Ayres Associates Bridge Design QA/QC Procedures

In general, Ayres Associates QA/QC Procedures utilize the highlighter method to detect and correct design errors in the plans and computations. This is done by using highlighters and colored pencils.

The highlighter method means that if an item is correct it will be highlighted with a yellow highlighter by the reviewer. If the item is incorrect, it will be circled in red and the correction will be penciled in red. Explanations or computations supporting the change will be noted in black pencil next to the correction or shown on an attached separate sheet.

When the corrections are made, the red comment will be checked off with a blue pencil. When a final review is performed to make sure that all of the corrections have all been made, the red comments will be checked off with a green pencil.

Therefore, a check set of documents will have all of the items either highlighted or marked in red and checked off with blue and green checkmarks. The check sets will also have 3 sets of initials and dates. [One in red (reviewer), one in blue (designer/detailer), and one in green (reviewer).]

NOTE: These procedures do not guarantee against plan errors. Instead, they are intended to ensure that the care and skill ordinarily employed by members in the field of bridge engineering under similar circumstances is followed.

Preliminary Plan Review

Preliminary plans are reviewed using the highlighter method described above. Plans are compared to previously approved similar bridge plans. The plans are reviewed for compliance with the WisDOT Bridge Manual and Standards, as well as sound engineering practices.

After review by the project engineer, the preliminary plans for the project will be independently reviewed for general engineering concepts, constructability, and general plan accuracy. The review will be completed by a senior designer who is experienced with the type of project.

1. An unmarked set of preliminary plans will be prepared for the reviewer.

2. Reports and data that may be required by the reviewer to complete the review will also be provided. Copies of small reports or of pertinent sections of large reports may be made for the reviewer if the project schedule does not allow concurrent reviews. Typical reports or data that may be required by the reviewer should include soil investigations, cost estimates, alternative comparisons, client meeting notes, site review or survey notes, and utility plans.

3. The reviewer will then do a general review to include the type of items typically listed below. **This review is not intended to be a plan check nor should it be done to the same detail as a plan check.** The reviewer will mark comments directly on the set of review plans with a red pencil.

4. After the review has been completed, the reviewer will meet with the appropriate design team member to discuss comments and recommend changes to the project. **The individual in responsible charge of the design (individual who will seal the plans) will make the final determination as to what changes will actually be made**. The disposition of the review plan comments should be identified by each comment on the actual review plan. The review plans should be kept in the project files until the project is constructed.

5. The following lists of items should typically be checked by the reviewer if applicable:

CONCEPTS:

------ Proper Structure Type and Length (Compare to study Bridge Site Report)

------ Loadings: Special; Pedestrian; Emergency Vehicles; Construction; Ice, Wind, Impact, etc.

------ Superelevation (finishing); Minimum Grades (drainage); Maximum Curvature (overhangs)

------ Skew

------ Deflections: DL; LL; Construction Loads; Camber

------ Railings: Pedestrian; Bike; Traffic

------ Expansion/Contraction: Temperature; Creep, Shrinkage; Construction Joints

------ Geotechnical: (Piling) Pre-Bore, Group Loading, Type, Variability in Length, Bedrock, Boulders, Lateral Resistance, Downdrag; (Other) Settlement, Slope Stability, Water Table

------ Maintenance: Access, Deck Repair/Replacement, Snowplowing

------ Painting, Coatings, Special Materials

------ Drainage

------ Lighting

------ Utilities: Empty Conduits, Suspended/Embedded

------ Hydraulics: Scour Analysis, Riprap, Regulatory Requirements, Ice, Debris, Roadway Overflow

------ Fabrication

------ Falsework, Forming

------ Retaining Walls/Temporary Sheeting

------ Lane Widths, Sidewalk Width/Height, “Lane Edge to Railing,” Median Width/Height

------ Environmental Requirements

------ Aesthetics

------ Temporary Railings, etc. for Stage Construction

------ Special Inspection Requirements (“Notes to Construction”)

------ Clearances (lateral, vertical, temporary)

------ Cost Estimate vs. Budget

------ Appropriate Bid Items for Structure Type

------ Type of Project Funding

CONSTRUCTIBILITY:

------ Staging: Coordinate sequence with Grading, Removals, Traffic
------ Sheeting Required for Excavation/Fill
------ Utility Conflicts (Underground, Overhead); RR Flagging
------ Storage/Access/Working Room
------ Weather (Wind, Rain, Freezing Temps); Water Table and Fluctuations
------ Transporting Girders
------ Erection
------ Construction Loadings, Vibrations, Deflections
------ Geometrics (Fit-Up, Tolerances)
------ Special Forming, Falsework, Bracing
------ Field Staking/Benchmarks
------ Time Required for Fabrication
------ Number of Working Days
------ Permits
------ River Stage Fluctuations
------ Navigation

