reviewed reports and plans should be on file. The consultant's project schedule should allow adequate time for QC reviews. If possible, the FDOT project manager schedules an office visit to observe a quality control review as it is taking place. The FDOT project manager must ensure that the individuals identified in the project QA/QC plan are actually performing assigned QA/QC tasks. Another control technique is to require that documentation of quality control activities accompany submittals. Documentation would include completed checklists, certifications or the reviewers' marked-up copy of the reviewed document itself. In some districts many of the actions discussed above have been formalized in a formal QC audit process.

FDOT conducts mandatory audits on all complex bridge design types. In the 1980's, an independent peer review was done on the Skyway Bridge in Tampa, Florida. The Skyway Bridge was designed as a parallel cable-stayed bridge. The peer review consisted of independent groups looking at the entire project.

**<u>Iowa DOT</u>**

NTSB investigators interviewed staff from the Iowa DOT (IA DOT) Office of Bridges and Structures on May 15, 2008.

The IA DOT is centrally organized with a total of 6 districts. The central office provides technical review of the bridge design plans while the district offices provide review of the non-structural aspects of the plans. A combination of the volume of bridge design work (including border bridges and interior bridges) and the retirement of experienced bridge staff in the late 1980's and 1990's, led to out-sourcing of work to consultants. The percentage of bridge design work done by consultants has varied over time. From fiscal years 1991 through 1999 the percentage of bridge design work done by consultants varied from 30% to 55%, from fiscal years 2000 through 2005 the percentage of bridge design work done by consultants varied from 70% to 80%, and from fiscal years 2006 through 2008 the percentage of bridge design work done by consultants varied from 50% to 60%.

The Mississippi River borders the eastern edge of the state and the Missouri River borders the western edge of the state. The term border bridge refers to a major bridge that spans one of these rivers. The navigation span length of a border bridge can vary from 350 to 850 feet.

The IA DOT pre-qualifies consultant engineering firms according to 3 bridge design types:

**Minor Bridge Design** – typically this includes design for culverts.

**Concrete Bridge Design** – typically this includes design for pre-stressed concrete beam bridges and deck slab bridges. Approximately 10 years ago, the maximum span length for a pre-stressed concrete beam bridge would be considered 95 feet long, however, today the maximum span length would be considered 150 feet long.

**Steel Bridge Design** – typically this includes design for steel girder bridges and includes complex bridge design types.

The quality control process used by the IA DOT includes an in-depth review of consultant engineering bridge plans and details. The in-depth review includes coordination with other IA DOT offices. Plans are reviewed for accuracy and adherence to the Office of Bridges & Structures (OB&S) Bridge Design Manual (BDM) policy, AASHTO Standard Specifications or LRFD Design Specifications, and the OB&S Plan Checklist. The plan checklist, assembled in 2000, addresses common plan errors and design oversights. The checklist contains over 300 items to consider and is updated twice a year to reflect changes in OB&S policy and to alert designers of recent common errors and oversights. The IA DOT uses the plan checklist as a quality control guide.

The IA DOT expects consultants to submit 100% unapproved plans in final form with no missing details. The IA DOT expects every effort should be made to resolve outstanding issues prior to the 100% unapproved plan submittal. The initiative to resolve outstanding issues is a separate category in a consultant evaluation, and can be rated unsatisfactory if outstanding issues are not resolved.

The IA DOT conducts an initial plan review on all consultant bridge plans. Comments on the plans are distributed to other IA DOT offices for review and to provide additional feedback. The initial plan review comments and any other comments received from the other IA DOT offices are forwarded to the design consultant for inclusion in the final plan submittal. The goal is to give the consultant 3 weeks to incorporate the review comments before the final plan submittal.

The IA DOT has not required independent peer reviews on border bridges and other complex bridge types; however, they are requiring an independent peer review on a current major project.

The IA DOT has an "Error and Omissions" article in their consultant engineering agreements. If it is determined the error was caused by the consultant, the IA DOT may ask the consultant to track their time to fix the error. The time worked to fix the error is not billed, and is annotated as such on subsequent invoices.

**Kansas DOT**

NTSB investigators interviewed staff from the Kansas DOT (KDOT) State Bridge Office on July 22, 2008.

The KDOT is centrally organized with a total of 6 districts. Kansas is one of six States that are split into State/Local venues. For the State system, the State bridge office is located within the Bureau of Design, and for the Local system, the bridge section is located within the Bureau of Local Projects. The State bridge office in Topeka is responsible for all structural design and inspections. Only minor maintenance plans are done in the district offices. Historically, the percentage of bridge design work done by consultants was 50%. However, the last two major programs (Highway 89-98 and Transportation 00-09) have led KDOT to out source approximately 70% of its bridge design work to consultants. The State bridge office consists of approximately 62 bridge design staff.

The KDOT pre-qualifies consultant engineering firms according to the following bridge design types:

**Standard Span Bridge Design –** typically this includes open span type structures such as slab, prestress, steel beam, and uniform depth welded plate girders with webs less than or equal to 5 feet 3 inches deep. Standard span bridge designs also include special culvert/box bridge designs and retaining wall designs.

Examples of services to be included in standard span bridge designs include:

- Special culvert designs with foundation problems
- Retaining wall designs
- Slab spans, steel and prestress beam spans, uniform depth welded plate girder spans
- Typical "land type" pier substructures (non-cofferdammed)
- Review of falsework and shop drawings
- Rating of beam spans
- Geotechnical and foundation designs of substructure and retaining walls

**Non-Standard Span Bridge Design –** typically this includes post-tensioned structures, curved or skewed open span structures, spans over 175 feet, or unique foundations (cofferdams, seals, etc.).

Any special design bridge will be included for this category. Examples of special design bridges include:

- Post tensioned
- Steel welded plate with over 175 foot spans

- Cofferdams
- Sloped leg steel structures
- Trusses, arches, etc.

The KDOT performs reviews of consultant engineering bridge plans at various stages of design and through construction. The first review is done at the Type, Size and Location (TS&L) phase of the project. The second review is done at the 90% plan submission. The third review is done at the Plan, Specifications, and Estimate (PS&E) phase of the project. A final review is done at the time of construction that consists of conformation of field check design criteria; and review of bid items, general notes, and adherence to the geology report.

The review of consultant plans is performed by a Senior Squad Leader and the Bridge Design Engineer for constructability and conformance to AASHTO specifications and the KDOT Bridge Design Manual. Spot checking is done but the structure is not re-analyzed structurally. An independent review by the consultant's staff is done and two sets of initials are expected on the plan drawings. Final plan drawings are furnished in an electronic format and an e-file of the model for load rating is furnished. A load rating review is done at the final plan stage to confirm the design concept, and to confirm the load rating. The e-file of the model is kept by KDOT to be used for future load rating of the bridge and permitting of overweight vehicles.

Following the NTSB and FHWA recommendations on January 15, 2008, the KDOT developed an innovative process of evaluating gusset plates. KDOT set a threshold for reporting section loss on all gusset plates at 20%. If a node had no reported corrosion in the "Fracture Critical Inspection Reports" then the element was assumed to have 20% section loss. If the section loss was reported in the "Fracture Critical Inspection Reports" then the section loss noted in the inspection report was used for that node. The impact of this innovative process was that KDOT inspectors were forced to verify whether the gusset plates had less than 20% section loss or more than 20% section loss. KDOT also observed 2 categories of gusset plate designs in which the geometry of the gusset connection was considered favorable or not favorable. The first category was an open section design primarily built prior to the 1950's. The open section type has:

- Designs consisting of the gusset plate located inside the main chord member and are open, which allows corrosive material to be washed off with precipitation.
- Vertical posts members are framed into the chord members, and thus do not rely only on the gusset plate to transfer load. This additional connectivity occurs at the critical section making the overall gusseted connection more robust.
- No splices of the bottom main chord are within the gusseted connection.

