ENGINEERING POLICY BALLOT

Effective: October 1, 2024

Level 2

Level two revisions require the approval of the **Assistant Chief Engineer** and the **Federal Highway Administration** only. The **Senior Management Team** is encouraged to review the content and provide comment to the appropriate director. For all other parties, these revisions are posted for information only.

ENGINEERING POLICY BALLOT

Effective: October 1, 2024

Issue 1: LRFD seismic bridge and retaining wall design policy implementation

Approval: Level 2 – Assistant Chief Engineer

Sponsor: Suresh Patel – BR

Summary: Updates to reflect LRFD seismic bridge and retaining wall design policy implementation.

Fiscal Impact: Unknown. Bridge Abutments for Major Routes in affected areas may see more reinforcement or even extra wings.

Publications: Missouri Standard Specification: Sec. 720, Sec 1052
Engineering Policy Guide: 321.2.4.4, 720.1, 747.2.6.2, multiple articles in 751, 756 and multiple articles in 1052

SECTION 720

MECHANICALLY STABILIZED EARTH WALL SYSTEMS

720.1 Description. This work shall consist of furnishing and constructing mechanically stabilized earth wall systems in accordance with these specifications, as shown on the plans or as directed by the engineer.

720.2 Material. All material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section
Concrete	501
Pipe Pile Spacers	724
Select Granular Backfill for Structural Systems	1010
Geotextile	1011
Miscellaneous Drainage Material	1013
Reinforcing Steel for Concrete	1036
Resin Anchor Systems	1039
Mechanically Stabilized Earth Wall (MSE) and Sound Wall System Components	1052

720.2.1 Whenever a wall system is located adjacent to and within ten feet of the limits of a permanent roadway, the steel reinforcement used in the concrete elements of the wall system shall be epoxy coated. This requirement will not apply to soil reinforcement and corresponding attachments used for connecting the reinforcement to the wall system units.

720.2.2 Reinforcement for wall system units shall be either Grade 60 deformed bars or an equivalent steel welded wire reinforcement. Reinforcement for coping or top cap units shall be Grade 60 deformed bars.

720.2.3 Joint material for precast modular panel wall (PMPW-MSE)~~large block wall~~ systems shall be used in accordance with the wall manufacturer's recommendations.

720.2.4 The unit fill that is used for drycast modular block wall (DMBW-MSE) systems and wetcast modular ~~small~~ block wall (WMBW-MSE) systems shall consist of a granular backfill in accordance with Gradation D or E of Sec 1005.

720.2.5 Class B or B-1 air entrained concrete shall be used for the coping or top cap units used for the wall system. Class B or B-1 concrete shall be used for cast-in-place concrete leveling pads used for the wall system.

720.3 Design Requirements.

720.3.1 Only the mechanically stabilized earth wall systems shown in the bridge prequalified products listing will be allowed for use by the contractor. The bridge prequalified products list may be obtained through Bridge or MoDOT's web site. Any deviations from the prequalified wall system details previously submitted to Bridge shall be specifically outlined in the cover letter submitted with the design plans, details and computations.

720.3.2 Drycast modular~~Small~~ block wall (DMBW-MSE) systems with approved soil reinforcement will be permitted for uses where the wall height does not exceed ten feet. This limit may be exceeded up to a maximum height of 12 feet to accommodate peaks in the wall or to accommodate lengths of the wall that do not exceed more than ten percent of the total wall length. Wetcast modular block wall (WMBW-MSE) systems with approved soil reinforcement will be permitted for uses where the wall height does not exceed 15 feet. This limit may be exceeded up to a maximum height of 17 feet to accommodate peaks in the wall or to accommodate lengths of the wall that do not exceed more than ten percent of the total wall length. The height of the wall will be determined by measuring from the top of the concrete leveling pad to the top of the cap on the wall.

720.3.3 The contractor shall submit electronically ~~six complete~~one sets of the manufacturer's design plans, details and computations for each individual wall structure to the engineer. All submitted information shall be clear and complete, and thoroughly checked before the information is submitted. All submitted information shall be legible and of sufficient contrast to be suitable for archiving in accordance with MoDOT's current practice for archiving. Submitted information determined to be unsuitable for archiving purposes will be returned for corrective action.