ACCURACY/COORDINATION: (Highway Plans, Geotechnical Sub, Lighting Sub)

------ Grades
------ Alignments
------ Sloped/Skewed Dimensions
------ New Work Matches Existing?
------ Stationing vs. Dimensions
------ Elevations vs. Dimensions
------ Required Clearances
------ "Interface" Items: Approach Guardrail, Approach Barrier, Approach Slab, Retaining Walls, Special Backfill, Undercut, Drainage (Median, Ditches), Crash Attenuators/Guardrail, Clear Zone Requirements

6. The following is a checklist to go through after the Preliminary Plan Review has been completed.

- Were all applicable reports or data available and reviewed?
- Were the plans reviewed for the Concepts items identified?
- Were the plans reviewed for the Constructability items identified?
- Were the plans reviewed for the Plan Accuracy items identified?
- Do the review plans contain notes as to how each comment was disposed of?

Final Structure Design

A final structural design will be completed for the project. The design shall be performed by an engineer familiar with structural design. The design shall provide a clear picture of the structure design, including overall structure dimensions, girder size & spacing (if applicable), girder strand pattern & stirrup spacing (if applicable), slab transverse & longitudinal reinforcement, superstructure camber & deflection data, bridge ratings, pile type, number, spacing, estimated length and the driving resistance (bearing) required. Abutment wing wall type, length, and pile requirements are also included in the design.

The design must be checked by another engineer familiar with structural design. The checking procedure will utilize the highlighter method listed above.

1. When designing the structure, the following items should be used as guidelines:

    - Approved Preliminary structure plan as received from the bridge section
    - Geotechnical Site Investigation (soils) Report
    - Recent similar structure design done by Ayres
    - WisDOT Bridge Manual (BM)
    - WisDOT Bridge Manual Standard Detail Drawings (SDD)
    - AASHTO LRFD Design Specifications
    - AASHTO Standard Specifications for Highway Bridges

2. When designing the structure, the following computer software should be used if applicable:

    - CONSPAN by LEAP Software, Inc.
    - RC-Pier by LEAP Software, Inc.
    - CONSYS by LEAP Software, Inc.
    - STAAD Pro Structural Analysis and Design
    - ECOM Structural Expert Series – Modules FA3 Frame Analysis and FA4 Beam Span Analysis
    - ECOM Structural Expert Series - Bridge Girder Analysis
    - CWALSHT (Sheet Pile Design) software by USACOE
    - BOXCAR (Precast Concrete Box Culvert Design) software by American Concrete Pipe Association
    - Geomath software
    - MathCAD design spreadsheets developed by Ayres
    - Excel design spreadsheets developed by Ayres

3. Complete design cover sheet (cover.doc)

4. Determine structure loadings. Refer to BM, AASHTO, and previous Ayres Design Examples.

    - Determine Live Loads
    - Determine Dead Loads
    - Determine Live Load Impact
    - Determine Live Load Distribution
    - Determine LRFD Parameters if applicable

5. Run appropriate design computer program (if applicable)

6. Determine slab reinforcement required

7. For multi-span bridges, run computer program to determine live load moments for the continuity steel design

    - Use CONSYS program for all bridge types
    - Use CONSYS or ECOM's Bridge Girder Analysis program for multi-span bridges with unequal span lengths
    - Use CONSYS or CONBGR-Continuous Bridge Girder Analysis program for bridges with equal span lengths

8. For multi-span bridges, design Continuity Steel using CON-SPAN results and Ayres MathCAD spreadsheet.

    - Provide sketch of bar size, spacing, and length

9. Determine Standard Permit Vehicle live load moment for rating computation.

    - For single-span bridges and multi-span bridges of equal span lengths, obtain maximum live load moments from BM Chapter 45 tables.
    - For multi-span bridges with unequal span lengths, run an Analysis Program to determine maximum moment.

10. Determine Bridge Ratings using the appropriate design program or the MathCAD spreadsheet developed by Ayres (whichever is applicable).

    - A minimum LRFD Operating Rating Factor of 1.0 is required by WisDOT for all new bridges
    - A minimum Standard Permit Vehicle Rating of 190 kips is required by WDOT for all new bridges
    - Indicate bridge ratings in a summary in the design

11. Determine Deflections and Camber using the appropriate design program or the MathCAD spreadsheet developed by Ayres (whichever is applicable).