The closed box section design was primarily built during the 1960's. The closed box section designs consist of the gusset plates located outside the main chord member and are closed, which does not allow corrosive material to be washed off with precipitation. This closed type has none of the drainage advantages, and the chord members are typically spliced within the gusseted connection. The closed box type chord structures are also difficult to inspect and maintain.

After the I-35W Bridge collapse in Minneapolis, MN:

- KDOT immediately conducted structural analysis on the State's six deck-truss bridges which had similar components to the I-35W Bridge.
- KDOT performed an in-depth analysis of the gusset plates for all bridges. This included the six deck truss bridges in addition to six other bridges in the state.
- KDOT inspected all 105 structurally deficient bridges on the State Highway System.
- KDOT formed the Kansas Local Bridge Task Force, which has been working to identify and evaluate options that local governments and KDOT can take to improve the local bridge inspection process.

**Maryland State Highway Administration**

NTSB investigators interviewed staff from the Maryland State Highway Administration (Maryland SHA) Office of Bridge Development on May 29, 2008.

The Maryland SHA is centrally organized with a total of 7 districts. All structural design originates at the central headquarters in Baltimore. No structural design is performed in any of the SHA's district offices, nor is there any bridge staff located in any of the district offices. Non-bridge personnel from the district offices provide review comments on bridge projects but these are not usually of a design or technical nature, they are related to constructability and project management issues. The percentage of bridge design work done by consultants versus the percentage that is done in-house is generally 50-50. The Maryland SHA experienced a downsizing of staff in the 1980's, from approximately 140-150 total bridge staff to approximately 110 total bridge staff that exist today.

The Maryland SHA uses a 2 stage process to select consultants for bridge design work. The first stage is for the consultant engineering firms to submit request for qualifications (RFQ). The Maryland SHA reviews the request for qualifications and develops a short list. The second stage is for the consultant engineering firms that are on the short list to submit proposals. The proposals shall consist of key staff and titles, a detailed proposal, and resumes. The consultant engineering firms will also submit a QA/QC process with their proposal. The Maryland SHA reviews the proposals and ranks and selects the consultant engineering firm.

During the procurement process for consultant engineering services, firms seeking to obtain design engineering contacts are expected to have in place their own internal QA/QC processes. Most of the firms that seek to provide design engineering services to SHA are either large, national firms, or firms that have worked for SHA in the past and are well known to SHA.

For a bridge that is unusual or complex, the Maryland SHA frequently uses a peer review by an independent consultant to check the design. On some of Maryland SHA recent mega-projects, the SHA have utilized the services of a General Engineering Consultant to manage the project. Their scope of services includes review of the design consultants plans.

For the new Woodrow Wilson Bridge that connects Maryland to Virginia over the Potomac River, the Maryland SHA used a team of consultants for the design and peer review. One consultant was responsible for the original design of the new bridge. A team of consultants was responsible for the peer review and detailed review of the design calculations. For the Inter-County Connector (ICC) project in Montgomery County, the project was a design-build project. The Maryland SHA used a General Engineering Consultant to manage the project. A team of consultants was responsible for the peer review that consisted of review of the plans, review of the design calculations, and holding bi-weekly progress meetings.

## Nebraska Department of Roads

NTSB investigators interviewed staff from the Nebraska Department of Roads (NDOR) Bridge Office on July 23, 2008.

The NDOR is centrally organized with a total of 8 districts. The Central office in Lincoln is responsible for all structural design of bridges and inspections. The inspectors work for and report directly to the Central Office. Routine bridge maintenance is performed by the district offices and more extensive maintenance or repairs are contracted. In either case, the repair plans are developed by the Central Office. On the State system, the percentage of bridge design work done in-house is approximately 95%. On the Local system, the percentage of bridge design work done in-house is approximately 5%. The Central Office consists of approximately 57 bridge design staff.

The NDOR pre-qualifies consultant engineering firms according to the following bridge design types:

**Major Bridge Design –** typically this includes preparation of construction plans for high level structures with underwater piers, complex interchange structures with curved girders or other major complex bridge structures, or those of advanced or unusual design concepts.

**Minor Bridge Design –** typically this includes preparation of construction plans for non-complex bridge structures. Non-complex bridge structures are all of those structures not covered under major bridge design.

A consultant engineering firm must have an approved form (DR Form 497) on file with the NDOR that shows the key personnel in the firm that will be performing the bridge design work. The approved form is necessary in order for a firm to be eligible to respond to a Request for Proposals (RFP) from the NDOR and also local governments when federal or state-aid is used. Certification is required annually and expires every March 31st. Firms must submit a current form or written notification of "no change" prior to February 1st of each year. The NDOR provides written or email notification that the form has been received and completed.

The NDOR performs reviews of consultant engineering bridge plans at various stages of design. The review of the plan submissions are done at the 65% stage, 90% stage, and 100% stages of development.

Consultant engineering firms are required to design the bridge, detail the bridge plans, and then perform an independent check of the bridge design and the bridge plan details as part of their internal quality control process. They are required to submit copies of the design computations and the check computations to show that this was done. All work is required to be done by or under the direct supervision of a professional engineer. The consultant is required to put the seal and signature of a registered professional engineer licensed in the State of Nebraska on all sheets of the final bridge plans.

## New York State DOT

NTSB investigators interviewed staff from the New York State DOT (NYSDOT) Office of Structures on June 25, 2008.

The Office of Structures has a central office located in Albany that is divided into 4 bureaus. The central office is responsible for structural engineering services, quality assurance, specialized structural services, bridge design services, and keeping track of all bridge projects. The state is divided into 11 regional offices. The regional offices are responsible for managing the bridge projects in each region. The regional offices also perform a coordination function that includes public hearings and coordination with the highway design group.

The 4 bureaus in the central office include the Structure Design Bureau, the Structural Engineering Services Bureau, the Bridge Evaluation Services Bureau, and the Structures Design Quality Assurance Bureau. The percentage of bridge design work done by consultants is approximately 50%. The NYSDOT experienced a downsizing of staff in the early 1990's, primarily through attrition and retirement incentives. In 1994, the central office consisted of approximately 268 bridge design staff. Today, the central office consists of approximately 165 bridge design staff.

The NYSDOT has two processes to select consultant engineering firms for bridge design work. Normally, the NYSDOT uses an electronic process in which the NYSDOT specifies the key elements of the work they want done and then scores the firm against those elements based on a project specific expression of interests (EOI) and a standing database of information submitted by the firms (i.e. prior projects completed, etc.). The automated scoring generates a shortlist of firms who get further review by a selection committee. In cases where the work does not match up with any standing information in the database, the NYSDOT follows a more conventional process (although rare for bridge design work) that requires the consultant to prepare an SF 255 submittal.

The NYSDOT ensures that quality assurance is provided in bridge design projects through technical progress reviews. Technical progress reviews are conducted at five project milestones for all structures. Technical progress reviews are considered integral to the design process and ensures standards, policies, guidelines and good engineering practice are being met. The five project milestones include the following:

- Project Scoping Document
- (Draft) Design Report (DDR)

- Preliminary Plan Development
- Advance Detail Plans (ADP)
- Final Plans, Specifications and Estimates (PS&E)

The Structure Design Quality Assurance Bureau within the Office of Structures provides quality assurance to the regional districts and to private consultants through a number of initiatives. The Structure Design Quality Assurance Bureau has five units that include the following:

- Standards and Policies Unit
  - Prepares standard details for bridges. Evaluates performance of details and recommends new standard practices.
  - Provides technical support to designers in the use of standard details and offers design advice.
- Program Development Unit (Regions 1 through 10, excluding New York City)
  - Communicates the Department's technical standards, guidelines, and best practices to designers.
  - Provides early project technical guidance to designers.
- Program Development Unit (Region 11, including New York City)
  - Liaison for the Structures Division with FHWA for the East River Bridge rehabilitation projects and other major New York City bridge projects that are federally funded.
- Hydraulic Engineering Unit
  - Provides quality assurance for regional and consultant prepared hydraulic analyses.
  - Performs hydraulic and scour analyses for in-house and consultant designed structure replacements.
- Program Development Unit
  - Provides quality assurance to the regions proposed bridge programs.
  - Provides tools to program developers to identify appropriate program candidates.
  - Serves as the Structure Division liaison to consultant managers; recommends technical activities and estimates the associated effort necessary to generate bridge project development / design products.
  - Serves as the Structures Division liaison to the FHWA for bridge program development and production activities.