720.3.4 The contractor will be solely responsible for the content of the design plans, details and computations that are submitted, and for the performance of the wall system. The contractor shall be solely responsible for ensuring that the information submitted by the manufacturer is in accordance with all contract plans and specifications and with the wall system used. Completed design plans shall contain all material, fabrication and construction requirements for erecting the wall system complete in place. The completed design plans shall show the longitudinal and lateral layout of the drainage systems used for the wall system. The contractor shall be responsible for the internal and external stability of the structure including compound stability. Overall global stability will be the responsibility of the engineer.

720.3.5 All design plans, details and computations submitted for distribution shall be signed, sealed and stamped in accordance with the laws relating to architects and professional engineers (Chapter 327, RSMo).

720.3.6 Mechanically stabilized earth wall systems shall be designed in accordance with the AASHTO specifications shown on the plans and in accordance with additional publications or specifications referenced within the AASHTO specifications. The seismic performance category, angle of internal friction for the selected granular backfill for structural systems and other design requirements shown on the plans shall be incorporated into the design of the wall system.

720.4 Construction Requirements.

720.4.1 Drycast Modular Block Wall (DMBW-MSE) Systems and Wetcast Modular ~~Small~~ Block Wall (WMBW-MSE) Systems.

720.4.1.1 The contractor shall use a unit fill to fill the voids of the blocks for the wall system. This unit fill shall extend a minimum distance of 12 inches beyond the extreme back face of the wall system. Each course of the wall system shall have the unit fill in place before the next course of the wall system is placed.

720.4.1.2 Precast top cap units shall be used on drycast modular block wall (DMBW-MSE) systems and wetcast modular~~small~~ block wall (WMBW-MSE) systems. The top cap units shall be permanently attached as shown on the plans, utilizing either a resin anchor system or an equivalent detail.

720.4.1.3 Any equivalent details used shall be part of the prequalified mechanically stabilized earth wall system details on file for the manufacturer of the wall system.

720.4.2 Precast Modular Panel Wall (PMPW-MSE)~~Large Block Wall~~ Systems.

720.4.2.1 A Class 1 geotextile filter cloth shall be placed between the wall and the select granular backfill for structural systems at all joints between the individual wall system units.

720.4.2.2 Precast or cast-in-place coping shall be placed on precast modular panel ~~large block~~ wall (PMPW-MSE) systems in accordance with the design plans. Capstone may be used in lieu of coping whenever coping is specified on the design plans. When coping or capstone is used, the maximum distance between construction joints shall be 20 feet. The joints for coping or capstone should align with the vertical joints in the MSE wall face.

720.4.3 Drainage Requirements. A drainage system shall be provided at the base of the wall system near the facing elements and at the interface of the select granular backfill for structural systems and the retained backfill. The drainage system shall consist of a perforated pipe wrapped in a Class 2 geotextile to prevent clogging of the perforations. The pipe shall be placed in such a manner that water drains freely from the pipe. When the wall length is such that the slope of the pipe becomes excessive in the engineer's judgment, lateral drain pipes shall be installed underneath the concrete leveling pad.

720.4.4 Foundation Preparation. The foundation for the wall system shall be graded level for a width equal to or exceeding the length of the reinforcing strips, or as shown on the plans. Prior to wall construction, the foundation, if not on rock, shall be proof-rolled or compacted as directed by the engineer. Any foundation soils found to be unsuitable shall be removed and replaced, as directed by the engineer.

720.4.5 Leveling Pad. An unreinforced cast-in-place concrete leveling pad shall be provided at the foundation level for each base unit of the wall system. Gravel leveling pads will not be allowed. The leveling pad shall be built to the elevations shown on the plans and shall not be raised in elevation to allow for the use of a particular wall system. The leveling pad shall be built a minimum width of 12 inches and a minimum depth of 6 inches. The concrete on the leveling pad shall be cured a minimum of 12 hours before any of the wall system panels are placed.

A geotextile shall be applied over the back of the area of any openings between the facing units and leveling pad steps. The geotextile shall extend a minimum of six inches beyond the edges of the opening. The elevation of the top of leveling pad shall be within 1/8 inch from the design elevation when measured over any 10-foot run of the leveling pad or as indicated in the manufacturer specifications.

