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Remarks and Instructions

The complete manual, revision packages, and individual chapters can be accessed at www.wsdot.wa.gov/publications/manuals/m23-50.htm.

Please contact Joe Fahoum at 360-705-7193 or fahoumj@wsdot.wa.gov with comments, questions, or suggestions for improvement to the manual.

For updating printed manuals, page numbers indicating portions of the manual that are to be removed and replaced are shown below.

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Signature

Washington State
Department of Transportation

Bridge Design Manual (LRFD)

M 23-50.11

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Engineering and Regional Operations

Bridge and Structures Office

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Chapter 4 Seismic Design and Retrofit

Chapter 5 Concrete Structures

1.3 Quality Control/Quality Assurance (QC/QA) Procedure

1.3.1 General

A. The purpose of the QC/QA procedure is to improve the quality of the structural designs and plans. The key element to the success of this process is effective communication between all parties. The goals of the QC/QA procedure are:

- Designed structures that improve public safety and meet state regulations.
- Designed structures which meet the requirements of the WSDOT *Bridge Design Manual* M 23-50, AASHTO LRFD Bridge Design Specifications, current structural engineering practices, and geometric criteria provided by the Region.
- Designed structures that are aesthetically pleasing, constructible, durable, economical, inspectable, and require little maintenance.
- Design contract documents that meet the customer's needs, schedule, budget, and construction staging requirements.
- Structural design costs are minimized.
- An organized and indexed set of design calculations are produced. Design criteria and assumptions are included in the front after the index.
- Plan quality is maximized.
- The QA/QC procedure allows for change, innovation, and continuous improvement.

The goals are listed in order of importance. If there is a conflict between goals, the more important goal takes precedence.

The Unit Supervisor determines project assignments and the QC/QA process to be used in preparation of the structural design. The intent of the QC/QA process is to facilitate plan production efficiency and cost-effectiveness while assuring the structural integrity of the design and maximizing the quality of the structural contract documents.

B. The Bridge and Structures Office QC/QA procedure is a component of the general WSDOT template for project management process. Included as part of the current WSDOT project management process are project reviews at specific milestones along the project timeline. The expected content of the documents being reviewed at each specific milestone are described in the Deliverable Expectations Matrix developed and implemented by the WSDOT Design Office in May 2006. This matrix can be viewed via the link www.wsdot.wa.gov/projects/projectmgmt/online_guide/delivery_expectation_matrix/de_matrix.pdf.

The overall matrix is generic for WSDOT design, but there is a line in the matrix that outlines the specific content expectations for structures (bridges retaining walls, noise barrier walls, overhead sign structures, etc.). This "structures specific" matrix line includes a link to a separate matrix. This structures matrix can be viewed via the link www.wsdot.wa.gov/projects/projectmgmt/online_guide/delivery_expectation_matrix/bridge.pdf.

The Bridge Preliminary Plan as described in Chapter 2 is equivalent to the Geometric Review milestone of the generic WSDOT matrix and the Permitting Submittal Review milestone of the structure specific matrix.

Intermediate stage constructability reviews conducted for certain projects by Region Design PE Offices or Local Agencies are equivalent to the General Plans Review milestone of the generic WSDOT matrix and the Intermediate PS&E Submittal Review milestone of the structure specific matrix.

The Bridge Plans turn-in as described in Section 12.4.3 is equivalent to the Preliminary Contract Review milestone of the generic WSDOT matrix and the PS&E Pre-submittal Review milestone of the structure specific matrix.

The Bridge PS&E turn-in as described in Section 12.4.3 is equivalent to the Final Contract Review milestone of the generic WSDOT matrix and the Final PS&E Submittal Review milestone of the structure specific matrix.

1.3.2 Design/Check Procedures

A. PS&E Prepared by WSDOT Bridge and Structures Office

1. **Design Team –** The design team usually consists of the Designer(s), Checker(s), Structural Detailer(s), and a Specification and Estimate Engineer, who are responsible for preparing a set of contract documents on or before the scheduled due date(s) and within the budget allocated for the project. On large projects, the Unit Supervisor may designate a designer to be a Project Coordinator with additional duties, such as: assisting the supervisor in communicating with the Region, coordinating and communicating with the Geotechnical Branch, and monitoring the activities of the design team.

   The QC/QA procedures may vary depending on the type and complexity of the structure being designed, and the experience level of the design team members. 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. All design team members should have the opportunity to provide input to maximize the quality of the design plans.

2. **Designer Responsibility –** The designer is responsible for the content of the contract plan sheets, including structural analysis, completeness and correctness. A good set of example plans, which is representative of the bridge type, is indispensable as an aid to less experienced designers and detailers.

   During the design phase of a project, the designer will need to communicate frequently with the Unit Supervisor and other stakeholders. This includes acquiring, finalizing or revising roadway geometrics, soil reports, hydraulics recommendations, and utility requirements. Constructability issues may also require that the designer communicate with the Region or Construction Office. The designer may have to organize face-to-face meetings to resolve constructability issues early in the design phase. The bridge plans must be coordinated with the PS&E packages produced concurrently by the Region.

   The designer shall advise the Unit Supervisor as soon as possible of any scope and project cost increases and the reasons for the increases. The Unit Supervisor will then notify the Region project office if the delivery schedule will have to be changed. If Region concurs with a change in the delivery date, the Unit Supervisor will notify the Bridge Projects Engineer or the Bridge Scheduling Engineer of the revised delivery dates.

   The designer or Project Coordinator is responsible for project planning which involves the following:

   a. Determines scope of work, identifies tasks and plans order of work.

   b. Prepare design criteria that are included in the front of the design calculations. Compares tasks with BDM office practice and AASHTO bridge design specifications.

      (1) Insures that design guidelines are sufficient?

      (2) Justification for deviation from *Bridge Design Manual*/AASHTO?

(3) Justification for design approach?

(4) Justification for deviation from office practices regarding design and details?

(5) Other differences.

c. Meet with the Region design staff and other project stakeholders early in the design process to resolve as many issues as possible before proceeding with final design and detailing.

d. Identify coordination needs with other designers, units, and offices.

e. Early in the project, the bridge sheet numbering system should be coordinated with the Region design staff. For projects with multiple bridges, each set of bridge sheets should have a unique set of bridge sheet numbers.

f. At least monthly or as directed by the design Unit Supervisor:

(1) Update Project Schedule and List of Sheets.

(2) Estimate percent complete.

(3) Estimate time to complete.

(4) Work with Unit Supervisor to adjust resources, if necessary.

g. Develop preliminary quantities for all cost estimates after the Preliminary Plan stage.

h. Near end of project:

(1) Develop quantities, *Not Included in Bridge Quantity List, and Special Provisions Checklist* that are to be turned in with the plans. (See Section 12.4.4).

(2) Prepare the Bar List.

(3) Coordinate all final changes, including review comments received from the Bridge Specifications and Estimates Engineer. Refer to Section 12.4.3 (B).

(4) Meet with Region design staff and other project stakeholders at the constructabality review/round table review meetings to address final project coordination issues.

The designer should inform the Unit Supervisor of any areas of the design, which should receive special attention during checking and review.

(5) Prepare the QA/QC Checklist, and obtain signatures/initials as required. This applies to all projects regardless of type or importance (bridges, walls, sign structures, overlay, traffic barrier, etc.). Refer to Appendix 1.5-A3-1.

The design calculations are prepared by the designer and become a very important record document. Design calculations will be a reference document during the construction of the structure and throughout the life of the structure. It is critical that the design calculations be user friendly. The design calculations shall be well organized, clear, properly referenced, and include numbered pages along with a table of contents. The design calculations shall be archived. Computer files should be archived for use during construction, in the event that changed conditions arise. Archive-ready design and check calculations shall be bound and submitted to the Unit Supervisor concurrently with the turn-in of the Bridge PS&E submittal. Calculations shall be stored in the design unit until completion of construction. After construction, they shall be sent to archives. (See Section 1.3.8 Archiving Design Calculations, Design Files, and S&E Files).

The designer or another assigned individual is also responsible for resolving construction problems referred to the Bridge Office during the life of the contract. These issues will generally be referred through the Bridge Technical Advisor, the Unit Supervisor, the Construction Support Unit, or the HQ Construction-Bridge.

3. **Checker Responsibility –** The checker is responsible to the Unit Supervisor for "quality assurance" of the structural design, which includes checking the design, plans and specifications to assure accuracy and constructability. The Unit Supervisor works with the checker to establish the level of checking required. The checking procedure for assuring the quality of the design will vary from project to project. Following are some general checking guidelines:
   a. **Design Calculations –** may be checked by either of two methods:
      (1) Design calculations may be checked with a line-by-line review and initialing by the checker. If it is more efficient, the checker may choose to perform his/her own independent calculations.
      (2) Iterative design methods may be best checked by review of the designer's calculations, while standard and straight-forward designs may be most efficiently checked with independent calculations. All the designer and checker calculations shall be placed in one design set.
      (3) Revision of design calculations, if required, is the responsibility of the designer.
   b. **Structural Plans**
      (1) The checker's plan review comments are recorded on a copy of the structural plans, including details and bar lists, and returned to the designer for consideration. These check prints are a vital part of the checking process, and shall be preserved. If the checker's comments are not incorporated, the designer should provide justification for not doing so. If there is a difference of opinion that cannot be resolved between the designer and checker, the Unit Supervisor shall resolve any issues. Check prints shall be submitted to the Unit Supervisor at the time of 100% PS&E turn-in.
      (2) If assigned by the Unit Supervisor, a structural detailer shall perform a complete check of the geometry using CADD or hand calculations.
      (3) Revision of plans, if required, is the responsibility of the designer.
   c. **Quantities and Barlist**
      (1) The checker shall provide an independent set of quantity calculations. These together with the designer's quantity calculations shall be placed in the job file.
      (2) Resolution of differences between the designer and checker shall be completed before the Bridge PS&E submittal. The checker shall also check the barlist.
4. **Structural Detailer Responsibility –** The structural detailer is responsible for the quality and consistency of the contract plan sheets. The structural detailer shall ensure that the Bridge Office drafting standards as explained in Chapter 11 of this manual are upheld.
   a. Refer to Chapter 11, for detailing practices.
   b. Provide necessary and adequate information to ensure the contract plans are accurate, complete, and readable.
   c. Detail plan sheets in a consistent manner and follow accepted detailing practices.
   d. Check plans for geometry, reinforcing steel congestion, consistency, and verify control dimensions.
   e. Check for proper grammar and spelling.

f. On multiple bridge contracts, work with the Designer/Project Coordinator to ensure that the structural detailing of all bridges within the contract shall be coordinated to maximize consistency of detailing from bridge to bridge. Extra effort will be required to ensure uniformity of details, particularly if multiple design units and/or consultants are involved in preparing bridge plans.

g. Maintain an ongoing understanding of bridge construction techniques and practices.

5. **Specialist Responsibility –** All bridge and wall projects initiated with a signed Bridge Preliminary Plan.

The primary responsibility of the specialist is to act as a knowledge resource for the Bridge and Structures Office, WSDOT, other governmental agencies and consultants. Designers are encouraged to consult specialists for complex projects early in the design process. Supervisors overseeing a design project should actively identify any complex or unusual features, early in the design process, and encourage the designers involved to seek input from the suitable Specialist. The Specialists maintain an active knowledge of their specialty area, along with a current file of products and design procedures. The Specialists maintain industry contacts. Specialists provide training in their area of expertise.

Specialists are expected to remain engaged with the design efforts being carried out in the office related to their specialty. At the discretion of the Design Unit Supervisor, the Specialists may be requested to review, comment on and initial plans in their area of expertise prepared by other designers. Specialists are expected to review selected design work for consistency with other WSDOT projects, and for adherence to current office practice and current industry practice. Specialist reviews are typically cursory in nature, and are not intended to fulfill the role of structural checker. Specialists shall initial the Project Turn-In QA/QC Worksheet of BDM Appendix 1.5-A3 at the 100% completion stage of certain projects including:

a. **Bearing and Expansion Joint Specialist –** All expansion joint or bearing rehab projects. All new bridges with modular expansion joints, unique strip seal joints (high skew, raised steel sliding plates at sidewalk, traffic islands, etc.), and bearings other than plain elastomeric pads.

b. **Concrete Specialist –** All post-tensioned super and substructures, and complex prestressed girder superstructures (long spans, large skews, tapered girders, etc.). All structures utilizing mass concrete, self-consolidating concrete (SCC), shotcrete or Grade 80 reinforcement.

c. **Steel Specialist –** All new and retrofit steel superstructure projects, or projects involving significant or complex welding.

d. **Seismic Specialist –** All retrofit projects, and new bridges with complex seismic design requirements.