The NYSDOT has incorporated an independent peer review on several unusual complex bridge design projects. An example of this is the Rosslyn Viaduct in Long Island, NY. The Rosslyn Viaduct is a segmental concrete bridge in which the peer review was performed by an independent consultant engineering firm.

Following the NTSB and FHWA recommendations on January 15, 2008, the NYSDOT identified a total of 680 truss bridges in the bridge inventory. The NYSDOT will be performing load rating checks and review of inspection reports on 150 of the total 680 truss bridges. The NYSDOT issued 2 advisories as a result of the NTSB and FHWA recommendations. The first advisory was a design advisory that included a design methodology for gusset plate design. The second advisory was a technical advisory that included Load Factor Design specifications for gusset plates.

## Oregon DOT

NTSB investigators interviewed staff from the Oregon DOT (ODOT) Bridge Section on April 29, 2008.

The ODOT was de-centralized in 2004 and has a total of 5 regions. Historically, the percentage of bridge design work done in-house was 80%. The use of in-house designers helped to ensure design quality and engineering accountability. Design teams were several people deep in most disciplines, with staff experience ranging up to 30 years. An individual designer's skills were developed over time with on-the-job training and mentoring. Today, ODOT has experienced a number of changes impacting the engineering workforce. A significant larger program without the hiring of additional staff, has led ODOT to out source over 70% of its bridge design work to consultants. In 2004, the de-centralization resulted in reassigning technical staff from headquarters to the regions. During the implementation of this change, ODOT experienced a turnover rate of 43% for professional staff. Changes in the public employment retirement system caused engineers to retire earlier than anticipated, contributing to the turnover rate. ODOT has a number of new staff, and a number of reassigned staff, many working with new managers and many working in new locations.

The ODOT has developed a design quality program that focuses on continuous improvement of the design process, to enhance quality, productivity and customer satisfaction. The design quality program is a comprehensive program that contains several key components that include quality control and quality assurance. Quality control, or due diligence, requires that the engineer take appropriate care and attention to detail of the design work and also requires that there are checks in the system to catch the inevitable mistake. The ODOT as a part of the comprehensive design quality program requires quality control plans from all groups who provide designs for ODOT; including each Region Technical Center, the Bridge Delivery Unit, and all consultant firms doing work for ODOT. Quality assurance describes the process of enforcing quality control standards to ensure overall quality, appropriate design practice, completeness and adherence to policy. ODOT is using an audit approach for quality assurance. Performance specifications for design projects are being developed and will be used to evaluate the quality of a sample population of design projects on a regular ongoing basis.

The ODOT requires consultants submit plans, specifications, estimates, and calculation books with all final designs. The calculation books shall consist of 2 parts; the design calculations and the design check calculations. The design check calculations is an independent check of the structural analysis and design of the bridge and related components, plan detail sheets, specifications and special provisions, and project quantities. The level of detail to be checked varies with the complexity of the project and the amount of experience of the designer and checker.

**Class I Check** – The Class I check is a comprehensive design review covering all aspects of the project. The Class I check is done primarily for major complex structures, steel and post-tensioned bridges, structures designed by an inexperienced designer, and structures checked by an inexperienced checker. The checker is responsible for the following:

- Review of location data and correspondence files.
- Review of construction time and seasonal requirements, permit applications, work-in-stream restriction, and utility installations and conflicts.
- Review of foundation and hydraulic requirements.
- Check for consistency of alignment and details with roadway plans.
- Thorough check of geometry, alignment, grades, clearances, and construction details.
- Verification of structure length, roadway width, structure type selection, aesthetic treatment, span arrangement, bent type and configuration, and rail type.
- Complete independent structural analysis of all components according to design specifications and current design practice. The checker should make a quick, longhand check of the most important structural elements before beginning a computer analysis of the design.
- Independent check of final estimate quantities and reconciliation of figures with designer.
- Conformation that all items listed in the checklist for final design have been satisfied.

**Class II Check** – The Class II check is a review of design concepts and construction details and does not necessarily include a structural analysis. The Class II check is done primarily for minor bridges designed by an experienced designer. The checker is responsible for the following:

- Review of correspondence, job files, and design calculations.
- Confirmation that foundation and hydraulic requirements are met.
- Verification of geometry, alignment, and structure type selection.
- Confirmation with designer that critical structural items have been analyzed during the final design.
- Completeness of plans.
- Check of construction details and final estimate quantities.

The ODOT has an “Error and Omissions” contract with consultants to enforce accountability and repercussions for poor engineering performance. If it is determined the error was caused by the consultant, the consultant shall correct the project deficiency at no cost to ODOT and assume financial responsibility for consequences resulting from the error.

## Pennsylvania DOT

NTSB investigators interviewed staff from the Pennsylvania DOT (PennDOT) Bridge Quality Assurance Division on May 28, 2008.

The PennDOT was de-centralized in the 1980's and has a total of 11 districts. The central office provides policy development, quality assurance, technical assistance and project oversight, review and approvals. The combination of additional bridge design work and the de-centralization of PennDOT have resulted in out-sourcing of work to consultants. On a statewide level, the percentage of bridge design work done by consultants is approximately 60%. In the urban districts (including Philadelphia and Pittsburgh), the percentage of bridge design work done by consultants is 95%. The PennDOT experienced a downsizing of staff as a result of the de-centralization in the 1980's. Today the central office consists of 25 bridge design staff.

The qualifications used by PennDOT to select consultant engineering firms for bridge design work is based on 3 factors: cost, qualifications, and past performance. The first step in any selection process is for the consultant engineering firms to submit a qualification package that includes a QA/QC plan and key personnel in the firm that will be performing the bridge design work. Consultants are required to update PennDOT on an annual basis of any changes to key personnel in the firm. The second step is for PennDOT to develop a short list of 3 firms for further interview. From the short list, each firm submits technical proposals. The third step is for PennDOT to review the technical proposals and conduct further interviews. The fourth step is for PennDOT to rank and select the consultant engineering firm.

The PennDOT performs reviews of consultant engineering bridge plans at various stages of design and through construction. Preliminary structural member sizes are verified at the Type, Size and Location (TS&L) phase of the project. Final structural members sizes are checked at the 90% plan submission and final plan submission.

At the district level, the designs are reviewed by the bridge units and also the construction units and maintenance units.

The PennDOT has developed tools that aid in the design process including a comprehensive design manual, design and construction standard drawings, quality assurance forms and software. The PennDOT has an extensive catalog of bridge design/analysis software that is continuously updated and thoroughly tested that provides a level of consistency and quality to the designs.

Another step in achieving a quality bridge design is for the consultant to complete QA forms at the time of 90% submission and final plan submission. The QA forms are included in PennDOT's Design Manual.

The PennDOT uses consultant engineering firms to assist with the bridge design review. The review level is consistent with the complexity of the design. Level 1 review is for unique design structures that include complex bridge design types. Level 1 entails a critical review of the plans and calculations for each component of the bridge. Level 2 review is for standard bridge design types. Level 2 entails a less intensive review of the plans and calculations.

**Tennessee DOT**

NTSB investigators interviewed staff from the Tennessee DOT (TDOT) Division of Structures on July 1, 2008.