720.4.6 Batter Requirements. Wall systems shall be built with some inward batter, as determined by the wall system manufacturer, to accommodate the horizontal movement created by the placement and compaction of selected granular backfill for structural systems. Negative (outward leaning) batter is not acceptable. Facing elements out of alignment shall not be pulled or pushed into proper place, as that may cause damage to the facing element or soil reinforcement strips. If misalignment occurs, the select granular backfill for structural systems and the soil reinforcement strips shall be removed and the facing elements reset to the proper alignment.

720.4.7 Pipe Pile Spacers.

720.4.7.1 The contractor shall install pipe pile spacers at pile locations in the select granular backfill of the mechanically stabilized earth walls to protect the soil reinforcement when driving pile for bridge substructure at end bents when shown on the bridge plans. The pipe pile spacers shall be accurately located and capped for future pile construction.

720.4.7.2 The pipe pile spacers shall be in accordance with the requirements of Sec 724 for Group C "Flexible Pipe – Metal" or "Flexible Pipe – Thermoplastic".

720.4.7.3 The pipe pile spacers shall have an inside diameter greater than that of the pile and large enough to avoid damage to the pipe when driving the pile. The size of pipe pile spacers shall be subject to approval by the engineer before work is started. The bottom of the pipe pile spacers shall be placed below the bottom of the MSE wall leveling pad as shown on the plans. The pipe pile spacers shall be filled with sand or other approved material after the pile is placed and before being driven. Shop drawings of the pipe pile spacers will not be required.

720.4.8 Select Granular Backfill for Structural Systems Placement.

720.4.8.1 Select granular backfill for structural systems shall be placed concurrently with the placement of the retained backfill. The placement of the select granular backfill for structural systems shall closely follow the erection of each course of the wall system and shall be placed in such a manner to avoid any damage or disturbance to the wall material or any misalignment of the facing elements of the wall system. Any wall system material that becomes damaged or disturbed during the installation of the wall system shall be removed, replaced or corrected at the contractor's expense, as directed by the engineer. Whenever placement of the select granular backfill for structural systems results in the wall facing system being misaligned or distorted outside the limits of this specification, the contractor shall correct the misalignment or distortion as directed by the engineer.

720.4.8.2 The select granular backfill for structural systems shall be compacted in accordance with Sec 203, with the following exceptions:

(a) The minimum density shall be no less than 95 percent of maximum density, determined in accordance with AASHTO T 99.

(b) When the material used contains more than 30 percent retained on the 3/4-inch sieve, a method of compaction consisting of at least four passes by a heavy roller shall be used.

(c) The moisture content of the material prior to and during compaction shall be uniformly distributed throughout each layer. The placement moisture content shall be no lower than three percentage points less than the optimum moisture content and shall be no more than the optimum moisture content.

(d) Compaction within 3 feet of the back face of the wall system shall be achieved by at least three passes of a lightweight mechanical tamper, roller or vibratory system.

(e) The contractor shall ensure that runoff within the wall system construction site is directed away from the wall facing during construction, and that runoff from adjacent areas of the general construction site is directed such that runoff does not enter the wall system construction site.

(f) Class 1 geotextile material shall be placed between the select granular backfill for structural systems, and the retained backfill and over the top of the select granular backfill for structural systems to prevent piping of in-situ soil into the wall system.

(g) Tamping-type (sheep's foot) rollers shall not be used for compaction of the select granular backfill for structural systems.

720.4.8.3 The select granular backfill for structural systems shall be initially placed parallel to the wall system, and at the rear and middle of the soil reinforcement strips, and then moved toward the facing elements of the wall system. Construction equipment shall at no time come in direct contact with the soil reinforcement strips. Each course or layer shall be compacted up to or slightly above the location of the next connection for the reinforcement strips prior to placing the next layer of reinforcement strips as designated in the erection sequence provided by the manufacturer of the wall system.