Specialists assist the Bridge and Structures Engineer in reviewing and voting on amendments to AASHTO specifications.

Specialists are responsible for keeping their respective chapters of the *Bridge Design Manual* M 23-50 up to date.

The Concrete, Steel, and Seismic Specialists act as Supervisors for the Structural Detailers within their unit. They are responsible for the day-to-day supervision of the Structural Detailers, including timesheet and evaluation responsibilities. The Specialists are also relied upon to assist the Design Unit Supervisor in allocating detailing staff, and completing Structural Detailer staffing projections.

A secondary responsibility of the Specialist is to serve as Unit Supervisor when the supervisor is absent.

Sign Structure design, Wall design, and Traffic Barrier & Rail design are three specialty areas where design and review work has traditionally been directed to dedicated staff in each of the three main design groups within the Bridge Design Office (see BDM 1.2.3). Design guidance or review requests for unusual or unique projects involving these three specialty areas should be directed to the applicable Design Unit Supervisor for design or review.

6. **Specification and Estimating Engineer Responsibilities –** There are currently four specialist positions in the Bridge and Structures Office. The four specialty areas in the Design Section are bearings and expansion joints, concrete (including prestressed concrete), seismic design and retrofit, and structural steel.

7. **Design Unit Supervisor Responsibility**

   a. The Unit Supervisor is responsible to the Bridge Design Engineer for the timely completion and quality of the bridge plans.

   b. The Unit Supervisor works closely with the Project Coordinator and the design team (designer, checker, and structural detailer) during the design and plan preparation phases to help avoid major changes late in the design process. Activities during the course of design include:

      (1) Evaluate the complexity of the project and the designer's skill and classification level to deliver the project in a timely manner. Determine both the degree of supervision necessary for the designer and the amount of checking required by the checker.

      (2) Assist the design team in defining the scope of work, identifying the tasks to be accomplished and developing a project work plan.

      (3) Make suitable staffing assignments and develop a design team time estimate to ensure that the project can be completed on time and within budget.

      (4) Review and approve design criteria before start of design.

      (5) Help lead designer conduct face-to-face project meetings, such as: project "kick-off" and "wrap-up" meetings with Region, geotechnical staff, bridge construction, and consultants to resolve outstanding issues.

      (6) Participate in coordinating, scheduling, and communicating with stakeholders, customers, and outside agencies relating to major structural design issues.

      (7) Facilitate resolution of major project design issues.

      (8) Assist the design team with planning, anticipating possible problems, collectively identifying solutions, and facilitating timely delivery of needed information, such as geometrics, hydraulics, foundation information, etc.

      (9) Interact with design team regularly to discuss progress, problems, schedule and budget, analysis techniques, constructability and design issues. Always encourage forward thinking, innovative ideas and suggestions for quality improvement.

      (10) Arrange for and provide the necessary resources, time and tools for the design team to do the job right the first time. Offer assistance to help resolve questions or problems.

      (11) Help document and disseminate information on special features and lessons learned for the benefit of others and future projects.

      (12) Mentor and train designers and detailers through the assignment of a variety of structure types.

c. The Unit Supervisor works closely with the design team during the plan review phase. Review efforts should concentrate on reviewing the completed plan details and design calculations for completeness and for agreement with office criteria and office practices. Review the following periodically and at the end of the project:

   (1) Design Criteria

   - Seismic design methodology, acceleration coefficient ("a" value), and any seismic analysis assumptions.
   - Foundation report recommendations, selection of alternates.
   - Deviations from AASHTO, this manual, and proper consideration of any applicable Design Memorandums.

   (2) Design Time and Budget

d. Estimate time to complete the project. Plan resource allocation for completing the project to meet the scheduled Ad Date and budget. Monitor monthly time spent on the project.

   At the end of each month, estimate time remaining to complete project, percent completed, and whether project is on or behind schedule.

   Plan and assign workforce to ensure a timely delivery of the project within the estimated time and budget. At monthly supervisors' scheduling meetings, notify the Bridge Projects Engineer if a project is behind schedule.

e. Advise Region of any project scope creep and construction cost increases. As a minimum, use quarterly status reports to update Region on project progress.

f. Use appropriate computer scheduling software or other means to monitor time usage, to allocate resources, and to plan projects.

g. Review constructability issues. Are there any problems unique to the project?

h. Review the final plans for the following:

   (1) Scan the job file for unusual items relating to geometrics, hydraulics, geotechnical, environmental, etc.

   (2) Overall review of sheet #1, the bridge layout for:

   - Consistency — especially for multiple bridge project
   - Missing information

   (3) Review footing layout for conformance to Bridge Plan and for adequacy of information given. Generally, the field personnel shall be given enough information to "layout" the footings in the field without referring to any other sheets. Plan details shall be clear, precise, and dimensions tied to base references, such as: a survey line or defined centerline of bridge.

   (4) Review the sequence of the plan sheets. The plan sheets should adhere to the following order: layout, footing layout, substructures, superstructures, miscellaneous details, barriers, and barlist. Also check for appropriateness of the titles.

   (5) Review overall dimensions and elevations, spot check for compatibility. For example, check compatibility between superstructures and substructure. Also spot check bar marks.

   (6) Use common sense and experience to review structural dimensions and reinforcement for structural adequacy. When in doubt, question the designer and checker.

i. Stamp and sign the plans in blue ink.

8. **Bridge Design Engineer's Responsibilities –** The Bridge Design Engineer is the coach, mentor, and facilitator for the WSDOT QC/QA Bridge Design Procedure. The leadership and support provided by this position is a major influence in assuring bridge design quality for structural designs performed by both WSDOT and consultants. The following summarizes the key responsibilities of the Bridge Design Engineer related to QC/QA:

    a. Prior to the Bridge Design Engineer stamping and signing any plans, he/she shall perform a structural/constructability review of the plans. This is a quality assurance (QA) function as well as meeting the "responsible charge" requirements of state laws relating to Professional Engineers.

    b. Review and approve the Preliminary Bridge Plans. The primary focus for this responsibility is to assure that the most cost-effective and appropriate structure type is selected for a particular bridge site.

    c. Review unique project special provisions and Standard Specification modifications relating to structures.

    d. Facilitate partnerships between WSDOT, consultants, and the construction industry stakeholders to facilitate and improve design quality.

    e. Encourage designer creativity and innovation through forward thinking.

    f. Exercise leadership and direction for maintaining a progressive and up to date *Bridge Design Manual* M 23-50.

    g. Create an open and supportive office environment in which Design Section staff are empowered to do high quality structural design work.

    h. Create professional growth opportunities through an office culture where learning is emphasized.

    i. Encourage continuing professional development through training opportunities, attendance at seminars and conferences, formal education opportunities, and technical writing.

9. **General Bridge Plan Stamping and Signature Policy –** The stamping and signing of bridge plans is the final step in the Bridge QC/QA procedure. It signifies a review of the plans and details by those in responsible charge for the bridge plans. At least one Licensed Structural Engineer shall stamp and sign each contract plan sheet (except the bar list).

    For contract plans prepared by a licensed Civil or Licensed Structural Engineer, the Unit Manager and the licensed Civil or Licensed Structural Engineer co-seal and sign the plans, except the bridge layout sheet. The bridge layout sheet is sealed and signed by the State Bridge and Structures Engineer or, in the absence of the State Bridge and Structures Engineer, the Bridge Design Engineer.

    For contract plans not prepared by a licensed Civil or Licensed Structural Engineer, the Unit Manager and the Bridge Design Engineer co-seal and sign the plans except the bridge layout sheet. The bridge layout sheet is sealed and signed by the State Bridge and Structures Engineer or, in the absence of the State Bridge and Structures Engineer, the Bridge Design Engineer.

    For Non-Standard Retaining Walls and Noise Barrier Walls, Sign Structures, Seismic Retrofits, Expansion Joint and Bearing Modifications, Traffic Barrier and Rail Retrofits, and other special projects, the Unit Manager with either the licensed designer or the Bridge Design Engineer (if the designer is not licensed) co-seal and sign the plans except for the layout sheet. The layout sheets for these plans are sealed and signed by the State Bridge and Structures Engineer, or in the absence of the State Bridge and Structures Engineer, the Bridge Design Engineer.

B. **Consultant PS&E — Projects on WSDOT Right of Way –** PS&E prepared by consultants will follow a similar QC/QA procedure as that shown above for WSDOT prepared PS&E's and, as a minimum, shall include the following elements:

1. **WSDOT Consultant Liaison Engineer's Responsibilities**
    a. Review scope of work.
    b. Negotiate contract and consultant's Task Assignments.
    c. Coordinate/Negotiate Changes to Scope of Work.
2. **Bridge Scheduling Engineer Responsibilities**
    a. Add review to the bridge schedule.
    b. Assign review to a bridge unit supervisor.
    c. Make 2 copies of the review plans and specifications – 1 for the design reviewer and 1 for the Specifications Engineer Reviewer
    d. Make a copy of the Layout for the Bridge Inventory Engineer.
3. **WSDOT Design Reviewer's or Coordinator's Responsibilities**
    a. Early in the project, review consultant's design criteria, and standard details for consistency with WSDOT practices and other bridge designs in project.
    b. Review the job file as prepared by the Preliminary Plan Engineer.
    c. Identify resources needed to complete work.
    d. Initiate a project start-up meeting with the Consultant to discuss design criteria, submittal schedule and expectations, and also to familiarize himself/herself with the Consultant's designers.
    e. Reach agreement early in the design process regarding structural concepts and design methods to be used.
    f. Identify who is responsible for what and when all intermediate constructability, Bridge Plans, and Bridge PS&E review submittals are to be made.
    g. Monitor progress.
    h. Facilitate communication, including face-to-face meetings.
    i. Verify that the Consultant's design has been checked by the Consultant's checker at the 100% submittal. The checker's calculations should be included in the designer's calculation set.
    j. Review 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. Also, selectively check dimensions and elevations.
    k. Resolve differences.
4. **WSDOT Design Unit Supervisor's Responsibilities**
    a. Encourage and facilitate communication.
    b. Early involvement to assure that design concepts are appropriate.
    c. Empower Design Reviewer or Coordinator.
    d. Facilitate resolution of issues beyond authority of WSDOT Reviewer or Coordinator.
    e. Facilitate face-to-face meetings.

5. **WSDOT S&E Engineer's Responsibilities –** See Section 12.4.8.
6. **WSDOT Bridge Design Engineer's Responsibilities**
   a. Cursory review of design plans.
   b. Signature approval of S&E bridge contract package.

C. **Consultant PS&E** — Projects on County and City Right of Way

Counties and cities frequently hire Consultants to design bridges. WSDOT Highways and Local Programs Office determine which projects are to be reviewed by the Bridge and Structures Office.

WSDOT Highways and Local Programs send the PS&E to the Bridge Projects Engineer for assignment when a review is required. The Bridge and Structures Office's Consultant Liaison Engineer is not involved.

A WSDOT Design Reviewer or Coordinator will be assigned to the project and will review the project as outlined for Consultant PS&E — Projects on WSDOT Right of Way (see Section 1.3.2.B).

Two sets of plans with the reviewers' comments marked in red should be returned to the Bridge Projects Unit. One set of plans will be returned to Highways and Local Programs. The Bridge Scheduling Engineer will file the other set in the Bridge Projects Unit.

The first review should be made of the Preliminary Plan followed later by review of the PS&E and design calculations. Comments are treated as advisory, although major structural issues must be addressed and corrected. An engineer from the county, city, or consultant may contact the reviewer to discuss the comments.

1.3.3 Design/Check Calculation File

A. **File of Calculations –** The Bridge and Structures Office maintains a file of all pertinent design/check calculations for documentation and future reference. (See Section 1.3.8 Archiving Design Calculations, Design Files, and S&E Files).

B. **Procedures –** After an assigned project is completed and the bridge is built, the designer shall turn in a bound file containing the design/check calculations for archiving. The front cover should have a label (See Figure 1.3.8-1).

C. **File Inclusions –** The following items should be included in the file:

1. **Index Sheets –** Number all calculation sheets and prepare an index by subject with the corresponding sheet numbers.

   List the name of the project, SR Number, designer/checker initials, date (month, day, and year), and Unit Supervisor's initials.

2. **Design Calculations –** The design calculations should include design criteria, design assumptions, loadings, structural analysis, one set of moment and shear diagrams and pertinent computer input and output data (reduced to 8½″ by 11″ sheet size).

   The design criteria, design assumptions, and special design features should follow in that order behind the index.