All bridge design, as well as bridge rating and evaluation of all bridges on public roads in the State, are centrally located at headquarters in Nashville and housed under the Division of Structures. All bridge inspection crews are disbursed statewide, reporting to one of four regional offices. All consultant contracts for bridge design are handled within the TDOT headquarters, and supervised by the Division of Structures staff. Through the 1970's and early 80's, the Division of Structures designed over 80% of its bridges in-house. Today, the percentage of bridge design work done in-house is 95%. The Central Office consists of approximately 40 bridge design staff.

The state is divided into 4 regions. Region 4 (west portion of State) has the highest percentage of bridge design work in the state. The predominant bridge design in Region 4 is pre-stressed concrete continuous structures using friction bearing devices. Seismic design of bridges in Region 4 is a key element in the design process. The predominant bridge design in Region 3 (central portion of State) is pre-stressed concrete or steel continuous structures with point bearing steel piles. The point bearing steel piles are necessary because of the predominance of rock in the region. Region 2 represents the southeast portion of the State and Region 1 represents the remaining portion of the State.

The TDOT pre-qualifies consultant engineering firms for bridge design work. Since very little bridge design work is performed by consultants in the Division of Structures, the selection process follows a similar procedure in the Division of Roadway Design. The percentage of roadway design work done by consultant engineering firms is approximately 60% to 70%. The procedure consists of the following:

- Advertise the project.
- Send out legal notice.
- Compile letter of interests from consultant engineering firms.
- Narrow the list to 10 firms.
- Firms send in qualifications and key personnel that will be working on the project (including a QA/QC plan).
- Firms are scored and a recommendation list is developed.
- Committee convenes that includes the Chief Engineer.
- Narrow the list to 3 firms.
- Select consultant engineering firm with input from the Commission.

The procedure in reviewing consultant engineering plans in the early 1960's does not differ substantially from today. Preliminary layouts with Type, Size and Location (TS&L) are submitted for review and comment. The consultant proceeds with final design and contract plans preparation once the corrections are made. Preliminary final plans are submitted for review by TDOT bridge staff, usually consisting of managerial and supervisory staff. The plan review consists of a study of the details and overall plan content, and consistency with TDOT format. Marked plans are sent for correction. If details are of a questionable nature, the consultant will be asked for specifics regarding the reasons or the design methods used. The review of consultant engineering bridge plans are performed by experienced TDOT staff. The reviewer scrutinizes the size and patterns of reinforcement for structural concrete members and size and distribution of plates for structural steel girders in comparison to like structures designed and constructed by TDOT staff.

Following the NTSB and FHWA recommendations on January 15, 2008, the TDOT identified a total of 67 truss bridges in the bridge inventory of which 44 truss bridges belong to TDOT. The TDOT has already advertised and selected 2 consultants to perform bridge inspections, develop a 3-dimensional model, retain the model to evaluate against future deterioration, and prepare plans for rehabilitation. The TDOT currently is in contract negotiations with the 2 consultants and expects work to begin in September.

**Texas DOT**

NTSB investigators interviewed staff from the Texas DOT (TxDOT) Bridge Division on May 6, 2008.

The Bridge Division is located in Austin and assists 25 districts around the state with the development of bridge plans. Only some of the larger districts, i.e. Dallas, El Paso, Fort Worth, Houston, and San Antonio have bridge sections of their own that perform bridge design and structural review. The five larger districts that have bridge sections review the plans prepared by the district or their consultants before sending the plans to Austin for final Plans, Specifications, and Estimates (PS&E) review. All sets of PS&E are submitted by the districts to the Design Division in Austin for letting regardless of who designed the bridge. The Design Division coordinates the review of all bridge plans with the Bridge Division before the project is cleared to be let for construction. The percentage of bridge design work done in-house is 60%.

A firm must be pre-certified prior to being awarded a professional services contract with TxDOT. In order to become pre-certified, firms must go through the pre-certification application process. Pre-certification is based on employee projects. TxDOT pre-certifies individuals based on prior work experience. An employee demonstrates his or her work experience by describing the work done on projects in the past. Pre-certification is then granted or denied based on this information. Once an employee is pre-certified in a work category, the firm employing that person is then automatically pre-certified in that category. If only one person employed by a firm is pre-certified in a particular category and that person leaves the firm, their pre-certification leaves with them. Pre-certification information can be updated at any time. If pre-certification is denied in one or more categories, it may be re-applied for. Pre-certification is required for all work categories that constitute 5% or more of the work on a contract.

Listed below are the pre-certification categories for Bridge Design and Bridge Inspection:

**Bridge Design**

Minor Bridge Design – this category includes the design of conventional, non-complex bridges, bridge replacements, simple bridge widening, railroad overpasses, non-standard retaining walls, and pedestrian bridges.

Major Bridge Design – this category includes the design of bridges with complex geometry, complexity of design, spans less than 350 feet, non-conventional substructures, substructures requiring ship impact design, design of dolphins for bridge pier protection, railroad underpasses, complex bridge widening, steel truss spans, and concrete arch bridges.

Multi-Level Interchange Design – this category includes design of bridges with three levels or more.

Exotic Bridge Design – this category includes the design of bridges with spans greater than 350 feet, suspension bridges, cable-stayed bridges, precast, post-tensioned segmental bridges, bridges requiring unique analytical methods, and movable bridges.

**Bridge Inspection**

Routine Bridge Inspection – this category includes the inspection of on-system and off-system bridges, inspection and load rating for culverts, pre-stressed beam bridges, cast-in-place concrete bridges, steel girder bridges, steel truss bridges, and timber bridges.

Complex Bridge Inspection – this category includes the inspection of on-system and off-system bridges, inspection and load rating for precast segmental structures, steel arch structures, cable stayed structures, fracture critical inspections, and movable bridges.

Consultant selection is based on qualifications. Firms are also selected based on their experience with similar projects. Evaluation of the consultants QA/QC process is another major selection criteria in the consultant selection process. Consultants are required to make submittals that demonstrate the use of an established QA/QC process.

The TxDOT expects consulting engineering firms to exercise their quality control plan and show evidence of internal mark-up (red-lines) at the time a deliverable is submitted for review. For example, if a consultant's contract scope requires them to submit a deliverable at 30, 60, 90, and 100 percent completion, a red-lined set of comments is required to be submitted at each stage in the deliverable process. The submission of this information is not intended to be additional information that TxDOT must review or check. The required submission of the information forces the consultant to take the step, as promised, and provides TxDOT the assurance that the deliverable was reviewed prior to submittal as expected. The actual deliverable should not be accepted as complete without the evidence of quality control. The submittals should be clearly labeled as the consultant's internal mark-ups. TxDOT is not expected to and should not attempt to check the actual deliverable against the mark-up. TxDOT project managers and staff involved in the process must understand that the mark-ups are work products that are used to develop a submittal. TxDOT's focus should be on the actual submittal and not the mark-up. The request for the mark-up, again, is to ensure that the consultant is reviewing their deliverables internally as a routine order of business before submittal.

The TxDOT conducts independent peer reviews on all exotic bridge designs and some major bridge and multi-level interchange designs. A recent example of an independent peer review was done on the Woodall Rogers Extension over the Trinity River in Dallas. An independent peer review was done by a separate consultant engineering firm that reviewed the plans and design calculations. Another example of an independent peer review was done on an in-house bridge design in Corpus Christi. The TxDOT used a private consultant to back check the design (peer review) that was originally done in-house.

For all in-house bridge design projects, an independent review of the plans and design calculations occurs at the Plans, Specifications, and Estimates (PS&E) submittal. The independent review is conducted by a separate design group, eliminating the possibility of a design group reviewing their own plans.

There is a bridge engineer on staff in each of the 25 districts around the state. The Dallas, El Paso, Fort Worth, Houston, and San Antonio district offices have bridge sections that can design major bridge and multi-level interchange designs. The Houston District is the only district that has the expertise to design exotic bridge designs besides the Bridge Division in Austin.

## Virginia DOT

NTSB investigators interviewed staff from the Virginia DOT (VDOT) Structure and Bridge Division on June 24, 2008.