720.4.9 Construction Tolerances.

720.4.9.1 Wall systems shall be built in accordance with the dimensions and elevations specified on the plans and in accordance with the requirements of the system manufacturer. Alignments shall be maintained within the following dimensional tolerances:

Item	**Tolerance**
Final Horizontal Joint Gaps Between Adjacent Facing Panels (Precast Modular Panel ~~Large Block~~ Walls (PMPW-MSE))	± 1/8 in.

Final Vertical Joint Gaps Between Adjacent Facing Panels (Precast Modular PanelLarge Block Walls (PMPW-MSE))	± 1/4 in.
Final Joint Gaps Between Adjacent Modular Block Units (Drycast Modular Block Walls (DMBW-MSE) and Wetcast Modular Block Walls (WMBW-MSE) Small Block Walls)	± 1/4 in.
Vertical and Horizontal Alignment of Facing Elements (All Wall Systems)	± 1/16 in. per ft
Soil Reinforcement Strip Elevations (All Wall Systems)	± 1 in.

720.4.9.2 Vertical alignments shall be measured along a theoretical vertical line established from the top of the wall system to the base of the wall system. For drycast modular block walls (DMBW-MSE), and wetcast modular small block walls (WMBW-MSE) that have a built-in setback, the alignment shall be measured along the theoretical vertical line and the straight line that describes the horizontal setback.

720.4.10 Technical Assistance. The contractor shall be responsible for having a technical advisor from the wall system manufacturer available for assistance during the installation of the wall system.

720.5 Method of Measurement.

720.5.1 Measurement of mechanically stabilized earth wall systems will be made to the nearest square foot. The quantity to be paid will be measured from the wall outline as shown on the plans. No adjustments in the measured quantity will be permitted for additional wall area required to meet the minimum wall elevations shown on the plans for any particular wall system.

720.5.2 Measurement of pipe pile spacers will be made per each.

720.5.3 Final measurement will not be made except for authorized changes during construction or where appreciable errors are found in the contract quantity. The revision or correction will be computed and added to or deducted from the contract quantity.

720.5.4 No measurement will be made for required excavation for placement of the leveling pad for the wall system. All other excavation required for the construction of the wall system will be included in roadway items.

720.6 Basis of Payment. The accepted quantity of mechanically stabilized earth wall systems, complete in place, will be paid for at the contract unit price for each of the pay items included in the contract.

Payment for furnishing and installing pipe pile spacers complete in place including all equipment, labor and any other incidental work necessary to complete this item will be considered completely covered by the contract unit price for pipe pile spacers.

SECTION 1052

MECHANICALLY STABILIZED EARTH WALL (MSE) AND SOUND WALL SYSTEM COMPONENTS

1052.1 This specification covers material requirements for metallic soil reinforcement, non-metallic soil reinforcement, concrete facing panels for precast modular panel ~~large block~~ wall (PMPW-MSE) systems and sound walls, and concrete blocks for drycast modular block wall (DMBW-MSE) and wetcast modular ~~small~~ block wall (WMBW-MSE) systems that are supplied as part of mechanically stabilized earth wall systems. All precast items shall be in accordance with Sec 1001.

SECTION 1052.10 METALLIC SOIL REINFORCEMENT.

1052.10.1 Scope. This specification covers metallic soil reinforcement and the accompanying attachments utilized in mechanically stabilized earth wall systems.

1052.10.2 Reinforcement Strips. Metallic soil reinforcement strips shall be in accordance with the specifications of the manufacturer of the wall system and the contract documents. The minimum grade of steel for strips and connection devices shall be AASHTO M 270, Grade 36.

1052.10.3 Reinforcement Mesh. Metallic soil reinforcement mesh shall be in accordance with the specifications of the manufacturer of the wall system and the contract documents. The minimum grade of steel for strips and connection devices shall be either AASHTO M 270 Grade 36, ASTM A 1011 Grade 50 or ASTM A 463 Grade 50. Welding shall be in accordance with AASHTO M 55.

1052.10.4 Fasteners. Fasteners shall consist of either AASHTO M 164 hexagon head bolts or AASHTO M 164 hexagonal cap screws with nuts and washers.