    - Indicate deflection and camber and provide a summary in the design

12. Complete design summary sheets showing the following if applicable.

    - Dimensions and sketches of the structural components (Such as cross section thru a box culvert)
    - Strand pattern and dimensions "A", "B", and "C" for prestressed girders
    - Draped or straight strand patterns
    - Concrete strengths
    - Camber and dead load deflection data
    - Reinforcement required

13. Design Substructure Units

    - Determine dead loads
    - Determine live loads
    - Read the soils report to verify foundation support and to obtain the design parameters
    - Provide substructure design summaries that include substructure type; substructure dimensions; number, spacing, driving resistance (bearing), and estimated length of piling (if applicable); and wing types and dimensions (if applicable).

14. Have design checked using the highlighter method listed above.

Final Structure Detailing

The final plan sheets are the second stage of creating final plans by a Cad Technician from the Engineer's design and the state's preliminary review of the structure. The plan sheets will give a clear picture of the project layout and design data for constructability.

1. Make sure a complete approved and checked Engineer's design is available to work from along with the state's preliminary review for possible changes.

2. Go through existing plans and find one that is similar to use as an example throughout detailing the new final plan sheets.

General Plan Sheet

1. Create a new file using the appropriate seed file or use a General Plan sheet from the most recent existing similar project. Rename with the job number of the new file.

2. If an existing drawing is referenced, move the plan view and elevation view off the sheet. Notes and symbols may be used for the new structure. Check all information to make sure that it reflects current standards.

3. When creating a new file, be sure to use the appropriate seed file and use another file similar to the project as a reference file to get information and details.

4. Use appropriate cell libraries found on our database.

5. Fill in information required for the needed cells.

6. Make sure the Final State Project Number and title block information is current. Page numbers should be added just prior to finishing the drawings.

7. Create the “Total Estimated Quantities” list. Do not fill in at this point. The engineer will fill in during the final plan check.

8. Place the “List of Drawings” which may change during detailing.

9. Double check Consultant Contact. This is the engineer who will be stamping and signing the plans.

10. If all doesn’t fit on one sheet, move “General Notes” and “Design Data” to another sheet and place a note in a big bold box saying “For General Notes and Design Data See Sheet –“.

Plan View

1. Make sure to that the appropriate changes noted on the State reviewed Preliminary Plan have been made.

2. If required, place longitudinal construction joint and label.

3. Double check water flow directions and north arrow.

4. Double check with a completed example to be sure all items are properly labeled and nothing has been forgotten.

For Elevation View

1. Dimension and label accordingly.

2. Update Elevation View with final elevations.

Structure Detail Sheets

1. Create new file and use the appropriate border seed file.

2. Dimension structure and show bar steel reinforcement and spacing. Space bars according to design and place in a legible manner. Don’t number bars as of yet.

3. Fill in state project number and title block information. May as well do this for all sheets at this point, leaving off page numbers for now.

4. Place north arrows where applicable and label centerline of structure.

4. Now the bars can be numbered. Fill in Bill of Bars table.

Bill of Bars

1. The purpose of this is to give needed information about each bar used for the detailed structure. The needed length and number, if the bar is bent or coated, and if the bar is included in a bar series are all indicated in an organized chart along with the bar number assigned and a description of where the bar is located.

2. There are also details showing specific dimensions of all bent bars used for the structure.

3. The "Bar Series" table needs to be filled in also. This chart tells the number needed and the shortest and longest bar used in the series. The average of the two bars is taken for the length used in the Bill of Bars.

Soils Sheet - Subsurface Exploration Sheet

1. Be sure to update any known changes.

2. Fill in the final state project number and page number.

Final Clean-Up of Drawings

1. The "List of Drawings" can now be completed and page numbers for each sheet can be filled in.

2. Be sure to enter page numbers where applicable throughout the structure plan sheets (e.g. Header - See Sheet __ for details)

3. Print out check set of drawings for use in Final Structure Plan Checking

4. The following is a checklist to go through after the detailing of the plan has been completed.

    - Was the structure detailed using a completed and checked design?
    - Was the structure detailed using the approved WisDOT Preliminary review?
    - Was a current similar project used for an example?
    - Were the latest design standards used?
    - Were all necessary 'blanks' filled in? (E.g. reference page numbers, elevations, etc.)
    - Was the correct State Project number and Structure number placed on all the sheets?
    - Does the List of Drawings match the Titles on the corresponding sheets?
    - Were the General Plan and Subsurface Exploration Sheets updated according to the WisDOT Preliminary review comments?

Final Structure Plan Checking

The final plans for the project will be checked. The plans will be checked by an engineer that is familiar with structural design.