The Structure and Bridge design function is organized as a Division in the VDOT Central Office, and as a Section in each of the 9 District Offices. The Central Office is responsible for providing direction, developing policies, performing design and providing Quality Control. The Central Office staff provides design services for bridges on the Interstate system and the Primary system. The Central Office staff also provides assistance to the District Offices for bridges on the Secondary system. All consultant contracts are procured and managed out of the Central Office.

The District Offices are responsible for providing NBIS safety inspections, providing rehabilitation design for bridges, and performing new and replacement designs for structures on the Secondary system. The District Offices coordinate and direct the work of consultants on projects related to the maintenance, repair and widening of existing structures.

In the late 1990's, the percentage of bridge design work done by consultants varied from 70 to 80%. Today, the percentage of bridge design work done by consultants is approximately 30%. The VDOT experienced a downsizing of staff in the early 1990's, primarily due to early buyouts afforded to employees. Some of the project management functions were pushed out to the District Offices. In the 1980's, the Central Office consisted of approximately 120 bridge design staff. Today, the Central Office consists of approximately 60 bridge design staff.

The VDOT uses a quality based procedure to select consultant engineering firms for bridge design work. The procedure consists of the following:

- Send out request for proposals (RFP) that includes a scope of work.
- Panel established that consists of bridge design staff from the Central Office and District Office.
- Consultant engineering firms submit expression of interests (QA/QC plan is included).
- Panel ranks expression of interests and develops a short list of firms.
- Technical presentations are given by the consultant engineering firms.
- Panel meets and scores and selects consultant engineering firm (firms are ranked in order of preference)

The VDOT performs reviews of consultant engineering bridge plans at the preliminary bridge plan stage, and the 60%, 90% and 100% stages of the plan development. The plans are reviewed at each stage for general concept, structural integrity and plan clarity. Comments are developed by the Structure and Bridge staff and those remarks are submitted to the consultant for corrections. The 100% plans undergo an additional review by one of the Assistant State Structure and Bridge Engineers before the plans are approved for construction. In addition, constructability reviews are conducted at each of the current engineering milestones.

The consultant coordinators who are assigned to review consultant engineering bridge plans are made up of senior engineers or supervisors. Each of the coordinators have years of design experience before they are assigned to a consultant contract. To aid the reviewers, the Structure and Bridge Division has developed a comprehensive checklist that relates to each type of plan sheet that may be included in a normal set of drawings. The checklist, which is also provided to the consultant, serves as an aid that helps ensure that key elements of design and plans are not omitted. The Division also maintains a Structure and Bridge Design Manual that consists of typical details and standard drawings that are used by both in-house and consultant designers.

The VDOT has incorporated an independent peer review on several bridge design projects. An example of this is the Gilmerton Bridge (Route 13) over the Elizabeth River. The peer review was performed by an independent consultant engineering firm.

Following the NTSB and FHWA recommendations on January 15, 2008, the VDOT identified all deck truss bridges and fracture critical bridges in the bridge inventory. The VDOT identified 12 deck truss bridges that were similar in design to the I-35W Bridge in Minneapolis, MN. The VDOT reviewed all of the inspection reports and nothing out of the ordinary was discovered during the review. All of the deck truss bridges had been inspected within the last 2 years and some were inspected as recently as May 2007. Re-inspections were performed on the deck truss bridges using a different consultant firm since the last inspection. The actions required as a result of the re-inspections were minor strengthening to the chord members of 2 bridges, Route 340 over Jeremy's Run and Route 340 over Overall Run. The VDOT identified 301 fracture critical bridges in the bridge inventory. All of the inspection reports were reviewed and nothing out of the ordinary was discovered during the review. All of the bridges had been inspected within the last year. The VDOT performed QA field reviews on 11.5% (or 35) of the total 301 fracture critical bridges. The QA field reviews indicated the bridge inspectors were well aware of the importance of properly identifying and inspecting fracture critical members. The QA field reviews, however, did reveal that more emphasis was needed on procedural items that were consistent with AASHTO inspection standards. The VDOT determined that the QA field reviews did not need to expand to the remaining fracture critical bridges.

The VDOT Chief Engineer advised NTSB staff of a joint FHWA-AASHTO study on gusset plates. The study is funded for approximately $1 million with a time period of 24 months. The main objectives of the research study are the following:

- Perform advanced finite element analyses of varying bridge gusset connection types, configurations, loadings, and failure modes to verify or modify existing procedures, or develop new design and rating procedures.
- Perform large-scale experimental investigations to validate the findings of the finite element analyses.
- Based on the analytical and experimental investigations, develop recommendations for optimal connection configurations to maximize the resistance of gusset connections and minimize the possibility of unfavorable failure modes.
- Develop guidelines, specifications, and examples for the load and resistance factor design and rating of gusset connections.

The new guidelines are expected to assure safety of new and existing bridges as well as simplify the design and rating to avoid unnecessary checks and avoid unfavorable failure modes.

## Washington State DOT

NTSB investigators interviewed staff from the Washington State DOT (WSDOT) Bridge and Structures Office on April 30, 2008.

The WSDOT is centrally organized with a total of 7 regions. The Bridge and Structures Office is a function of the Headquarters Environmental & Engineering Programs and work as an agent to the regions. The Bridge and Structures Office reviews all bridge designs in the central office located in Tumwater, WA. The Bridge and Structures Office has approximately 130 staff that consists of 65 bridge design staff and 65 preservation staff. The preservation staff is responsible for the bridge inspections and load ratings of bridges. The percentage of bridge design work done in-house is 90%.

The WSDOT has number of mega-projects (SR520, Alaskan Way Viaduct, Tacoma HOV, SR405, Snoqualmie Pass & Columbia River Crossing) that are supported by general engineering consultants to get through the environmental process. For many of these projects, the WSDOT Bridge and Structures Office is preparing the plans, specifications, and estimates level of bridge plans. The final design of the mega projects is done by consultants, since the size of these projects would take up the time of the entire staff in the WSDOT Bridge and Structures Office.

The QA/QC procedure used by the WSDOT on the plans, specifications, and estimates level of bridge plans consists of a design team that includes the designer, checker, structural detailer, and a specification and estimate engineer, who are responsible for preparing a set of contract documents on or before the scheduled due date and within the budget allocated for the project. The QA/QC procedures may vary depending on the type and complexity of the structure being designed, and the experience level of the design team members. On complex structures, an independent analysis and design check of the major stresses may be required. More supervision, review, and checking may be required when the design team members are less experienced. In general, it is a good practice to have some experienced designers on every design team.

The checker's responsibility is to review the design, plans and specifications to assure accuracy and constructability. The checking procedure consists of reviewing the design calculations, structural plans, quantities and barlist. The design calculations may be checked by either of two methods; a line-by-line review and initializing by the checker or performing independent calculations.

The QA/QC procedure used by consultants on the plans, specifications, and estimates level of bridge plans follows a similar procedure used by the WSDOT. In addition to the internal QA/QC procedure used by the consultant firm, the WSDOT will review the consultant's design calculations and plans for completeness and conformance to Bridge Office design practice. The plans shall be checked for constructability, consistency, clarity, and compliance.

The WSDOT has incorporated an independent peer review in several design-build projects. An example of this is the Tacoma Narrows Bridge project over Puget Sound. The new bridge opened in 2007 and is a complex suspension bridge that cost approximately $849 million. The Tacoma Narrows Bridge project was the second design-build bridge project for WSDOT. The WSDOT currently have 3 active design-build projects.

## 5. INTERVIEW OF PRIVATE CONSULTANT ENGINEERING FIRMS

NTSB investigators with the assistance of the FHWA Turner-Fairbank Highway Research Center interviewed 3 private consultant engineering firms to understand the internal quality assurance / quality control (QA/QC) procedures used in each firm to prepare engineering bridge plans. The 3 private consultant engineering firms interviewed included Modjeski and Masters Inc., HNTB Corporation, and HDR Engineering Inc.