1052.10.5 Galvanizing and Aluminizing. All soil reinforcement material shall be either galvanized or aluminized. Galvanized soil reinforcement shall be in accordance with AASHTO M 111. Aluminized soil reinforcement shall be in accordance with ASTM A 463 Aluminized Type 2-100, SS, Grade 50, Class 2. Fasteners, including bolts, nuts and washers, shall be galvanized in accordance with AASHTO M 232. All connection devices shall be galvanized in accordance with either AASHTO M 111 or M 232.

1052.10.6 Certification. The manufacturer of the wall system shall certify in writing that the soil reinforcement, connections and fasteners meet the minimum requirements directed by the design and this specification. The contractor shall provide this certification and any other supporting documentation to the engineer prior to the material being delivered to the construction site.

SECTION 1052.20 NON-METALLIC SOIL REINFORCEMENT.

1052.20.1 Scope. This specification covers non-metallic or geosynthetic soil reinforcement utilized in mechanically stabilized earth wall systems.

1052.20.2 Geogrids. Non-Metallic or geosynthetic soil reinforcement shall be of a polymeric nature and shall consist of a geogrid determined by the wall manufacturer or supplier.

1052.20.2.1 The geogrid shall be dimensionally stable and shall be able to maintain geometry during transport, handling and installation.

1052.20.2.2 The geogrid manufacturer shall maintain a quality control program to ensure that the manufactured material meets the requirements of the index tests shown below. Sampling and conformance testing for the index tests shown in the table shall be done in accordance with ASTM D 4354.

Geogrids	
Property	**Test Procedure**
Specific Gravity (HDPE only)	ASTM D 1505
Wide Width Tensile	ASTM D 4595, GRI GG1
Melt Flow (HDPE and PP only)	ASTM D 1238
Inherent Viscosity (PET only)	ASTM D 4603, GRI GG8
Hydrolysis Resistance (PET only)	GRI GG7
UV Oxidation Resistance	ASTM D 4355
Survivability	ASTM D 5261

1052.20.3 Certification. The manufacturer of geogrid shall certify in writing that the geogrid is in accordance with this specification. The certification shall include the roll numbers and identification, the sampling procedures, the results of the quality control tests along with the tests used, and the Minimum Average Roll Value (MARV) for each roll. This certification and any other supporting documentation shall be provided to the engineer prior to the material being delivered to the construction site.

SECTION 1052.30 PRECAST MODULAR PANEL WALL (PMPW-MSE) ~~PANEL~~ AND SOUND WALL~~S~~ SYSTEMS – CONCRETE FACING PANELS

1052.30.1 Scope. This specification covers the concrete facing panels used as part of mechanically stabilized earth wall systems and sound wall systems.

1052.30.2 Acceptance.

1052.30.2.1 Lot Definition. A production lot will be defined as a group of panels and precast posts that will be represented by a single compressive strength sample, and shall consist of either 40 panels and or precast posts or a single day's production, whichever is less.

1052.30.2.2 Quality Control. The QMP shall define QC testing and inspection frequencies including the following.

1052.30.2.3 Compressive strength of cylinders or cores shall be taken at least once a lot in accordance with AASHTO M199. Compressive strength testing may also be performed to control handling and curing operations. Cylinders shall be cured in accordance with AASHTO T23 field curing procedures. For field cure compressive strength samples sufficient cylinders shall be cured in the same manner as the panels and precast posts and tested in accordance with AASHTO T22, shall represent the initial strength of the concrete. In addition, a set of cylinders shall be cured in accordance with AASHTO T23 and tested at 28 days. The average compressive strength of these cylinders, when tested in accordance with AASHTO T22, shall represent the compressive strength of the production lot.

1052.30.2.4 Air content testing shall be performed in accordance with AASHTO T152 or AASHTO T196. Air content samples shall be taken at the beginning of each day's production and at the same time as compressive samples are taken to ensure compliance with this specification.

1052.30.2.5 Slump testing shall be performed in accordance with AASHTO T119. The slump shall be determined at the beginning of each day's production and at the same time as the compressive strength samples are taken.

1052.30.2.6 Aggregate gradation and quality shall be checked at least once a month per aggregate source to ensure compliance with the specifications.

1052.30.2.7 Steel placement shall be checked for each unit.

1052.30.2.8 All equipment used for testing shall be maintained and calibrated in accordance with AASHTO R18 or equivalent program.