   Computer-generated design calculations may be used instead of longhand calculations. The calculation sheets shall be formatted similar to WSDOT standard calculation sheets (WSDOT Form 232-007) for longhand designs. The header for electronic calculation sheets shall carry WSDOT logo along with project name, S.R. number, designer and checker's name, date, supervising engineer, and sheet numbers.

   All computer-generated or longhand design calculations shall be initialed by the designer and checker. Checker's initial may not be necessary if separate check calculations are provided.

Output from commercial software shall be integrated into design calculations with a cover sheet that includes the WSDOT logo along with project name, S.R. number, designer and checker's name, date, supervising engineer, and sheet numbers.

Consultant submitted design calculations shall comply with the above requirements.

Design calculations prepared by the Bridge Design Office or Consultants need not be sealed and signed. Design calculations are considered part of the process that develops contract plans which are the final documents.

See Appendix 1.5-A4-1 for examples of Excel template for computer-generated design calculations. Code and other references used in developing calculations shall be specified. In general, when using Excel spreadsheet, enough information and equations shall be provided/ shown in the spreadsheet so that an independent checker can follow the calculations.

3. **Special Design Features –** Brief narrative of major design decisions or revisions and the reasons for them.
4. **Construction Problems or Revisions –** Not all construction problems can be anticipated during the design of the structure; therefore, construction problems arise during construction, which will require revisions. Calculations for revisions made during construction should be included in the design/check calculation file when construction is completed.

D. **File Exclusions –** The following items should not be included in the file:

1. Geometric calculations.
2. Irrelevant computer information.
3. Prints of Office Standard Sheets.
4. Irrelevant sketches.
5. Voided sheets.
6. Preliminary design calculations and drawings unless used in the final design.
7. Test hole logs.
8. Quantity calculations.

1.3.4 PS&E Review Period

See Section 12.4.10 for PS&E Review Period and Turn-in for AD Copy activities.

1.3.5 Addenda

Plan or specification revisions during the advertising period require an addendum. The Specifications and Estimate Engineer will evaluate the need for the addendum after consultation with the HQ Construction — Bridge, Region, and the HQ or Region Plans Branch. The Bridge Design Engineer or the Unit Supervisor must initial all addenda.

For addenda to contract plans, obtain the original drawing from the Bridge Projects Unit. Use shading to mark all changes (except deletions) and place a revision note at the bottom of the sheet (Region and HQ Plans Branch jointly determine addendum date) and a description of the change. Return the 11″ by 17″ signed original and copy to the Specifications and Estimate Engineer who will submit the copy to the HQ Plans Branch for processing. See Chapter 12 for additional information.

For changes to specifications, submit a copy of the page with the change to the Specifications and Estimate Engineer for processing.

1.3.6 Shop Plans and Permanent Structure Construction Procedures

This section pertains to fabrication shop plans, weld procedures, electrical and mechanical items, geotechnical procedures, such as: drilled shafts and tieback walls, and other miscellaneous items related to permanent construction.

The following is a guide for checking shop plans and permanent structure construction procedures.

A. **Bridge Shop Plans and Procedures**

1. Mark one copy of each sheet with the following, near the title block, in red pen or with a rubber stamp:

   Office Copy
   Contract (number)
   (Checker's initials) (Date)
   Approval Status (A, AAN, RFC or Structurally Acceptable)

2. On the Bridge Office copy, mark with red pen any errors or corrections. Yellow shall be used for highlighting the checked items. The red pen marks will be copied onto the other copies and returned to the Region Project Engineer. Comments made with red pen, especially for 8½″ by 11″ or 11″ by 17″ size sheets, shall be clear, neat, and conducive to being reproduced by Xerox. These comments should be "bubbled" so they stand out on a black and white Xerox copy. Use of large sheets should be discouraged because these require extra staff assistance and time to make these copies by hand.

3. Items to be checked are typically as follows: Check against Contract Plans and Addenda, Special Provisions, Previously Approved Changes and Standard Specifications.

   a. Material specifications (ASTM specifications, hardness, alloy and temper, etc.).

   b. Size of member and fasteners.

   c. Length dimensions, if shown on the Contract Plans.

   d. Finish (surface finish, galvanizing, anodizing, painting, etc.).

   e. Weld size and type and welding procedure if required.

   f. Strand or rebar placement, jacking procedure, stress calculations, elongations, etc.

   g. Fabrication — reaming, drilling, and assembly procedures.

   h. Adequacy of details.

   i. Erection procedures.

   For prestressed girders and post-tensioning shop plan review see Sections 5.6.3A and 5.8.6C respectively.

4. Items Not Requiring Check

   a. Quantities in bill of materials.

   b. Length dimensions not shown on Contract Plans except for spot checking and is emphasized by stamping the plans: *Geometry Not Reviewed by the Bridge and Structures Office.*

5. Project Engineer's Copy

   Do not use the Project Engineer's copy (comments or corrections are in green) as the office copy. Transfer the Project Engineer's corrections, if pertinent, to the office copy using red pen. The Project Engineer's comments may also be received by e-mail.

6. Marking Copies

   When finished, mark the office copy with one of five categories in red pen, lower right corner.

   a. "A"

      Approved, No Corrections required.

   b. "AAN"

      Approved As Noted — minor corrections only. Do not place written questions on an approved as noted sheet.

   c. "RFC"

      Returned for Correction — major corrections are required which requires a complete resubmittal.

   d. "Structurally Acceptable"

      This is appropriate for items that are not required to be "Approved" per the contract, such as: work platforms, submittals from various local agencies or developers, and other items that are reviewed as a courtesy.

   e. "Structurally Acceptable But Does Not Conform to the Contract Requirements"

      This is appropriate when a deviation from the contract is found but is determined to be structurally acceptable.

   If in doubt between AAN and RFC, check with the Unit Supervisor or Construction Support Engineer. An acceptable detail may be shown in red. Mark the plans *Approved As Noted* provided that the detail is clearly noted *Suggested Correction — Otherwise Revise and Resubmit*.

   Do not mark the other copies. The Construction Support Unit will do this.

   Notify the Construction Support Engineer if there are any structurally acceptable deviations to the contract plans. The Construction Support Engineer will notify both the Region Project Engineer and HQ Construction-Bridge, who may have to approve a change order and provide justification for the change order.

   Notify the Unit Supervisor and the Construction Support Engineer if problems are encountered which may cause a delay in the checking of the shop plans or completion of the contract. Typically, WSDOT administered contracts require reviews to be completed within 30 days. The review time starts when the Project Engineer first receives the submittal from the Contractor and ends when the Contractor has received the submittal back from the Project Engineer. The Bridge Office does not have the entire 30-day review period to complete the review. Therefore, designers should give construction reviews high priority and complete reviews in a timely manner so costly construction delays are avoided. Time is also required for marking, mailing and other processing. It is the goal of the Bridge and Structures Office to return reviewed submittals back to the Project Engineer within 7 to 14 days of their receipt by the Bridge Construction Support Unit.

   Return all shop drawings and Contract Plans to the Construction Support Unit when checking is completed. Include a list of any deviations from the Contract Plans that are allowed and a list of any disagreements with the Project Engineer's comments (regardless of how minor they may be).

   If deviations from the Contract Plans are to be allowed, a Change Order may be required. Alert the Construction Support Unit so that their transmittal letter may inform the Region and the HQ Construction - Bridge.

   Under no circumstances should the reviewer mark on the shop plans that a change order is required or notify the Project Engineer that a change order is required. The authority for determining whether a change order is required rests with HQ Construction - Bridge.

B. **Sign Structure, Signal, and Illumination Shop Plans –** In addition to the instructions described under Section 1.3.6A Bridge Shop Plans and Procedures, the following instructions apply:

1. Review the shop plans to ensure that the pole sizes conform to the Contract Plans. Determine if the fabricator has supplied plans for each pole or type of pole called for in the contract.
2. The Project Engineer's copy may show shaft lengths where not shown on Contract Plans or whether a change from Contract Plans is required. Manufacturer's details may vary slightly from contract plan requirements, but must be structurally adequate to be acceptable.

C. **Geotechnical Submittals –** The Bridge Office and the Geotechnical Services Branch concurrently review these submittals which may include special design proprietary retaining walls, drilled shafts, ground anchors, and soldier piles. HQ Construction Office - Bridge is included for the review of drill shaft installation plans. The Construction Support Unit combines these comments and prepares a unified reply that is returned to the Project Engineer

1.3.7 Contract Plan Changes (Change Orders and As-Builts)

A. **Request for Changes –** The following is intended as a guide for processing changes to the design plans after a project has been awarded.

For projects which have been assigned a Bridge Technical Advisor (BTA), structural design change orders can be approved at the Project Engineer's level provided the instructions outlined in the *Construction Manual* M 41-01 are followed.

For all other projects, all changes are to be forwarded through the Construction Support Unit, which will inform the HQ Construction Engineer - Bridge. Responses to inquiries should be handled as follows:

1. **Request by Contractor or Supplier –** A designer, BTA, or Unit Supervisor contacted directly by a contractor/supplier may discuss a proposed change with the contractor/supplier, but shall clearly tell the contractor/supplier to formally submit the proposed change though the Project Engineer and that the discussion in no way implies approval of the proposed change. Designers are to inform their Unit Supervisor if they are contacted.
2. **Request From the Region Project Engineer –** Requests for changes directly from the Project Engineer to designer or the Unit Supervisor should be discouraged. The Project Engineer should contact HQ Construction - Bridge, who in turn will contact the designer or Unit Supervisor if clarification is needed regarding changes. The Construction Support Unit should be informed of any changes.
3. **Request From the Region Construction Engineer –** Requests from the Region Construction Engineer are to be handled like requests from the Region Project Engineer.
4. **Request From the HQ Construction - Bridge –** Requests for changes from HQ Construction - Bridge are usually made through the Construction Support Unit and not directly to the Design Unit. However, sometimes, it is necessary to work directly with the Design Unit. The Construction Support Unit should be informed of any decisions made involving changes to the Contract Plans.
5. **Request From the Design Unit –** Request for changes from the Design Unit due to plan errors or omissions shall be discussed with the Bridge Design Engineer prior to revising and issuing new plan sheets.

B. **Processing Contract Revisions –** Changes to the Contract Plans or Specifications subsequent to the award of the contract may require a contract plan revision. Revised or additional plan sheets, which clearly identify the change on the plans, may be needed. When a revision or an additional drawing is necessary, request the original plan sheets from the Construction Support Unit's Bridge Plans Engineer and prepare revised or new original plan sheets.

Sign, date, and send the new plan sheets to the Bridge Plans Engineer. Send two paper copies to HQ Construction-Bridge. The Construction Support Unit requires one paper copy. The Design Unit requires one or more paper copies. One paper print, stamped *"As Constructed Plans"*, shall be sent to the Project Engineer, who shall use it to mark construction changes and forward them as *"As-Built Plans"* to the Bridge Plans Engineer upon project completion. The Designer is responsible for making the prints and distributing them.

This process applies to all contracts including HQ Ad and Award, Region Ad and Award, or Local Agency Ad and Award.

Whenever new plan sheets are required as part of a contract revision, the information in the title blocks of these sheets must be identical to the title blocks of the contract they are for (e.g., Job Number, Contract No., Fed. Aid Proj. No., Approved by, and the Project Name). These title blocks shall also be initialed by the Bridge Design Engineer, Unit Supervisor, designer, and reviewer before they are distributed. If the changes are modifications made to an existing sheet, the sheet number will remain the same. A new sheet shall be assigned the same number as the one in the originals that it most closely resembles and shall be given a letter after the number (e.g., if the new sheet applies to the original sheet 25 of 53, then it will have number 25A of 53). The Bridge Plans Engineer in the Construction Support Unit shall store the 11″ by 17″ original revision sheets.

Every revision will be assigned a number, which shall be enclosed inside a triangle. The assigned number shall be located both at the location of the change on the sheet and in the revision block of the plan sheet along with an explanation of the change.

Any revised sheets shall be sent to HQ Construction-Bridge with a written explanation describing the changes to the contract, justification for the changes, and a list of material quantity additions or deletions.

C. **As-Built Plan Process –** For more information on the as-built plan process for bridges, see the *As-Built Plans Manual*, prepared by the Bridge and Structures Office, dated August 2003. Copies are available from the Bridge Plans Engineer.

1.3.8 Archiving Design Calculations, Design Files, and S&E Files

A. **Upon Award –** The Bridge Plans Engineer will collect the Design File (Job File), S&E File and Design Calculations. Files will be placed in a temporary storage space marked as "Design Unit Document Temporary Storage". These cabinets will be locked, and only the Bridge Plans Engineer, the Scheduling Engineer, and the Office Administrator will have keys to them. The Design Files, S&E Files, and Design Calculations are stored under the contract number.