Listed below is a summary of the interviews conducted with each private engineering consultant engineering firm.

### Modjeski and Masters Inc.

NTSB investigators with the assistance of the FHWA Turner-Fairbank Highway Research Center interviewed the Chairman and CEO from Modjeski and Masters Inc. on May 18, 2008.

Modjeski and Masters is widely respected for its specialized technical expertise in design, inspection, and rehabilitation of all types of bridges. The firm's full-range of services includes fixed bridge design, movable bridge design, bridge inspection services, highways and interchanges, toll facilities design, bridge research, bridge instrumentation, vessel collision analysis, railroad services, bridge rehabilitation, emergency evaluations, scour analysis, seismic evaluation and design, foundation design, engineering course development, bridge code development, bridge modeling and design visualization. Modjeski and Masters performs these services for a wide variety of clients including State DOTs, Federal Agencies, Railroads, Turnpike Authorities, Bridge and Port Authorities, Local and County Governments, Universities, and other Private Organizations. Modjeski and Masters is comprised of structural, highway, electrical, mechanical and field services engineers and technicians.

The headquarters office of Modjeski and Masters is located in Harrisburg, Pennsylvania. The firm maintains six regional design offices throughout the country. The firm employs approximately 140 professionals and is approximately 115 years old.

The project managers employed in the firm are primarily responsible for the implementation of the project specific quality control/quality assurance plans. The firm seeks project managers with a considerable amount of bridge design experience and strong ethical standards. Generally, the employee needs to be in-charge of projects for approximately 5 to 7 years, and observed by key personnel in the firm, before the employee can be considered a project manager. The majority of project managers in the firm have at least a master’s degree and 10-15% percent have a doctorate degree. The vast majority of employees in the firm have been hired as a result of faculty recommendations from universities throughout the country.

The process by which bridge design plans are reviewed has changed over the last 40 years. In the 1960’s, the bridge design plans were mainly reviewed using hand calculations. With the advent of the computer, some aspects of the quality control review are now done by the computer. The downsizing of staff over the years at the State Department of Transportation (DOT) agencies has resulted in the burden of review to be done by consultants. At the same time, the economic pressure of maintaining and rehabilitating a bridge infrastructure is intense and the profit margins for private consultant engineering firms are relatively low.

Modjeski and Masters provided a sample project specific quality control/quality assurance plan for a bridge design project in Pennsylvania. Listed below are excerpts from the project specific quality control/quality assurance plan:

*"**General***

*This Project Specific Quality Control/Quality Assurance (PSQC/QA) Plan is intended to establish guidelines to promote quality in our engineering and administrative approach to the owner's bridge design. Quality is obtained when the plans, specifications and reports, correspondence, invoices and oral communication, related to this particular project, are delivered to the owner in an accurate, error-free, professional, and timely manner, and in a presentation consistent with the owner's requirements, within the fiscal limitation that the owner has placed upon our endeavors.*

*The PSQC/QA Plan relates to both the technical and administrative aspects of the full engineering service life cycle of a project, including proposal preparation, staffing, design activities, field activities, internal and external communication, project review, field operations, including inspection and construction observation, and document storage. The PSQC/QA Plan is applicable to all engineering services offered by the firm including: bridge design, highway design, bridge rehabilitation, bridge inspection, construction consultation, inspection of construction, research and code development. Checklists are often developed to monitor special needs of the client and/or a specific engineering activity…*

***Specific Technical Quality Control/Quality Assurance Procedures***

- *The Project Manager will identify the design criteria established for the project, and ensure that the staff is kept updated on any changes or additions to the criteria as the project progresses.*
- *Reports and technical documents will be reviewed by the Project Manager or his designee to confirm that the results and/or recommendations utilize the current design criteria.*
- *Design staff shall provide calculations for checking that include assumptions, design criteria and all reference material used to develop the calculations. Calculations shall be in a neat and orderly format. Individual sheet (or sheets) considered as trial designs, or no longer valid, shall be marked to prevent checking of preliminary or superseded work. All formal design calculation sheets will be checked, initialed and dated by the originator and the checker.*

- *Drawings for the design will be developed by qualified technicians and reviewed and checked by engineers or qualified technicians. Drawings will be initialed and/or signed, as applicable, by the originator and the checker. Drawings marked up with changes and/or corrections resulting from the review process are returned to the designer for action. Upon completion of the revisions, the reviewer or the Project Manager will compare the revised drawings with the marked up review drawings to ensure that all comments have been incorporated into the plans.*
- *To the extent practical, the owner approved programs will be used for the project. However, due to the span lengths anticipated for the structure, it is likely that other analysis software will be used for completion of the work. All of these programs have been checked independently by Modjeski and Masters as part of the approval process to make them part of our analytical tools. Program input is checked to confirm that the appropriate geometry, section properties and material properties have been used, and the output assessed to make certain that the results are trending in the right direction, based on both the current project, as well as past experience, prior to the results being used to complete the design. Spreadsheets are checked to confirm that the appropriate design criteria and specifications are being utilized, and that the results of the analysis programs are being transferred correctly and appropriate load factors are being applied.*
- *Specifications (to be completed when initiated by contract)*
- *Construction cost estimates will be developed based on estimated quantities for the various pay items associated with the design. Both an in-house cost estimate will be determined, and a Subconsultant will also be utilized to provide an independent construction cost estimate based on Modjeski and Masters plan details. In addition, industry experts (suppliers, fabricators and contractors) will be consulted in development of the estimates. Current bid price (averages) and similar recently bid and/or completed projects will also be reviewed to confirm that the estimate is reasonable.*
- *Plans Specifications & Estimate (PS&E) Package (to be completed when initiated by contract)*
- *The Project Manager or a qualified designee will review all calculations, drawings and specifications to determine that work is being completed in accordance with applicable specifications and the requirements of the client. This is not to be a number-by-number, line-by-line review, but is to be sufficiently in-depth to identify significant shortcomings in content or presentation, and to determine that the intent of design specifications is being met. This review also includes checking the constructability of the project. The Project Manager will submit the complete project to the Project Principal for final review prior to submission to the client.*
- *The Project Manager will be responsible to determine that the project is successfully and completely finalized. This will include:*

1. *The filing and indexing of design calculations and record copies of drawings,*
2. *Confirmation that the correspondence file and accounting files are in their proper locations, and*
3. *Confirmation of the delivery of all required drawings, calculations, reports, correspondence and other documentation to the owner.*

- *All files, storage boxes or other containers shall be clearly identified with the proper name of the project, the colloquial name, if applicable, the year completed, the owner's project identification number and Modjeski and Masters, Inc.'s project number. The accounting office will be notified that the project is complete and that final invoicing may take place.*

***Internal Quality Auditing***

*The Project Principal will be primarily responsible for confirming that the PSQC/QA Plan and Procedures are being implemented by the Project Manager on the project. The results of these internal quality audits will be provided to the Project Manager. If any deficiencies are noted, the Project Manager will be responsible for taking corrective action, follow-up and providing documentation of the actions taken.*

*Frequency of review meetings for the following items are anticipated to be as follows:*

- *Schedules – monthly*
- *Scope – bi-weekly*
- *Budget – monthly*
- *Team organization adjustments – bi-weekly (max), or as needed*
- *Approvals – as needed*
- *Coordination – at the discretion of the Design Team*

***Owner Design Manager Auditing***

*Modjeski and Masters will accommodate and facilitate owner audits at various times throughout the duration of the project."*

**HNTB Corporation**

NTSB investigators with the assistance of the FHWA Turner-Fairbank Highway Research Center interviewed a Senior Vice-President and a Vice-President from HNTB Corporation on May 20, 2008.