1. When checking final plans, the following items should be used as guides:

    - WisDOT Bridge Manual Standard Detail drawings. Make sure that Standard Details are up to date.
    - Recent similar structure plans done by Ayres
    - Checked structure design calculations that include design summary sheets
    - Approved Preliminary structure plans as received from WDOT Bureau of Structures.

2. Checking the final structure plans consists of using highlighters and colored pencils (Do Not use pen) to check the final plans created by the technician. The plan checker should check the completeness of the drawings. Some of the items to check include the following:

    - Elevations
    - Dimensions (Including dimension lines and arrowheads)
    - Drawing Titles
    - Notes
    - Reinforcement (Size, Spacing, Number, Length, etc.)

3. If the item is correct as drawn, use a yellow highlighter and cross it out.

4. If an item is incorrect, circle the item in red and then write or draw the correction in red pencil.

5. If an item has been corrected, explain the correction in black pencil near the correction or attach a sheet showing the calculation or sketch. Examples of black pencil comments are:

    - “As Per Standard 19.5”
    - “S406: 24’ – 2” CL. – 2” CL. = 23’-8” ”
    - “Changed to match section shown on sheet 4”

6. Plan checking should be done in the following order:

    - Check the general plan against the approved preliminary plan received from Bridge Section. (This is a check of overall geometry and the main bridge layout.) Note any items the designer might have changed. (Designer changes should be made in red and initialed and dated).
    - Make sure that profile and alignment match the roadway plans.
    - Check plan from top down. Start with superstructure and work down to the substructures.
    - Check structure dimensions
    - Check reinforcement size, length, spacing, etc.
    - Check that all required bid items and amounts are included and are correct.

7. Accuracy of the plan check should keep the following items in mind:

    - Elevations are O.K. if within 1/8-inch
    - Dimensions are O.K. if within 1/8-inch
    - Minor bar steel (steel that is not designed, but taken from standard detail drawings) lengths are O.K. if within 1-inch

    The checker should write the number that they have calculated on the check set in black pencil, and then yellow out the drawn number if within the tolerances listed above.

8. Once all of the items in the plan have been checked (all items either highlighted in yellow or corrected in red) the plan set should be stapled together and the check set should be dated and initialed by the checker in red on the left margin.

9. The technician will then make the required changes. Any discrepancies between the technician's numbers and the checkers numbers will be agreed upon as the changes are being made. Once a change is made, the technician crosses out the red comment or writes in the agreed upon value in green. After all the changes have been made, the check set should be initial and dated by the technician in green on the left margin.

10. The check set and revised drawings are then given back to the checker. The checker now backchecks the plans to make sure that the required changes have been made to the drawings and then crosses the changes out on the check set in brown pencil. Once all the changes have been made, the check set is initialed and dated by the backchecker in the left margin.

11. The following is a checklist to go through after the plan check has been completed.

    - Was the checked Final design, approved preliminary plan from bridge section, Standard Detail drawings, and a similar example used to check the final plans?
    - Were all items either yellowed-out or corrected in red?
    - Was the check set initialed and dated by the checker?
    - Were all the changes made to the drawings?
    - Was the check set initialed and dated by the technician and backchecker?

Internal Final Plan Review (Required on Large, Complex, or Unique Structures)

An internal final plan review to check the completeness, constructability, and accuracy of the plans will be done for large, complex, or unique structures. Depending on complexity of project, an Internal Final Plan Review team is set up (usually just before draft final plan submittal). Each team member utilizes the following procedures and checklists during their independent review of plans. Each team member also fills out comments for listed applicable considerations. A meeting of the peer review team to discuss comments as a group with engineer of record making final decision is then set up. Routine plans and smaller structures generally do not follow this process, but a more cursory review is performed by a senior structural engineer.

The final plan package for the project is independently reviewed for plan completeness, construction considerations, accuracy and coordination, and PS&E items by the Internal Plan

Review team. The review will be completed by at least two senior designers who are experienced with the type of project and not previously associated with the project as a team member.

1. The project manager will assemble an unmarked set of final plans for each reviewer. The plans will be permanently identified as a "REVIEW COPY" and marked with the date of the review and the name of the reviewer.

2. The project manager will also assemble a list of reports or data that may be required by the reviewer to complete the review. These reports or the location of the reports should be made available to each reviewer. Copies of small reports or of pertinent sections of large reports may be made for each reviewer if the project schedule does not allow concurrent reviews. Typical reports or data that may be required by the reviewers include soil investigations, cost estimates, Bridge Office review comments, and utility plans.