A Bridge and Structures staff member may access the Design Files, S&E Files, or Design Calculations by requesting the files from the Bridge Plans Engineer or the Scheduling Engineer, who will check out the files and note the date and person's name. If a person other than a Bridge and Structures Office staff member requests these documents, the approval of the Bridge Design Engineer or Bridge Projects Engineer will be required for release of the documents.

B. **Upon Contract Completion –** The designer will place a job file cover label on the file folder (see Figure 1-3.8-1) and update the file with any contract plan changes that have occurred during construction.

Two years after physical completion of the contract, the Bridge Plans Engineer will box and send the documents to the Office of Secretary of State for archive storage, except as otherwise approved by the Bridge Design Engineer.

The Bridge Plans Engineer will maintain a record of the documents location and archive status.

SR # ____________ County ________________ CS # ____________

Bridge Name ____

Bridge # ____________________ Contract # ____________________

Contents ____

Designed by ___________________ Checked by __________________

Archive Box # ____________________ Vol. #____________________

Cover Label

Figure 1.3.8-1

1.3.9 Public Disclosure Policy Regarding Bridge Plans

The Bridge Management Engineer is the Bridge and Structures Office's official Public Disclosure contact and shall be contacted for clarification and/or direction.

Executive Order, E1023.0 *Public Disclosure*, which replaced Directive D 72-21 *Release of Public Records*, provides a specific procedure to follow when there is a request for public records. (See wwwi.wsdot.wa.gov/Publications/Policies/default.htm.)

The Bridge and Structures Office is the "owner" of only two types of "official" records: (1) Design Calculations (until they are turned over to the State Archives Office) and (2) Bridge Inspection Documents.

No records will be disclosed without a written request. This request is to be specific.

As-built plans available on the Bridge and Structures website are not "official" as-built plans. The Regions are the owners of the "official" as-built plans and the procedure for providing requested copies of these plans is similar to the procedure outlined above with the following modifications:

- If you receive a written or verbal request for a set of plans from a person indirectly working for WSDOT (i.e. contractor, consultant), advise them to contact and request the plans from the WSDOT Project Engineer.
- If the request comes from a person directly working on a Bridge Office project as an on-call consultant, have them contact and request the plans from the Bridge and Structures Office's Consultant Liaison Engineer.
- If the request comes from a person not working for WSDOT, they must submit their written request to the person and address noted below and it will be forwarded to the appropriate Region to provide the requested documents.

  Written requests must be sent to:

  Records and Information Service Office
  Washington State Department of Transportation
  310 Maple Park Avenue
  P. O. Box 47410
  Olympia, WA 98504-7410
  Attn: Ms. Cathy Downs

1.3.10 Use of Computer Software

A. **Protection of Intellectual Property –** Many of the software tools used by the Bridge and Structures Office are licensed from commercial software vendors. WSDOT is committed to using these tools only as allowed by law and as permitted by software license. WSDOT employees shall comply with the terms and conditions of all licensing agreements and provisions of the Copyright Act and other applicable laws.

Before using any software tools WSDOT employees shall read and understand Instructional Letter 4032.00 *Computer Software Piracy Prevention, and the Protection of Intellectual Property*.[1]

B. **Policy on Open Source Software –** It is the policy of the Bridge and Structures Office to license its own engineering software as open source, and to prefer and promote the use of open source software, within the bridge engineering community.

To support this policy on open source bridge engineering software, the Bridge and Structures Office is a founding and participating member of the Alternate Route Project. The purpose of the Alternate Route Project is to serve as a focal point for the collaborative and cooperative development of open source bridge engineering software tools.

C. **Approved Software Tools –** A list of approved software tools available for use by WSDOT bridge design engineers is available at wwwi.wsdot.wa.gov/eesc/bridge/software. Note that this list is only available on the WSDOT intranet. WSDOT does not require consulting engineers to use any specific software tools, so long as the use of the tools are in accordance with sound engineering practice, and does not violate software licensing agreements and Copyright law.

When using personal design tools created by others, such as a spreadsheet or MathCAD document, the designer is responsible for thoroughly checking the tool to ensure the integrity of the structural analysis and design.

PROJECT TURN-IN QA/QC WORKSHEET (per BDM Chapter 1.3)

Project Name:

Charge Number:
Design Lead:
Date:

		CHECKLIST (Initials required under respective title)										
		Names Listed				SPECIALIST APPROVAL						
Design Item	Name	DESIGNER	CHECKER	DETAILER	SPECIFICATION WRITER	ARCHITECT	BEARING AND EXPANSION JOINT	CONCRETE	STEEL	SEISMIC	JOB FILE COMPLETE	CALCULATIONS BOUND*

Bridge Design Engineer Check at 90%: ______________ Date:

Supervisor Plan Review: ______________ Date:

NOTES:

* Only Bridges are archived. Sign Structures and Walls are kept on file in the office by designer of record.

Required Actions for each Design Item:

1) Elevations and Dimensions
2) Quantities and Barlist
3) Detailing Sheet Consistency
4) Detailing Plan Consistency
5) Detailing Office Practices
6) Specification Review
7) 100% region Comments Incorporated

4.1 General

Seismic design of new bridges and bridge widenings shall conform to *AASHTO Guide Specifications for LRFD Seismic Bridge Design* as modified by Sections 4.2 and 4.3. Analysis and design of seismic retrofits for existing bridges shall be completed in accordance with Section 4.4. Seismic design of retaining walls shall be in accordance with Section 4.5. For nonconventional bridges, bridges that are deemed critical or essential, or bridges that fall outside the scope of the Guide Specifications for any other reasons, project specific design requirements shall be developed and submitted to the WSDOT Bridge Design Engineer for approval.

The importance classifications for all highway bridges in Washington State are classified as "Normal" except for special major bridges. Special major bridges fitting the classifications of either "Critical" or "Essential" will be so designated by either the WSDOT Bridge and Structures Engineer or the WSDOT Bridge Design Engineer. The performance object for "normal" bridges is life safety. Bridges designed in accordance with AASHTO Guide Specifications are intended to achieve the life safety performance goals.

4.2 WSDOT Modifications to *AASHTO Guide Specifications for LRFD Seismic Bridge Design*

WSDOT amendments to the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* are as follows:

4.2.1 Definitions

Guide Specifications Article 2.1 – Add the following definitions:

- **Oversized Pile Shaft –** A drilled shaft foundation that is larger in diameter than the supported column and has a reinforcing cage larger than and independent of the columns. The size of the shaft shall be in accordance with Section 7.8.2.
- **Owner –** Person or agency having jurisdiction over the bridge. For WSDOT projects, regardless of delivery method, the term "Owner" in these Guide Specifications shall be the WSDOT Bridge Design Engineer or/and the WSDOT Geotechnical Engineer.

4.2.2 Earthquake Resisting Systems (ERS) Requirements for SDCs C and D

Guide Specifications Article 3.3 – WSDOT Global Seismic Design Strategies:

- **Type 1** – Ductile Substructure with Essentially Elastic Superstructure. This category is permissible.
- **Type 2** – Essentially Elastic Substructure with a Ductile Superstructure. This category is not permissible.
- **Type 3** – Elastic Superstructure and Substructure With a Fusing Mechanism Between the Two. This category is permissible with WSDOT Bridge Design Engineer's approval.

Type 3 ERS may be considered only if Type 1 strategy is not suitable and Type 3 strategy has been deemed necessary for accommodating seismic loads. Isolation bearings shall be designed per the requirement of the *AASHTO Guide Specifications for Seismic Isolation*. Use of isolation bearings needs the approval of WSDOT Bridge Design Engineer.

The decision for using isolation bearings should be made at the early stage of project development based on the complexity of bridge geotechnical and structural design. A cost-benefit analysis comparing Type 1 design vs. Type 3 design with isolation bearings shall be performed and submitted for approval. The designer needs to perform two separate designs, one with and one without seismic isolation bearings. The cost-benefit analysis shall at least include:

- Higher initial design time and complexity of analysis.
- Impact of the initial and final design time on the project delivery schedule.
- Time required for preliminary investigation and correspondences with the isolation bearings suppliers.
- Life-cycle cost of additional and specialized bearing inspections.
- Potential cost impact for bearings and expansion joints replacements.

- Issues related to long-term performance and maintenance.
- Need for large movement expansion joints.

Seismic isolation bearings shall not be used between the top of the column and the bottom of the crossbeam in single or multi-column bents.

Once approval has been given for the use of seismic isolation bearing, the designer shall send a set of preliminary design and specification requirements to at least three seismic isolation bearing suppliers for evaluation to ensure that they can meet the design and specification requirements. Comments from isolation bearing suppliers should be incorporated before design of structure begins. Sole source isolation bearing supplier may be considered upon Bridge Design Office, and Project Engineer's office approval.

The designer shall submit to the isolation bearing suppliers maintenance and inspection requirements with design calculations. Isolation bearing suppliers shall provide maintenance and inspection requirements to ensure the isolators will function properly during the design life and after seismic events. The contract plans shall include bearing replacement methods and details.

Use of seismic isolation bearings are not recommended for conventional short and medium length bridges or bridges with geometrical complexities. Use of isolation bearings may not be beneficial for concrete bridges under 700 ft long, steel bridges under 800 ft long, bridges with skew angles exceeding 30 degrees, bridges with geometrical complexities, variable superstructure width, and bridges with drop-in spans.

The response modification factors (R-factors) of the *AASHTO Guide Specifications for Seismic Isolation Design* Article 6 shall not be used for structures if the provisions of *AASHTO Guide Specifications for LRFD Seismic Bridge Design* are being followed for the design of the bridge.

Suitability of isolation bearings for bridge projects should be carefully studied prior to approval. Isolation bearings may not be the effective solution for some bridges and sites since shifting the period to longer period may not reduce the force demand for the soft soils. Design shall consider the near fault effects and soil structure interaction of soft soil sites. The designer shall carefully study the effect of isolation bearings on the longitudinal bridge movement. The need for large movement expansion joints shall be investigated. Inspection, maintenance, and potential future bearing replacement should be considered when using the isolation bearings.

In order to have isolators fully effective, sufficient gap shall be provided to eliminate pounding between frames. Recommended bridge length and skew limitation are set to avoid using the modular joints. Most modular joints are not designed for seismic. Bridges are designed for extreme event which may or may not happen in the life span of the bridge. Introducing the modular joints to the bridge system could cause excessive maintenance issues. In estimation of life-cycle cost, specialized bearing inspections, potential cost impact for bearings, and expansion joints replacements the isolation bearing suppliers should be consulted.

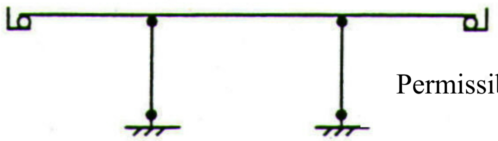
If the columns or pier walls are designed for elastic forces, all other elements shall be designed for the lesser of the forces resulting from the overstrength plastic hinging moment capacity of columns or pier walls and the unreduced elastic seismic force in all SDCs. The minimum detailing according to the bridge seismic design category shall be provided. Shear design shall be based on 1.2 times elastic shear force and nominal material strengths shall be used for capacities. Limitations on the use of ERS and ERE are shown in Figures 3.3-1a, 3.3-1b, 3.3-2, and 3.3-3.

- Figure 3.3-1b Type 6, connection with moment reducing detail should only be used at column base if proved necessary for foundation design. Fixed connection at base of column remains the preferred option for WSDOT bridges.
- The design criteria for column base with moment reducing detail shall consider all applicable loads at service, strength, and extreme event limit states.
- Figure 3.3-2 Types 6 and 8 are not permissible for non-liquefied configuration and permissible with WSDOT Bridge Design Engineer's approval for liquefied configuration

For ERSs and EREs requiring approval, the WSDOT Bridge Design Engineer's approval is required regardless of contracting method (i.e., approval authority is not transferred to other entities).