HNTB is a multidisciplinary firm known and respected for its work in transportation, bridges, aviation, architecture, urban design and planning, environmental engineering, water and construction services. The HNTB Companies provide professional services in three primary markets – transportation, architecture and federal. The HNTB Companies include four individual firms:

- **HNTB Corporation** – serving the transportation and municipal markets for bridge, highway, aviation, rail and water infrastructure by delivering comprehensive services from more than 60 offices in five regions.
- **HNTB Architecture Inc**. – serving the architectural market for aviation, federal, education, local government and corporate.
- **HNTB Federal Services Corporation** – serving the federal government in most major markets by drawing on resources from HNTB Corporation and HNTB Architecture Inc.
- **HNTB International** – serving clients with infrastructure projects overseas using the full resources of the HNTB Companies.

HNTB Corporation has designed some of the world's longest spans, most inventive lift mechanisms, and most elegant cable-stayed structures. The firm's commitment to creativity has produced award-winning bridges that span the globe.

The firm's full-range of bridge and tunnel services includes long-span bridge design, short-span bridge design, segmental bridge design, movable bridge design, railroad bridge design, interchange and viaduct design, tunnel design, bridge inspection and rehabilitation, seismic retrofit services, and bridge replacement.

The HNTB Companies is more than 93 years old, employing more than 3,400 professionals in more than 62 offices worldwide.

HNTB has developed four manuals to serve as a guide for professionals at HNTB in preparing bridge plans, specifications and estimates. HNTB recognizes that each bridge project is unique as to size, location and complexity. Each HNTB bridge office has preferred methods and procedures and client requirements that must be adhered to. The following four manuals provide a common basis and approach for design issues and quality control measures:

2. HNTB Manual of Professional Practice (January 2007),
3. HNTB Corporation Bridge & Tunnel Service Group Quality Control Manual (December 1996),

4. HNTB Complex Bridge Project Procedures, West Division Sample (June 2007), and
5. HNTB Bridge Inspection Policy for Fracture Critical Bridges (currently under development)

Listed below are excerpts from the HNTB Corporation Bridge & Tunnel Service Group Quality Control Manual (December 1996) describing the benefits of a good quality control program:

*"**WHAT IS QUALITY CONTROL***

*Quality control is the means whereby the quality of a product or service is established and maintained during its business lifespan. Through good quality control, a firm builds a reputation for excellence. Such a reputation is achieved by conscious efforts over many years. Through lack of quality control, a reputation for excellence can be lost in a fraction of that time.*

***Why Do We Need Quality Control?***

*A business is built on reputation. Without a reputation for excellence it is difficult to obtain new clients or gain repeat business from existing clients. Our business is competitive, it is free enterprise in a very real way, and unless we can maintain a reputation for consistently producing excellent work, others will get the work on which our livelihood depends.*

*HNTB needs quality control for repeat business. Our clients are knowledgeable people, many are engineers. If the products purchased from us, whether reports, designs, plans and specifications, or services at a job site, are not the best obtainable for the price paid, they will look elsewhere when the next job comes along.*

*Quality control is needed to minimize claims because of allegedly faulty products or performance. Such claims are a drain upon the profitability of the firm and ultimately affect the compensation of the individual employee. Good quality control will result in plans, specifications and construction services which do not generate such claims, or which in those instances where claims are made, can readily be defended...*

***How Do We Achieve Quality Control?***

*There are only two essentials to good quality control and they are:*

4. *Know the standard for the work being performed.*
5. *Perform so as to meet or exceed this standard.*

*The success of a quality control program rests with each individual employee, because individual performance determines whether standards of quality are met. There are many characteristics which affect performance, including:*

1. *A sense of individual responsibility for work assignments.*
2. *Pride of authorship in the written word, whether it be a report, letter, specifications, notes on a drawing or contract for new work.*
3. *Pride in the quality and appearance of a drawing.*
4. *A concern for the future of the firm.*
5. *A desire for advancement and increasing monetary rewards."*

Listed below are excerpts from the HNTB Corporation Bridge & Tunnel Service Group Quality Control Manual (December 1996) describing the methods for checking of calculations:

*"**CHECKING PROCEDURES***

*While checking does not assure accuracy, it is the most systematic means of reducing errors in calculations. Calculations are to be checked by a second individual familiar with the work. The checker's initials and the date of the check are to be placed in the proper box of the heading at the time the check is made. Calculations are not complete if the maker and checker have not completed the heading of each sheet. In addition, the job number is to be shown on each sheet so that misplaced sheets may be identified.*

*Checking of calculations is more than just a verification of arithmetic. The checker should question the validity of the calculations before, during and after checking of the calculations. Questions to ask may include, but are not limited to, the following:*

1. *Has the design criteria been satisfied?*
2. *What assumptions has the maker made, and are the assumptions valid?*
3. *Are the methods of calculation/design reasonable for the application?*
4. *Have the laws of statics been satisfied?*
5. *Has the maker omitted any pertinent items, or sketches that may affect the calculations?*
6. *Have units been consistently used throughout the calculations? Watch for mixing of feet and inches. Centimeters should be avoided.*
7. *Is the use of SI forces, density and mass correct in the calculations?*

*Even after calculations have been checked, they are often reviewed by others for applicability, completeness or relationship to other disciplines. A record of these reviews should be provided by placing the reviewer's initials and date on the cover sheet of the calculations.*

*Two types of checking are available:*

1. *Actual checking of the original calculations.*
2. *Independent calculations.*

*The method of checking of calculations is a function of the clients' and individual office policy. Quite frequently clients will require independent calculations to verify such values as design, quantities, geometry, etc. When there is neither a local office policy or client preferences it is recommended that the following calculations be checked by independent calculation.*

1. *Quantities*
2. *Geometry*
3. *Critical Details (to be defined by the project manager)"*

**HDR Engineering Inc.**

NTSB investigators with the assistance of the FHWA Turner-Fairbank Highway Research Center interviewed a Senior Vice-President from HDR Engineering Inc. on May 21, 2008.

HDR offers a wide range of specialized knowledge and experience in bridge design and inspection. The firm has engineered thousands of bridges spanning rivers, reservoirs and lakes; canyons and ravines; and roadways, rail and transit lines. HDR also offers planning, design and construction expertise for tunnel projects, including cut-and-cover, portal and approach structures. The firm's full-range of services includes bridge foundations, bridge inspection and rating; bridge rehabilitation, widening and upgrading; bridge scour, concrete segmental bridges, construction engineering and inspection, curved girder bridges, geotechnical engineering, historic preservation; long-span girder, arch, truss, and cable-stayed bridges; movable bridges, pedestrian bridges, railroad structures, research and innovation, seismic retrofit, short-span bridges, specialty wall systems, steel and concrete box girder bridges, and tunnels.

The employee-owned firm of HDR is more than 90 years old, and has blossomed into one of the nation's largest and most respected architecture-engineering companies, employing more than 7,500 professionals in more than 165 locations worldwide.

HDR developed an internal comprehensive Quality Assurance Procedure. The QA/QC Program is designed to achieve one of HDR's mission of maintaining a reputation for quality performance while satisfying the individual requirements of HDR's clients. The QA/QC Program promotes prevention rather than detection, and being proactive rather than reactive. It focuses on documenting and improving HDR's business processes.

All HDR employees are individually responsible for being aware of, understanding and implementing the QA/QC Program. The Quality Assurance Procedure outlines the responsibilities of each employee that includes the President, the Quality Office Director, the QA/QC Program Director, the Business Group National Directors and the National Director of Marketing, the Directors of Professional Services, the Regional Directors, the Regional Quality

Directors, the Department Managers, the Office QA/QC Program Coordinators, and the Project Managers.