1052.30.2.9 QC shall ensure the concrete plant is calibrated, monitored, and maintained in a manner sufficient to provide uniform compliant concrete.

1052.30.2.10 Quality Assurance. The QMP shall reference an industry organization or define independent QA testing frequencies including the following:

Tested Property[a]	Test Method	Independent QA
Air	T152	Twice a year
Slump	T119	Twice a year
Coarse Aggregate Deleterious	TM71	Twice a year
Coarse Aggregate Absorption	T85	Twice a year
Compressive Strength	T22	Twice a year
[a] All samples shall be taken at the precast plant		

1052.30.2.11 MoDOT QA and Auditing. The engineer may perform MoDOT QA testing or audit the producer's QMP, documentation and production at any time, which may include coring of the precast units at the producer's expense.

1052.30.2.12 Other Criteria. Concrete facing panels, coping and precast posts will not be accepted if any of the following defects in physical characteristics are found: imperfect molding, honeycombing or open texture concrete, cracked or severely chipped panels and precast posts, soil reinforcement attachment devices improperly installed/damaged, lifting inserts not useable, exposed reinforcing steel, and color variation on the front face of the panel due to excess form oil or other reasons.

1052.30.3 Material.

1052.30.3.1 Concrete. Concrete material, proportioning, air entraining, mixing, slump and transporting of concrete shall be in accordance with Sec 501, except as noted in this section.

1052.30.3.2 Aggregate. Fine and coarse aggregate for the concrete mixture shall be in accordance with Sec 1005, except that the requirements for gradation and percent passing the No. 200 sieve will not apply.

1052.30.3.3 Steel Reinforcement. Reinforcement shall be in accordance with Sec 1036.

1052.30.4 Design. Shop drawings shall be approved by the Bridge Division when the MSE wall is constructed in conjunction with a bridge abutment.

1052.30.4.1 The concrete shall be an approved MoDOT mix that is air-entrained, with a minimum compressive strength of 4,000 psi at 28 days. No additional admixtures will be permitted unless approved by the engineer.

1052.30.4 Casting. The panels shall be cast in such a manner that the acceptance criteria of this specification are met. Soil reinforcement connection devices shall not be in contact with or attached to the reinforcing steel in the concrete facing panels.

1052.30.5 Manufacturing.

1052.30.5.1 Casting. The panels and precast posts shall be cast in such a manner that the acceptance criteria of this specification are met. Soil reinforcement connection devices shall not be in contact with or attached to the reinforcing steel in the concrete facing panels.

1052.30.5.2 Curing. One of the following methods shall be used. Curing as recommended by the wall designer. Curing membrane, in accordance with Sec 1055, may be applied and if used shall be left intact until the strength requirements are met. Steam and moisture curing methods shall be in accordance with Sec 1029.

1052.30.5.3 Tolerances.

1052.30.5.3.1 Panel and Post Systems. Shall be in accordance with approved shop drawings. Any variations from the approved shop drawings such as dimensions, materials, or finish must be approved by the wall manufacturer. Post dimensions for sound walls shall be within 1/4 inch in width and depth and within one inch along the length dimension.

1052.30.5.3.2 Panel Dimensions. Panel connection devices shall be within one inch of the specified dimension. The panel face and thickness dimensions shall be within 1/8 inch of the specified dimension. All other dimensions or items shall be within 1/4 inch of the specified dimensions.

1052.30.5.3.3 Panel Squareness. Squareness, as determined by the difference between the two diagonals, shall not exceed 1/2 inch.

1052.30.5.3.4 Panel Surface Finish. Surface defects on smooth formed surfaces measured over a length of 5 feet shall not exceed 1/8 inch. Surface defects on the textured-finish surfaces, measured over a length of 5 feet, shall not exceed 3/8 inch.

1052.30.5.4 Other Criteria. Concrete facing panels, coping and precast posts will not be accepted if any of the following defects in physical characteristics are found: imperfect molding, honeycombing or open texture concrete, cracked or severely chipped panels and precast posts, soil reinforcement attachment devices improperly installed/damaged, lifting inserts not usable, exposed reinforcing steel, and color variation on the front face of the panel due to excess form oil or other reasons.