1

Longitudinal Response

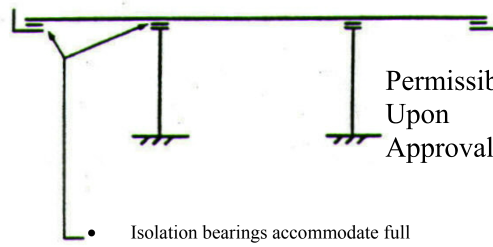


Permissible

- Plastic hinges in inspectable locations.
- Abutment resistance not required as part of ERS
- Knock-off backwalls permissible

2

Longitudinal Response

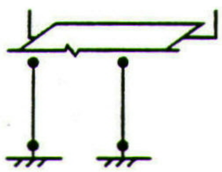


Permissible Upon Approval

- Isolation bearings accommodate full displacement
- Abutment not required as part of ERS

3

Transverse Response

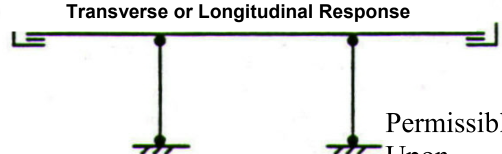


Permissible

- Plastic hinges in inspectable locations.
- Abutment not required in ERS, breakaway shear keys permissible with WSDOT Bridge Design Engineer's Approval

4

Transverse or Longitudinal Response

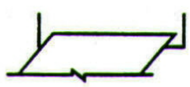


Permissible Upon Approval

- Plastic hinges in inspectable locations
- Isolation bearings with or without energy dissipaters to limit overall displacements

5

Transverse or Longitudinal Response

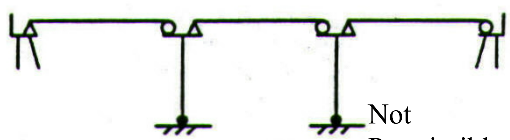


Permissible Upon Approval

- Abutment required to resist the design earthquake elastically
- Longitudinal passive soil pressure shall be less than 0.70 of the value obtained using the procedure given in Article 5.2.3

6

Longitudinal Response



Not Permissible

- Multiple simply-supported spans with adequate support lengths
- Plastic hinges in inspectable locations.

Figure 3.3-1a Permissible Earthquake-Resisting Systems (ERSs)
BDM Figure 4.2.2-1

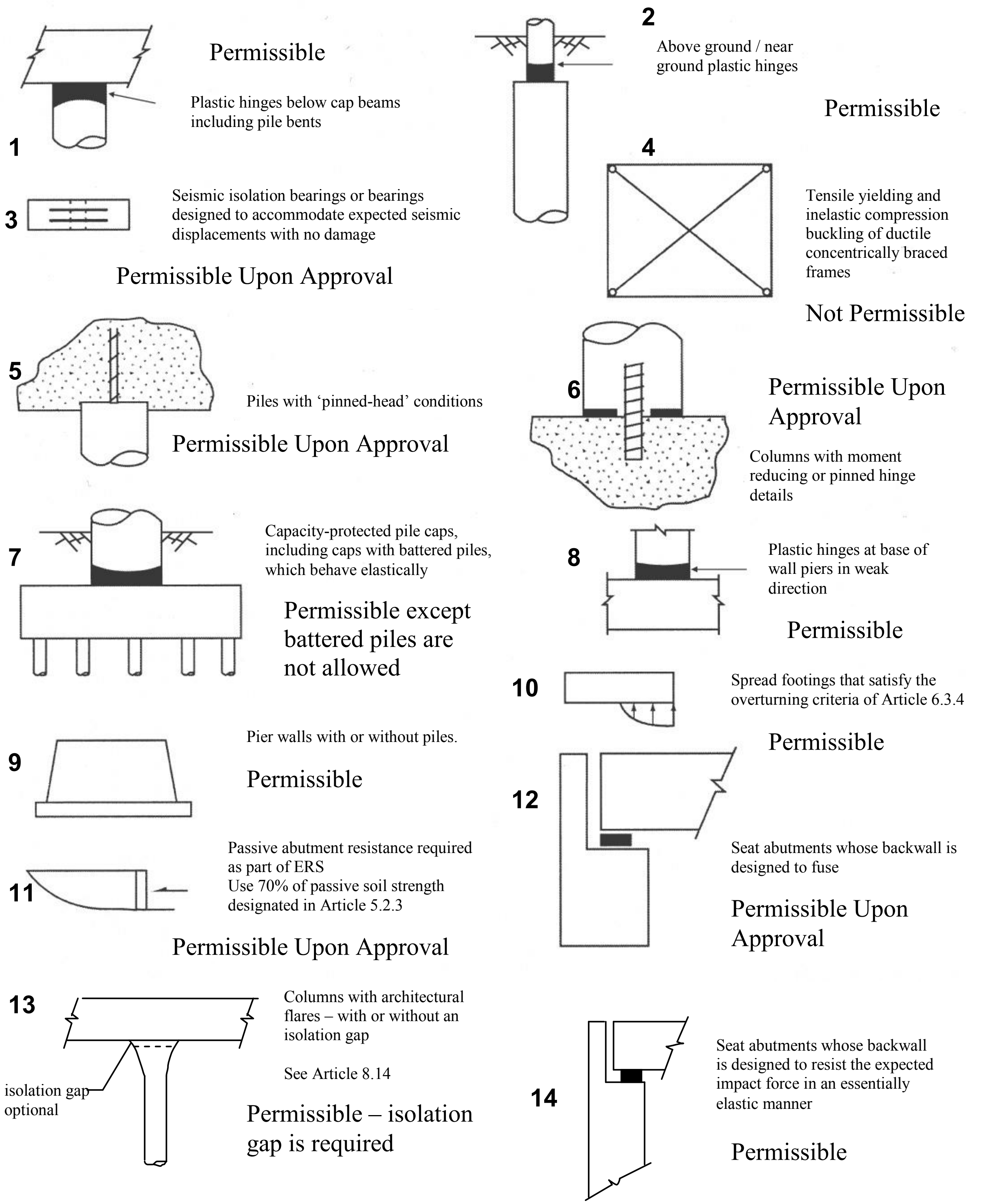


Figure 3.3-1b Permissible Earthquake-Resisting Elements (EREs)
BDM Figure 4.2.2-2

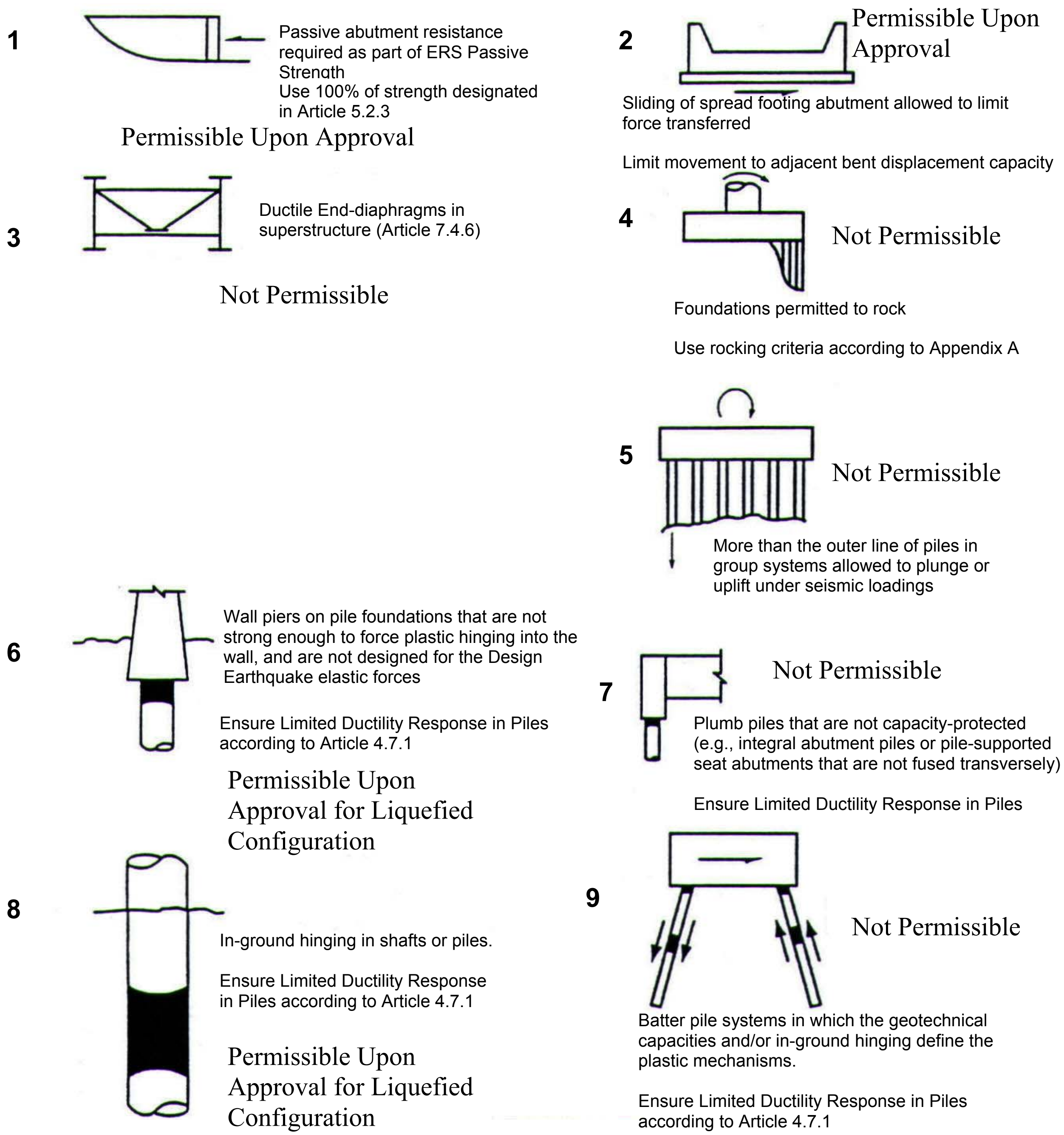


Figure 3.3-2 Permissible Earthquake-Resisting Elements That Require Owner's Approval
BDM Figure 4.2.2-3

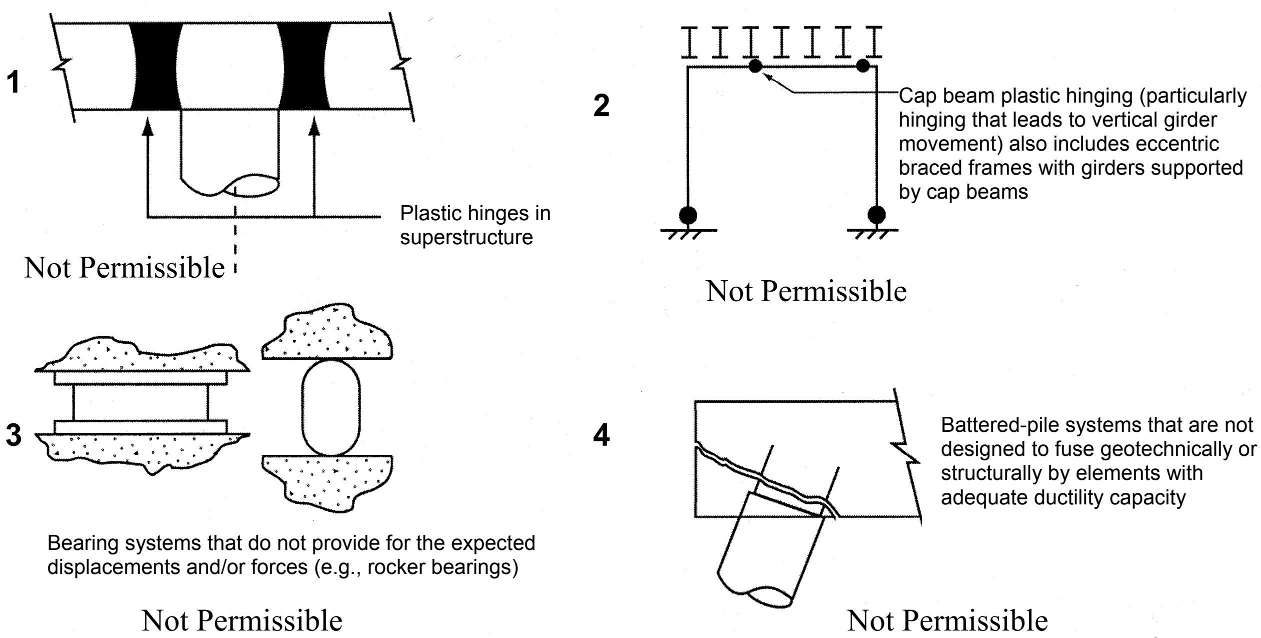


Figure 3.3-3 Earthquake-Resisting Elements that Are Not Recommended for New Bridges
BDM Figure 4.2.2-4

4.2.3 Seismic Ground Shaking Hazard

Guide Specifications Article 3.4 – For bridges that are considered critical or essential or normal bridges with a site Class F, the seismic ground shaking hazard shall be determined based on the WSDOT Geotechnical Engineer recommendations.