Listed below are excerpts from the Quality Assurance Procedure that discuss the responsibilities of the Project Managers:

> *"Project Managers are to incorporate applicable portions of the QA/QC Program into each project. Project Managers are responsible for achieving and maintaining product and service quality as measured by standards of professional practice and by standards of quality established by the Business Group National Directors, National Director of Marketing and clients. Project Managers are responsible for effectively communicating project quality requirements to project team members and for budgeting project costs for QA/QC Program requirements, as appropriate."*

Listed below are excerpts from the Quality Assurance Procedure that identifies the requirements and guidelines for checking of final design calculations:

> *"**Final Design Calculations***
>
> *All Final Design Calculations shall receive a complete calculation check using either the Detail Check Method or the Independent Check Method. The Detail Check Method shall be the standard method used for checking Final Design Calculations unless the Independent Check Method is specifically required by the client or when fulfilling a specific project function identified in the scope of services. The project QC Plan shall specify the required method of checking Final Design Calculations if it is to be other than the Detail Check Method.*
>
> *Subsequent to completion of calculation checking, Final Design Calculations shall also have a QC Review in accordance with the project QC Plan. The QC Reviewer shall, at a minimum, determine whether:*
>
> - *the calculations have been organized and checked properly,*
> - *appropriate assumptions and methods were used,*
> - *the results are reasonable based upon similar projects or experience, and*
> - *the calculations are consistent with project criteria and scope, and standard industry practice.*
>
> *Final Design Calculations are not completed until they have been verified, checked and accompanied by a calculation cover sheet signed by the QC Reviewer, Calculation Checker and Calculation Originator...*
>
> ***Detail Check Method***

*The Detail Check Method involves a complete check by the Calculation Checker of the calculations, associated means and methods, and resulting final outcome developed by the Calculation Originator.*

*The Project Manager or Discipline Leader will determine the point at which work has progressed sufficiently that checking can begin on a completed portion of the calculations. Calculation checking shall be performed as soon as practicable so that follow-on work is not negatively impacted. The Project Manager or Discipline Leader shall assign a qualified individual as the Calculation Checker. Checking shall be done by an individual who is not the Calculation Originator.*

*The Project Manager or Discipline Leader shall review the project scope with the assigned Calculation Checker; advise the Calculation Checker of the schedule; and provide the Calculation Checker with any specific project criteria defined in the Project Guide, or any specific project checking criteria defined in the project QC Plan.*

*The Calculation Checker shall first verify that all reference data and information, provided by others and used as a basis for the calculations, has been checked and is reasonable for use. Calculations shall not be checked until verification of reference data and information provided by others has been completed and confirmed for use by the Project Manager or Discipline Leader.*

*The Calculation Checker shall review, check and agree with:*

- *assumptions,*
- *methods (standard or client specific),*
- *code requirements,*
- *formulas and mathematical hand computations,*
- *appropriate use of computer programs,*
- *spreadsheet accuracy,*
- *validity of computer models used for analysis,*
- *accuracy of computer program input, and*
- *resulting outcome, including sketches, graphs and figures...*

*The Detail Check Method can be applied by using either of two acceptable methods:*

- *Dot Check Method (performed on the original calculation sheets), or*
- *Yellow Line Method (performed on copies of the calculation sheets)*

*The Project Manager, Discipline Leader or QC Reviewer shall verify that any project changes that may have occurred before, during and/or after the calculation checking process have been incorporated into the Final Design Calculations and ultimately into the final deliverables, and that appropriate back-checking has been performed.*

***Independent Check Method***

*The Independent Check Method involves the development of a completely separate set of calculations by the Calculation Checker to verify that the Calculation Originator's outcome reasonably satisfies the project requirements and standards. The Independent Check Method shall be used only when required by the client or when fulfilling a specific project function identified in the scope of services.*

*In this method, the Calculation Checker receives only the Calculation Originator's final outcome or deliverable, and does not review the original calculations or methods used to obtain the solution. The Calculation Checker must develop independent and appropriate calculation means and methods to verify all elements of the original calculation outcome. The independent check does not rely on the assumptions or judgment of the Calculation Originator, and is not constrained by decisions made by the Calculation Originator in the development of the original outcome. Each independent check shall include an independent development of the assumptions, analysis, specific details and final outcome to be used for the project.*

*The Calculation Checker may use a team of individuals to perform the independent analysis. The independent check team shall consist of individuals who are not members of the original team that developed the calculations being checked.*

*The independent set of calculations shall be prepared to the same level of detail and requirements as the original calculations, and shall incorporate the following items.*

- *The independent calculations shall be legibly written with references to author, date and subject included.*
- *References to applicable standards, criteria and specifications shall be clearly shown.*
- *Only computer software approved for the project by the Project Manager of Discipline Leader shall be used. Computer programs used for original calculations shall not be used in the Independent Check Method unless specifically identified in the project QC Plan.*
- *All computer analysis included in the Independent Check Method calculations shall contain hardcopies of both input and output, and shall be in a format that clearly documents the usage, purpose and limitations of the program.*
- *Special attention shall be paid to the evaluation of all computer output for reasonableness before continuing with the independent design process. This should include spot checks of results using hand computations to verify orders of magnitude for results. Graphical plots should be used*

*wherever possible or applicable to verify consistency and reasonableness of results.*

- *A calculation cover sheet shall be prepared for the Independent Check Method calculations.*

*The Calculation Checker shall document all comments and recommended changes to the original design using the Independent Check Review Comment Form. The Calculation Originator shall review the form and include responses for each item. Changes to the original calculation outcome made as a result of the Independent Check Method shall be clearly identified in the original calculations and Independent Check Method calculations. Both sets of calculations shall be maintained in the project files.*

*After any disagreements have been resolved, the completed Independent Check Review Comment Form shall be maintained in the project files."*

## E. ATTACHMENTS

Attachment 36 - Minnesota Classification Questionnaire dated February 24, 1960

Attachment 37 - Minnesota Highway Department Bridge Design Manual dated April 12, 1972

Attachment 38 - Consultant agreement between Mn/DOT and Sverdrup and Parcel and Associates, Inc. dated November 5, 1962

Attachment 39 - Mn/DOT consultant services work type definition dated March 26, 2003

Attachment 40 - Letter to the National Transportation Safety Board from the Minnesota Department of Transportation dated March 6, 2008

Attachment 41 - Letter to the National Transportation Safety Board from the Minnesota Department of Transportation dated March 24, 2008

Attachment 42 - Mn/DOT Load and Resistance Factor Design (LRFD) Bridge Design Manual

Attachment 43 - Email to the National Transportation Safety Board from the Federal Highway Administration – Minnesota Division Office dated March 7, 2008

Attachment 44 - FHWA Memorandum to Division Administrators dated February 22, 2007

Attachment 45 - FHWA Bridge Program Manual dated August 2004

Attachment 46 - Sverdrup & Parcel and Associates, Inc. document entitled Procedure for Checking Design Notes and Coordinating Same with Detail Checker dated September 1953

Attachment 47 - Sverdrup & Parcel and Associates, Inc. document entitled Quality Control Coordination and Checking Procedures dated April 1975

Attachment 48 – Answers to standard set of questions by the California DOT (Caltrans)

Attachment 49 – Answers to standard set of questions by the Florida DOT

Attachment 50 – Answers to standard set of questions by the Iowa DOT

Attachment 51 – Answers to standard set of questions by the Kansas DOT

Attachment 52 – Answers to standard set of questions by the Maryland State Highway Administration

Attachment 53 – Answers to standard set of questions by the Minnesota DOT

Attachment 54 – Answers to standard set of questions by the Nebraska Department of Roads

Attachment 55 – Answers to standard set of questions by the New York State DOT

Attachment 56 – Answers to standard set of questions by the Ohio DOT

Attachment 57 – Answers to standard set of questions by the Oregon DOT

Attachment 58 – Answers to standard set of questions by the Pennsylvania DOT

Attachment 59 – Answers to standard set of questions by the Tennessee DOT

Attachment 60 – Answers to standard set of questions by the Texas DOT

Attachment 61 – Answers to standard set of questions by the Virginia DOT

Attachment 62 – Answers to standard set of questions by the Washington State DOT

*Dan Walsh /s/*

**Dan Walsh, P.E.**
**Highway Accident Investigator**