3. The reviewers will then do a general review to include the type of items typically listed below. **This review is not intended to be a plan check nor should it be done to the same detail as a plan check.** The reviewer will mark comments directly on the set of review plans with a red pencil. He will also mark each item with one of the following:

    - SC = see comments below
    - OK = no comments, item appears to be adequately addressed
    - N/R = no review, not applicable, or out of my area of experience
    - NMI = need more information (see below)

4. After the independent reviews have been completed, all reviewers will meet with the appropriate team members as a group to discuss comments and recommend changes to the project. **The Engineer of Record (individual who will seal the plans) will make the final determination as to what changes will actually be made**. The disposition of the review plan comments should be identified by each comment on the actual review plan. The review plans should be kept in the project files until the project is constructed.

5. The following lists of items should typically be checked by each reviewer if applicable:

    PLAN COMPLETENESS:

    ------ Structure Type and Length (Compare to approved Preliminary plan)

    ------ Geometrics: Lane Widths, Shoulder Width, Sidewalk Width/Height, Median Width/Height

    ------ Ratings/Loadings: Standard Truck; Standard Permit Vehicle; Construction

    ------ Superelevation/Crown

    ------ Deflections: Camber; Top-of-Deck Elevations

    ------ Railings: Pedestrian; Bike; Traffic, Fencing

    ------ Expansion/Contraction: Expansion Joints; Construction Joints

------ Geotechnical: Piling (Type, Length, Loading, Pre-Bore, Pile Points, Downdrag); Spread Footings (Bearing, Temporary Sheeting); Water Table

------ Hydraulics: Scour Analysis, Riprap, Regulatory Requirements, Roadway Overflow

------ Drainage: Grades, Surface Drains

------ Painting, Coatings, Special Materials

------ Aesthetics

------ Lighting

------ Utilities: Empty Conduits, Suspended/Embedded

------ Retaining Walls/Temporary Sheeting

------ Temporary Railings, etc. for Stage Construction

------ Plans complete with initials and P.E. seal

CONSTRUCTION CONSIDERATIONS:

------ Staging: Coordinate sequence with Grading, Removals, Traffic

------ Sheeting Required for Excavation/Fill

------ Fabrication, Time for Fabrication, Transporting Girders

------ Erection, Falsework, Forming, Special Falsework/Forming

------ Utility Conflicts (Underground, Overhead); RR Flagging

------ Storage/Access/Working Room

------ Construction Loadings, Vibrations, Deflections

------ Geometrics: Fit-Up, Tolerances

------ Field Staking/Benchmarks

------ Permits

------ Navigation, River Stage Fluctuations

------ Environmental Requirements

------ Calendar: Spring, Summer, Fall, Winter

------ Bridge Contractor Prime or Sub?

------ Single Structure or Multi-Structure Contract?

ACCURACY/COORDINATION: (Highway Plans, Geotechnical Sub, Lighting Sub)

------ Grades and Profiles

------ Alignments

------ Traffic Data

------ New Work Matches Existing?

------ Stationing

------ Elevations

------ Utilities

------ "Interface" Items: Approach Guardrail, Approach Barrier, Approach Slab, Retaining Walls, Special Backfill, Undercut, Drainage (Median, Ditches), Crash Attenuators/Guardrail, Clear Zone Requirements

PS&E:

------ Quantities: Plan Quantities match Cost Estimate Quantities

------ Cost Estimate: Unit Costs

------ Contract Time: Working Days, Calendar Days, Completion Date

------ Special Provisions

------ Notes to Construction

6. The following is a checklist to go through after the Internal Final Plan Review has been completed.

- Were all applicable reports or data available and reviewed?
- Were the plans reviewed for the Plan Completeness items identified in the QA procedure?
- Were the plans reviewed for the Construction Considerations items identified in the QA procedure?
- Were the plans reviewed for the Accuracy/Coordination items identified in the QA procedure?
- Were the plans reviewed for the PS&E items identified in the QA procedure?
- Were the comments discussed at a group meeting with the project team?
- Do the review plans contain notes as to how each comment was disposed of?

AYRES ASSOCIATES

Ayres Associates QA/QC Verification Summary Sheet

Final Plan Submittal:_____
(date)

Structure Number:_____

Project ID:_____

Name of Project:_____

Engineer of Record:_____

Final Review and Plans Sealed on:_____
(date)

Designed By:_____; Comps Finalized on:_____
(initial) (date)

Design Checked By:_____; Changes Resolved on:_____
(initial) (date)

Detailed By:_____; Final Corrections on:_____
(primary detailer) (date)

Detailed By:_____; Final Corrections on:_____
(secondary detailer) (date)

Plans Checked By:_____; Final Back Check of Corrections on:_____
(initial) (date)