4.2.4 Selection of Seismic Design Category (SDC)

Guide Specifications Article 3.5 – Pushover analysis shall be used to determine displacement capacity for both SDCs C and D.

4.2.5 Temporary and Staged Construction

Guide Specifications Article 3.6 – For bridges that are designed for a reduced seismic demand, the contract plans shall either include a statement that clearly indicates that the bridge was designed as temporary using a reduced seismic demand or show the Acceleration Response Spectrum (ARS) used for design.

4.2.6 Load and Resistance Factors

Guide Specifications Article 3.7 – Revise as follows:

Use load factors of 1.0 for all permanent loads. The load factor for live load shall be 0.0 when pushover analysis is used to determine the displacement capacity. Use live load factor of 0.5 for all other extreme event cases. Unless otherwise noted, all ϕ factors shall be taken as 1.0.

4.2.7 Balanced Stiffness Requirements and Balanced Frame Geometry Recommendation

Guide Specifications Articles 4.1.2 and 4.1.3 – Balanced stiffness and balanced frame geometry are required for bridges in both SDCs C and D. Deviations from balanced stiffness and balanced frame geometry requirements require approval from the WSDOT Bridge Design Engineer.

4.2.8 Selection of Analysis Procedure to Determine Seismic Demand

Guide Specifications Article 4.2 – Analysis Procedures:

- Procedure 1 (Equivalent Static Analysis) shall not be used.
- Procedure 2 (Elastic Dynamic Analysis) shall be used for all "regular" bridges with two through six spans and "not regular" bridges with two or more spans in SDCs B, C, or D.
- Procedure 3 (Nonlinear Time History) shall only be used with WSDOT Bridge Design Engineer's approval.

4.2.9 Member Ductility Requirement for SDCs C and D

Guide Specifications Article 4.9 – In-ground hinging for drilled shaft and pile foundations may be considered for the liquefied configuration with WSDOT Bridge Design Engineer approval.

4.2.10 Longitudinal Restrainers

Guide Specifications Article 4.13.1 – Longitudinal restrainers shall be provided at the expansion joints between superstructure segments. Restrainers shall be designed in accordance with the FHWA *Seismic Retrofitting Manual for Highway Structure* (FHWA-HRT-06-032) Article 8.4 The Iterative Method. See the earthquake restrainer design example in the Appendix of this chapter. Restrainers shall be detailed in accordance with the requirements of Guide Specifications Article 4.13.3 and Section 4.4.5. Restrainers may be omitted for SDCs C and D where the available seat width exceeds the calculated support length specified in Equation C4.13.1-1.

Omitting restrainers for liquefiable sites shall be approved by the WSDOT Bridge Design Engineer.

Longitudinal restrainers shall not be used at the end piers (abutments).

4.2.11 Abutments

Guide Specifications Article 5.2 – Diaphragm Abutment type shown in Figure 5.2.3.2-1 shall not be used for WSDOT bridges.

With WSDOT Bridge Design Engineer's approval, the abutment may be considered and designed as part of earthquake resisting system (ERS) in the longitudinal direction of a straight bridge with little or no skew and with a continuous deck. For determining seismic demand, longitudinal passive soil pressure shall not exceed 50 percent of the value obtained using the procedure given in Article 5.2.3.3.

Participation of the wingwall in the transverse direction shall not be considered in the seismic design of bridges.

4.2.12 Foundation – General

Guide Specifications Article 5.3.1 – The required foundation modeling method (FMM) and the requirements for estimation of foundation springs for spread footings, pile foundations, and drilled shafts shall be based on the WSDOT Geotechnical Engineer's recommendations.

4.2.13 Foundation – Spread Footing

Guide Specifications Article C5.3.2 – Foundation springs for spread footings shall be determined in accordance with Section 7.2.7, WSDOT *Geotechnical Design Manual* Section 6.5.1.1 and the WSDOT Geotechnical Engineer's recommendations.

4.2.14 Procedure 3: Nonlinear Time History Method

Guide Specifications Article 5.4.4 – The time histories of input acceleration used to describe the earthquake loads shall be selected in consultation with the WSDOT Geotechnical Engineer and the WSDOT Bridge Design Engineer.

4.2.15 I_{eff} for Box Girder Superstructure

Guide Specifications Article 5.6.3 – Gross moment of inertia shall be used for box girder superstructure modeling.

4.2.16 Foundation Rocking

Guide Specifications Article 6.3.9 – Foundation rocking shall not be used for the design of WSDOT bridges.

4.2.17 Drilled Shafts

Guide Specifications Article C6.5 – It is cautioned that the scaling factor for diameter effects should not be used blindly without a sound mechanistic basis. A significant amount of pile load test data have been accumulated within the offshore industry on large diameter driven steel pipe piles including tests on 5 ft (1.5 m) piles. The diameter effects for offshore piles have either been concluded not valid or considered insignificant within the offshore industry. Juirnarongrit and Ashford (2005) performed vibration tests and lateral load tests on drilled shafts ranging from 16 in (0.4 m) to 4 ft (1.2 m) installed in dense weakly cemented sand. Data from the tests for each shaft diameter were used to back-calculate p-y curves. Their analyses indicate that the shaft diameter has insignificant effect on the p-y curves at the displacement level below the ultimate soil resistance. Beyond this range, the ultimate soil resistance increased as the shaft diameter increased. It is found that the pile diameter effect depend on the pile head moment-to-shear ratio and the distribution of soil modulus with depth (Pender, 2004). For WSDOT bridges, the scale factor for p-y curves for large diameter shafts shall not be used unless approved by the WSDOT Geotechnical Engineer and WSDOT Bridge Design Engineer.

4.2.18 Longitudinal Direction Requirements

Guide Specifications Article 6.7.1 – Case 2: Earthquake Resisting System (ERS) with abutment contribution may be used provided that the mobilized longitudinal passive pressure is not greater than 50 percent of the value obtained using procedure given in Article 5.2.3.3.

4.2.19 Liquefaction Design Requirements

Guide Specifications Article 6.8 – Soil liquefaction assessment shall be based on the WSDOT Geotechnical Engineer's recommendation and WSDOT *Geotechnical Design Manual* Section 6.4.2.8.

4.2.20 Reinforcing Steel

Guide Specifications Article 8.4.1 – ASTM A 615 reinforcement shall not be used in WSDOT Bridges. Only ASTM A 706 Grade 60 reinforcing steel shall be used in members where plastic hinging is expected for SDCs B, C, and D. ASTM A 706 Grade 80 reinforcing steels may be used for capacity-protected members specified in Article 8.9. ASTM A 706 Grade 80 reinforcing steel shall not be used for oversized shafts where in-ground plastic hinging is considered as a part of ERS.

Deformed welded wire fabric may be used with the WSDOT Bridge Design Engineer's approval.

Wire rope or strands for spirals and high strength bars with yield strength in excess of 75 ksi shall not be used.

Guide Specifications Article C8.4.1 – Add the following paragraph to Article C8.4.1.

The requirement for plastic hinging and capacity protected members do not apply to the structures in SDC A, therefore use of ASTM A706 Grade 80 reinforcing steel is permitted in SDC A.

For SDCs B, C, and D moment-curvature analysis based on strain compatibility and nonlinear stress-strain relations are used to determine the plastic moment capacity of all ductile concrete member, further research is required to establish the shape and model of the stress-strain curve, expected reinforcing strengths, strain limits, and the stress-strain relationships for concrete confined by lateral reinforcement made with ASTM A 706 Grade 80 reinforcing steel.

4.2.21 Concrete Modeling

Where in-ground plastic hinging approved by WSDOT Bridge Design Engineer is part of the ERS, the confined concrete core shall be limited to a maximum compressive strain of 0.008. The clear spacing between longitudinal reinforcements and between spirals and hoops shall not be less than 6 in or more than 9 in.

4.2.22 Expected Nominal Moment Capacity

Guide Specifications Article 8.5 – Add the following paragraphs after third paragraph.

The expected nominal capacity of capacity protected member using ASTM A 706 Grade 80 reinforcement shall be determined by strength design based on the expected concrete strength and yield strength of 80 ksi when the concrete reaches 0.003 or the reinforcing steel strain reaches 0.090 for #10 bars and smaller, 0.060 for #11 bars and larger.

4.2.23 Interlocking Bar Size

Guide Specifications Article 8.6.7 – The longitudinal reinforcing bar inside the interlocking portion of column (interlocking bars) shall be the same size of bars used outside the interlocking portion.

4.2.24 Splicing of Longitudinal Reinforcement in Columns Subject to Ductility Demands for SDCs C and D

Guide Specifications Article 8.8.3 – The splicing of longitudinal column reinforcement outside the plastic hinging region shall be accomplished using mechanical couplers that are capable of developing a minimum tensile strength of 85 ksi. Splices shall be staggered at least 2 ft. Lap splices shall not be used. The design engineer shall clearly identify the locations where splices in longitudinal column reinforcement are permitted on the plans. In general where the length of the rebar cage is less than 60 ft (72 ft for No. 14 and No. 18 bars), no splice in longitudinal reinforcements shall be allowed.

4.2.25 Development Length for Column Bars Extended into Oversized Pile Shafts f or SDCs C and D

Guide Specifications Article 8.8.10 – Extending column bars into oversized shaft shall be per Section 7.4.4.C, based on TRAC Report WA-RD 417.1 "Non Contact Lap Splice in Bridge Column-Shaft Connections."

4.2.26 Lateral Confinement for Oversized Pile Shaft for SDCs C and D

Guide Specifications Article 8.8.12 – The requirement of this article for shaft lateral reinforcement in the column-shaft splice zone may be replaced with Section 7.8.2 K of this manual.

4.2.27 Lateral Confinement for Non-Oversized Strengthened Pile Shaft for SDCs C and D

Guide Specifications Article 8.8.13 – Non-oversized column-shaft is not permissible unless approved by the WSDOT Bridge Design Engineer.

4.2.28 Requirements for Capacity Protected Members

Guide Specifications Article 8.9 – Add the following paragraphs:

For SDCs C and D where liquefaction is identified, with the WSDOT Bridge Design Engineer's approval, pile and drilled shaft in-ground hinging may be considered as an ERE. Where in-ground hinging is part of ERS, the confined concrete core should be limited to a maximum compressive strain of 0.008 and the member ductility demand shall be limited to 4.

Bridges shall be analyzed and designed for the nonliquefied condition and the liquefied condition in accordance with Article 6.8. The capacity protected members shall be designed in accordance with the requirements of Article 4.11. To ensure the formation of plastic hinges in columns, oversized pile shafts shall be designed for an expected nominal moment capacity, M_{ne}, at any location along the shaft, that is, equal to 1.25 times moment demand generated by the overstrength column plastic hinge moment and associated shear force at the base of the column. The safety factor of 1.25 may be reduced to 1.0 depending on the soil properties and upon the WSDOT Bridge Design Engineer's approval.

The design moments below ground for extended pile shaft may be determined using the nonlinear static procedure (pushover analysis) by pushing them laterally to the displacement demand obtained from an elastic response spectrum analysis. The point of maximum moment shall be identified based on the moment diagram. The expected plastic hinge zone shall extend 3D above and below the point of maximum moment. The plastic hinge zone shall be designated as the "no-splice" zone and the transverse steel for shear and confinement shall be provided accordingly.

4.2.29 Superstructure Capacity Design for Transverse Direction (Integral Bent Cap) for SDCs C and D

Guide Specifications Article 8.11 – Revise the last paragraph as follows:

For SDCs C and D, the longitudinal flexural bent cap beam reinforcement shall be continuous. Splicing of cap beam longitudinal flexural reinforcement shall be accomplished using mechanical couplers that are capable of developing a minimum tensile strength of 85 ksi. Splices shall be staggered at least 2 ft. Lap splices shall not be used.

4.2.30 Superstructure Design for Non Integral Bent Caps for SDCs B, C, and D

Guide Specifications Article 8.12 – Non integral bent caps shall not be used for continuous concrete bridges in SDC B, C, and D except at the expansion joints between superstructure segments.

4.2.31 Joint Proportioning

Guide Specifications Article 8.13.2 – Revise Article 8.13.2 as follows:

Moment-resisting joints shall be proportioned so that the principal stresses satisfy the requirements of Eq. 1 and Eq. 2

- For principal compression, p_c:

$$p_c \leq 0.25f'_c \quad (8.13.2\text{-}1)$$

- For principal tension, p_t:

$$p_t \leq 0.38\sqrt{f'_c} \quad (8.13.2\text{-}2)$$

In which:

$$p_t = \left(\frac{f_h+f_v}{2}\right) - \sqrt{\left(\frac{f_h-f_v}{2}\right)^2 + v_{jh}^2} \quad (8.13.2\text{-}3)$$

$$p_c = \left(\frac{f_h+f_v}{2}\right) + \sqrt{\left(\frac{f_h-f_v}{2}\right)^2 + v_{jh}^2} \quad (8.13.2\text{-}4)$$

Where:

f_h = Average axial horizontal stress (ksi)
f_v = Average axial vertical stress (ksi)
v_{jh} = Average joint shear stress (ksi)

The horizontal axial stress is based on the mean axial force at the center of joint.

$$f_h = \frac{P_b}{B_{cap} D_s} \quad (8.13.2\text{-}5)$$

Where:

P_b = Beam axial force at the center of the joint including the effects of prestressing and the shear associated with plastic hinging (kips)

B_{cap} = Bent cap width (in)

D_s = Depth of superstructure at the bent cap for integral joints under longitudinal response and depth of cap beam for nonintegral bent caps and integral joint under transverse response (in)

For most projects, f_h can typically be ignored since there is typically no prestress in the cap.

In the vertical direction, the average axial stress in the joint is provided by the axial force in the column. Assuming a 45° spread away from the boundary of the column to a plane at mid-depth of the bent cap, the average axial stress is calculated by the following equation:

$$f_v = \frac{P_c}{(D_c + D_b) B_{cap}} \quad (8.13.2\text{-}6)$$

Where:

P_c = Column axial force including the effects of overturning (kips)

B_{cap} = Bent cap width (in)

D_c = Diameter or cross-sectional dimension of column parallel to bent cap (in)

D_b = Depth of bent cap (in)

Eq. 6 shall be modified if the cap beam does not extend beyond the column exterior face greater than the bent cap depth.

The average joint shear stress, v_{jh}, can be approximated with the following equation:

$$v_{jh} = \frac{M}{h_b D_c B_{eff}} \quad (8.13.2\text{-}7)$$

Where:

M = The column overstrength moment, M_{po}, in addition to the moment induced due to eccentricity between the column plastic hinge location and the c.g. of bottom longitudinal reinforcement of the cap beam or superstructure (kip-in)

D_c = Diameter or cross-sectional dimension of column in the direction of loading (in)

h_b = The distance from c.g. of tensile force to c.g. of compressive force on the section (in) This level arm may be approximated by D_s.

B_{eff} = Effective width of joint (in)

The effective width of joint, $B_{eff,}$ depends on the shape of the column framing into the joint and is determined using the following equations.

- For circular columns:

$$B_{eff} = \sqrt{2}\, D_c \quad (8.13.2\text{-}8)$$

- For rectangular columns:

$$B_{eff} = B_c + D_c \quad (8.13.2\text{-}9)$$

For transverse response, the effective width will be the smaller of the value given by the above equations or the cap beam width. Figure 8.13.2-1 clarifies the quantities to be used in this calculation.

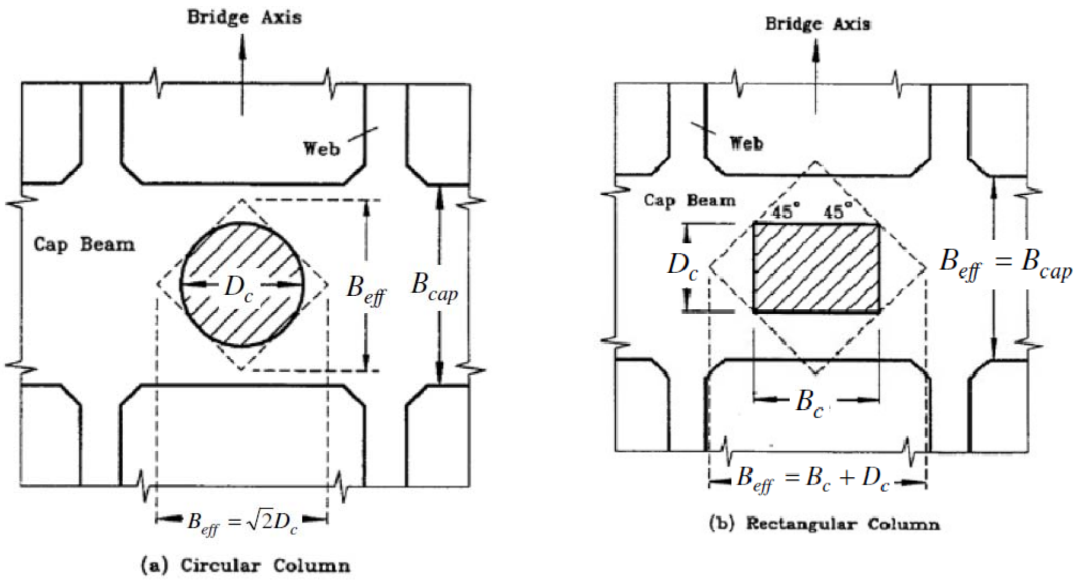


Figure 8.13.2-1 Effective Joint Width for Shear Stress Calculation
BDM Figure 4.2.30-1

4.2.32 Cast-in-Place and Precast Concrete Piles

Guide Specifications Article 8.16.2 – Minimum longitudinal reinforcement of 0.75 percent of A_g shall be provided for CIP piles in SDCs B, C, and D. Longitudinal reinforcement shall be provided for the full length of pile unless approved by the WSDOT Bridge Design Engineer.

4.3 Seismic Design Requirements for Bridge Widening Projects

4.3.1 Seismic Analysis and Retrofit Policy

Widening of existing bridges is often challenging, specifically when it comes to determining how to address elements of the existing structure that do not meet current design standards. The Seismic Analysis and Retrofit Policy for Bridge Widening Projects (Figure 4.3-1) has been established to give bridge design engineers guidance on how and when to address structural deficiencies in existing bridges that are being widened. This policy balances the engineers responsibility to "safeguard life, health, and property" (WAC 196-27A-020) with their responsibility to "achieve the goals and objectives agreed upon with their client or employer" (WAC 196-27A-020 (2)(a)). Current versions of bridge design specifications/codes do not provide guidance on how to treat existing structures that are being widened. This policy is based on and validated by the requirements of the International Building Code (2009 IBC Section 3403.4). The IBC is the code used throughout the nation for design of most structures other than bridges. Thus, the requirements of the IBC can be taken to provide an acceptable level of safety that meets the expectations of the public.

This "Do No Harm" policy requires the bridge engineer to compare existing bridge element seismic capacity/demand ratios for the before widening condition to those of the after widening condition. If the capacity/demand ratio is not decreased, the widening can be designed and constructed without retrofitting existing seismically deficient bridge elements. In this case retrofit of seismically deficient elements is recommended but not required. The decision to retrofit these elements is left to the region and is based on funding availability. If the widened capacity/demand ratios are decreased, the seismically deficient existing elements must be retrofitted as part of the widening project.

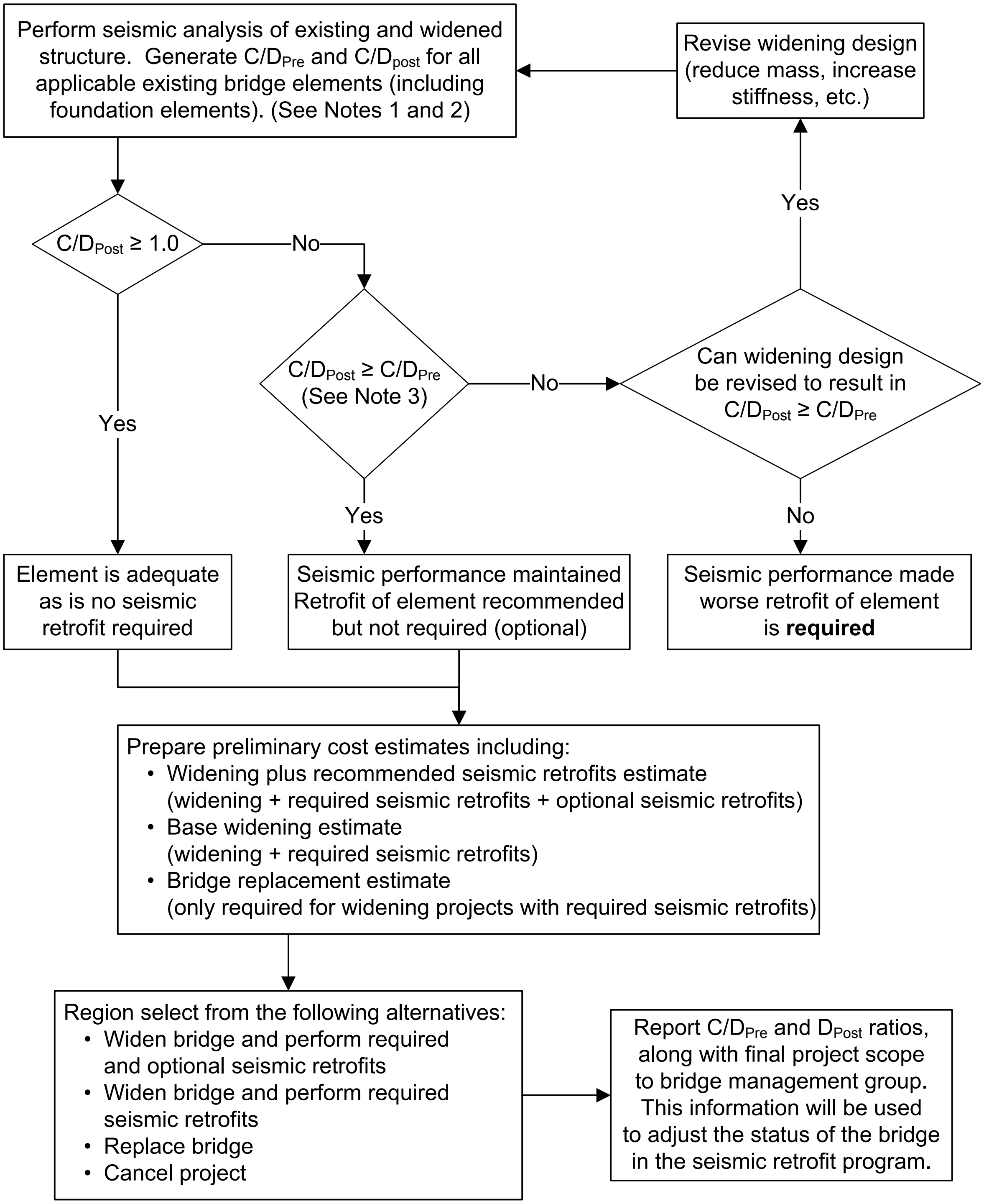
This policy allows bridge widening projects to be completed without addressing existing seismic risks, provided "No Harm" is done to the existing structure. The existing seismic risks are left to be addressed by a bridge seismic retrofit project. This approach maintains the priorities that have been set by the Washington State Legislature. Most widening projects are funded by the I1 - Mobility Program. The objective of the I1-Mobility Program is to improve mobility… not to address seismic risks. Bridge seismic risks are addressed through bridge seismic retrofit projects that are funded as part of the P2 - Structures Preservation Program. The Legislature has established the priority of these and other programs and set funding levels accordingly. This policy upholds the priorities established by the Legislature, by accomplishing widening (mobility) projects without requiring that retrofit (preservation/risk reduction) work be added to the scope, provided the existing structure is not made worse.

Widening elements (new structure) shall be designed to meet current WSDOT standards for new bridges.

A seismic analysis is not required for single-span bridges. However, existing elements of single span bridges shall meet the requirements of *AASHTO Guide Specifications for LRFD Seismic Bridge Design* Section 4.5.

A seismic analysis is not required for bridges in SDC A. However, existing elements of bridges in SDC A shall meet the requirements of *AASHTO Guide Specifications for LRFD Seismic Bridge Design* Section 4.6.

When the addition of the widening has insignificant effects on the existing structure elements, the seismic analysis may be waived with the WSDOT Bridge Design Engineer's approval. In many cases, adding less than 10 percent mass without new substructure could be considered insignificant.



Legend:

C/D_{Pre} = Existing bridge element seismic capacity demand ratio before widening

C/D_{Post} = Existing bridge element seismic capacity demand ratio after widening

Notes:

1. Widening elements (new structure) shall be designed to meet current WSDOT standards for New Bridges.
2. Seismic analysis shall account for substandard details of the existing bridge.
3. C/D ratios are evaluated for each existing bridge element.

WSDOT Seismic Analysis and Retrofit Policy for Bridge Widening Projects
Figure 4.3.1-1

4.3.2 Design and Detailing Considerations

Support Length – The support length at existing abutments, piers, in-span hinges, and pavement seats shall be checked. If there is a need for longitudinal restrainers, transverse restrainers, or additional support length on the existing structure, they shall be included in the widening design.

Connections Between Existing and New Elements – Connections between the new elements and existing elements should be designed for maximum over-strength forces. Where yielding is expected in the crossbeam connection at the extreme event limit state, the new structure shall be designed to carry live loads independently at the Strength I limit state. In cases where large differential settlement and/or a liquefaction-induced loss of bearing strength are expected, the connections may be designed to deflect or hinge in order to isolate the two parts of the structure. Elements subject to inelastic behavior shall be designed and detailed to sustain the expected deformations.

Longitudinal joints between the existing and new structure are not permitted.

Differential Settlement – The allowable differential settlement of bridges depends on the type of construction, the type of foundation, and the nature of soil (sand or clay). The geotechnical designer should evaluate the potential for differential settlement between the existing structure and widening structure. Additional geotechnical measures may be required to limit differential settlements to tolerable levels for both static and seismic conditions. The bridge designer shall evaluate, design, and detail all elements of new and existing portions of the widening structure for the differential settlement warranted by the Geotechnical Engineer. Experience has shown that bridges can and often do accommodate more movement and/or rotation than traditionally allowed or anticipated in design. Creep, relaxation, and redistribution of force effects accommodate these movements. Some studies have been made to synthesize apparent response. The angular distortion appears to be the useful criteria for establishing the allowable limits. These studies indicate that angular distortions between adjacent foundations greater than 0.008 (RAD) in simple spans and 0.004 (RAD) in continuous spans should not be permitted in settlement criteria (Moulton et al. 1985; DiMillio, 1982; Barker et al. 1991). Other angular distortion limits may be appropriate after consideration of:

- Cost of mitigation through larger foundations, realignment, or surcharge
- Rideability
- Aesthetics
- Safety

Rotation movements should be evaluated at the top of the substructure unit (in plan location) and at the deck elevation.

The horizontal displacement of pile and shaft foundations shall be estimated using procedures that consider soil-structure interaction (see *Geotechnical Design Manual* M 46-03 Section 8.12.2.3). Horizontal movement criteria should be established at the top of the foundation based on the tolerance of the structure to lateral movement with consideration of the column length and stiffness. Tolerance of the superstructure to lateral movement will depend on bridge seat widths, bearing type(s), structure type, and load distribution effects.

Foundation Types – The foundation type of the new structure should match that of the existing structure. However, a different type of foundation may be used for the new structure due to geotechnical recommendations or the limited space available between existing and new structures. For example, a shaft foundation may be used in lieu of spread footing.

Existing Strutted Columns – The horizontal strut between existing columns may be removed. The existing columns shall then be analyzed with the new unbraced length and retrofitted if necessary.

Non Structural Element Stiffness – Median barrier and other potentially stiffening elements shall be isolated from the columns to avoid any additional stiffness to the system.

Deformation capacities of existing bridge members that do not meet current detailing standards shall be determined using the provisions of Section 7.8 of the *Retrofitting Manual for Highway Structures: Part 1 – Bridges*, FHWA-HRT-06-032. Deformation capacities of existing bridge members that meet current detailing standards shall be determined using the latest edition of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*.

Joint shear capacities of existing structures shall be checked using Caltrans *Bridge Design Aid*, 14-4 Joint Shear Modeling Guidelines for Existing Structures.

In lieu of specific data, the reinforcement properties provided in Table 4.3.2-1 should be used.

Property	Notation	Bar Size	ASTM A706	ASTM A615 Grade 60	ASTM A615 Grade 40*
Specified minimum yield stress (ksi)	f_y	No. 3 - No. 18	60	60	40
Expected yield stress (ksi)	f_{ye}	No. 3 - No. 18	68	68	48
Expected tensile strength (ksi)	f_{ue}	No. 3 - No. 18	95	95	81
Expected yield strain	ε_{ye}	No. 3 - No. 18	0.0023	0.0023	0.00166
Onset of strain hardening	ε_{sh}	No. 3 - No. 8	0.0150	0.0150	0.0193
		No. 9	0.0125	0.0125	
		No. 10 & No. 11	0.0115	0.0115	
		No. 14	0.0075	0.0075	
		No. 18	0.0050	0.0050	
Reduced ultimate tensile strain	ε_{su}^{R}	No. 4 - No. 10	0.090	0.060	0.090
		No. 11 - No. 18	0.060	0.040	0.060
Ultimate tensile strain	ε_{su}	No. 4 - No. 10	0.120	0.090	0.120
		No. 11 - No. 18	0.090	0.060	0.090

* ASTM A615 Grade 40 is for existing bridges in widening projects.

Stress Properties of Reinforcing Steel Bars
Table 4.3.2-1

Isolation Bearings – May be used for bridge widening projects to reduce the demands through modification of the dynamic properties of the bridge as a viable alternative to strengthening weak elements or non ductile bridge substructure members of existing bridge. Isolation bearings shall be designed per the requirement of the AASHTO *Guide Specifications for Seismic Isolation*.

The decision for using isolation bearings should be made at the early stage of project development based on the complexity of bridge geotechnical and structural design. A cost-benefit analysis comparing design with strengthening weak elements vs. design with isolation bearings shall be performed and submitted for approval. The designer needs to perform two separate designs, one with and one without seismic isolation bearings. The cost-benefit analysis shall at least include:

- Higher initial design time and complexity of analysis.
- Impact of the initial and final design time on the project delivery schedule.
- Time required for preliminary investigation and correspondences with the isolation bearing suppliers.
- Life-cycle cost of additional and specialized and bearing inspections.
- Potential cost impact for bearing and expansion joints replacements.
- Issues related to long-term performance and maintenance.
- Need for large movement expansion joints.

Once approval has been given for the use of seismic isolation bearings, the designer shall send a set of preliminary design and specification requirements to at least three seismic isolation bearing suppliers for evaluation to ensure that they can meet the design and specification requirements. Comments from isolation bearing suppliers should be incorporated before design of structure begins. Sole source isolation bearing supplier may be considered upon Bridge Design Office and Project Engineer's office approval.

The designer shall submit to the isolation bearing suppliers maintenance and inspection requirements with design calculations. Isolation bearing suppliers shall provide maintenance and inspection requirements to ensure the isolators will function properly during the design life and after seismic events. The contract plans shall include bearing replacement methods and details.

4.4 Seismic Retrofitting of Existing Bridges

Seismic retrofitting of existing bridges will be performed in accordance with the FHWA publication FHWA-HRT-06-032, *Seismic Retrofitting Manual for Highway Structures: Part 1 – Bridges*.

4.4.1 Seismic Analysis Requirements

The first step in retrofitting a bridge is to analyze the existing structure to identify seismically deficient elements. The initial analysis consists of generating capacity/demand ratios for all relevant bridge components. Seismic displacement and force demands shall be determined using the multi-mode spectral analysis of Section 5.4.2.2 (at a minimum). Prescriptive requirements, such as support length, shall be considered a demand and shall be included in the analysis. Seismic capacities shall be determined in accordance with the requirements of the *Seismic Retrofitting Manual*. Displacement capacities shall be determined by the Method D2 – Structure Capacity/Demand (Pushover) Method of Section 5.6. For most WSDOT bridges, the seismic analysis need only be performed for the upper level (1,000 year return period) ground motions with a life safety seismic performance level.

4.4.2 Seismic Retrofit Design

Once seismically deficient bridge elements have been identified, appropriate retrofit measures shall be selected and designed. Table 1-11, Chapters 8, 9, 10, 11, and Appendices D thru F of the *Seismic Retrofitting Manual* shall be used in selecting and designing the seismic retrofit measures. The WSDOT Bridge and Structure Office Seismic Specialist will be consulted in the selection and design of the retrofit measures.

4.4.3 Computer Analysis Verification

The computer results will be verified to ensure accuracy and correctness. The designer should use the following procedures for model verification:

- Using graphics to check the orientation of all nodes, members, supports, joint, and member releases. Make sure that all the structural components and connections correctly model the actual structure.
- Check dead load reactions with hand calculations. The difference should be less than 5 percent.
- Calculate fundamental and subsequent modes by hand and compare results with computer results.
- Check the mode shapes and verify that structure movements are reasonable.
- Increase the number of modes to obtain 90 percent or more mass participation in each direction. GTSTRUDL/SAP2000 directly calculates the percentage of mass participation.
- Check the distribution of lateral forces. Are they consistent with column stiffness? Do small changes in stiffness of certain columns give predictable results?

4.4.4 Earthquake Restrainers

Longitudinal restrainers shall be high strength bars in accordance with the requirements of Bridge Special provision BSP022604.

4.4.5 Isolation Bearings

Isolation bearings may be used for seismic retrofit projects to reduce the demands through modification of the dynamic properties of the bridge as a viable alternative to strengthening weak elements of non ductile bridge substructure members of existing bridge. Use of isolation bearings needs the approval of WSDOT Bridge Design Engineer. Isolation bearings shall be designed per the requirement of the *AASHTO Guide Specifications for Seismic Isolation*.

The decision for using isolation bearings should be made at the early stage of project development based on the complexity of bridge geotechnical and structural design. A cost-benefit analysis comparing design with strengthening weak elements vs. design with isolation bearings shall be performed and submitted for approval. The designer needs to perform two separate designs, one with and one without seismic isolation bearings. The cost-benefit analysis shall at least include:

- Higher initial design time and complexity of analysis.
- Impact of the initial and final design time on the project delivery schedule.
- Time required for preliminary investigation and correspondences with the isolation bearing suppliers.
- Life-cycle cost of additional and specialized bearing inspection.
- Potential cost impact for bearings and expansion joints replacements.
- Issues related to long-term performance and maintenance.
- Need for large movement expansion joints.

Once approval has been given for the use of seismic isolation bearing, the designer shall send a set of preliminary design and specification requirements to at least three seismic isolation bearing suppliers for evaluation to ensure that they can meet the design and specification requirements. Comments from isolation bearing suppliers should be incorporated before design of structure begins. Sole source isolation bearing supplier may be considered upon Bridge Design Office and Project Engineer's office approval.

The designer shall submit to the isolation bearing suppliers maintenance and inspection requirements with design calculations. Isolation bearing suppliers shall provide maintenance and inspection requirements to ensure the isolators will function properly during the design life and after seismic events. The contract plans shall include bearing replacement methods and details.

4.5 Seismic Design Requirements for Retaining Walls

4.5.1 General

All retaining walls shall include seismic design load combinations. The design acceleration for retaining walls shall be determined in accordance with the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*. Once the design acceleration is determined, the designer shall follow the applicable design specification requirements listed below:

Wall Types	Design Specifications
Soldier Pile Walls With and Without Tie-Backs	AASHTO *LRFD Bridge Design Specifications*
Pre-Approved Proprietary Walls	AASHTO *LRFD Bridge Design Specifications* or the AASHTO *Standard Specifications for Highway Bridges*-17th Edition and 1,000 yr map design acceleration
Non-Preapproved Proprietary Walls	AASHTO *LRFD Bridge Design Specifications*
Standard Plan Geosynthetic Walls	AASHTO *LRFD Bridge Design Specifications*
Non Standard Geosynthetic Walls	AASHTO *LRFD Bridge Design Specifications*
Standard Plan Reinforced Concrete Cantilever Walls	AASHTO *LRFD Bridge Design Specifications*
Non Standard Non Proprietary Walls	AASHTO *LRFD Bridge Design Specifications*
Soil Nail Walls	AASHTO *LRFD Bridge Design Specifications*
Standard Plan Noise Barrier Walls	*AASHTO Guide Specifications for Structural Design of Sound Barriers* – 1989 and Interims
Non- Standard Noise Barrier Walls	Design per Chapter 3
Pre Approved and Standard Plan Moment Slabs for SE Walls and Geosynthetic Walls	AASHTO *LRFD Bridge Design Specifications*
Non-Pre Approved and Non Standard Moment Slabs for SE Walls and Geosynthetic Walls	AASHTO *LRFD Bridge Design Specifications*
Non Standard Non Proprietary Walls, Gravity Blocks, Gabion Walls	AASHTO *LRFD Bridge Design Specifications*

Exceptions to the cases described above may occur with approval from the WSDOT Bridge Design Engineer and/or the WSDOT Geotechnical Engineer.

4.99 References

AASHTO *LRFD Bridge Design Specifications*, 5th Edition, 2010

AASHTO *Guide Specifications for LRFD Seismic Bridge Design*, 2nd Edition, 2011

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FHWA *Seismic Retrofitting Manual for Highway Structures: Part 1-Bridges*, Publication No. FHWA-HRT-06-032, January 2006

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