1052.30.6 Marking. The date of manufacture, production lot number and piece mark shall be clearly scribed on an unexposed face of each panel.

1052.30.7 MoDOT Identification Number. When the manufacturer contacts the engineer one business day, or earlier, in advance of shipping precast products the engineer will assign a specific MoDOT identification number for each size and type of product in the shipment.

1052.30.7.1 Prior to delivery to the jobsite, the source, intermediate agent, shipper or contractor's representative shall notify the inspecting District by fax or electronically a minimum of one business day, or earlier, prior to the impending shipment of precast material. This notification shall include a shipping form (Precast Shipping Form) and will include, at minimum, the following:

a) The specific contract number.

b) Receiving Purchaser/Contractor.

c) Line number for which the material will be used.

d) Type and quantity of material.

e) Date of expected delivery to the jobsite.

f) Manufacturer's name.

g) Stationing or structure number on precast unit, if applicable.

h) Panel type, quantity and wall number for MSE panels.

1052.30.7.2 Upon approval, the precaster will receive an identification number. The precast unit shall be clearly and permanently marked by the precaster with the ID number as required by appropriate 1000 specification prior to shipment. Requests for alternate precast labeling shall be submitted to the inspecting District for approval. Material without proper identification number(s) will not be permitted for use on a project.

1052.30.8 Handling, Storage and Shipping. All panels shall be free of chips, discoloration, cracks, fractures, and any other defects determined to be detrimental to the cosmetic value or to the performance characteristics of the panels. The panels shall not be subjected to excessive bending stresses and the panel connection devices and exposed exterior finish shall be protected from damage.

1052.30.9 Documentation. Copies of test results for all required tests, and any other supporting documentation shall be in accordance with Sec 1001.14.

1052.30.10 Delivery. A bill of lading or delivery receipt shall be furnished to the engineer at the destination point. The bill of lading shall contain an itemized statement of the sizes and lengths of precast units with the corresponding MoDOT identification number provided to the manufacturer for each size and type of precast unit for that shipment. The bill of lading shall contain a certified statement. The certified statement shall be signed by an authorized representative of the manufacturer and shall state the following:

“This certifies that the precast products in this shipment are in accordance with MoDOT specifications.”

SECTION 1052.40 DRYCAST MODULAR BLOCK WALL (DMBW-MSE) AND WETCAST MODULAR ~~SMALL~~ BLOCK WALL (WMBW-MSE) SYSTEMS - CONCRETE BLOCKS.

1052.40.1 Scope. This specification covers the concrete blocks used as part of drycast modular block and wetcast modular ~~small~~ block mechanically stabilized earth wall systems. Wet cast modular blocks shall be produced in accordance with Sec 1052.30. Dry cast modular blocks shall be produced at stated below.

1052.40.2 Acceptance. Acceptance will be based upon manufacture test results compliant with the following requirements.

1052.40.2.1 Freeze Thaw Testing. The concrete blocks shall be tested for freeze-thaw durability in accordance with ASTM C1262. Freeze-thaw durability shall be based on tests from five specimens made with the same material, concrete mix design, manufacturing process and curing method conducted not more than 18 months prior to delivery. Test results will be required for each project.

1052.40.2.2 Units that are not exposed to deicing salts shall be in accordance with the following testing requirements. When tested in water, the weight loss of each of five test specimens at the conclusion of 100 cycles shall not exceed 1.0 percent of its initial weight; or the weight loss of each of four of the five test specimens at the conclusion of 150 cycles shall not exceed 1.5 percent of its initial weight.

1052.40.2.3 Test results for units that are exposed to deicing salts shall be tested in a 3 percent saline solution and shall be in accordance with the following:

a) When tested in 3 percent saline solution the weight loss of each of five test specimens at the conclusion of 40 cycles shall not exceed 1.0 percent of the initial weight; or the weight loss of each of four of the five test specimens at the conclusion of 50 cycles shall not exceed 1.5 percent of its initial weight.

1052.40.2.4 Compressive Strength. Acceptance of the compressive strength of the concrete blocks will be based on production lots in compliance with ASTM C140. Acceptance of the compressive strength of a production lot will occur if the compressive strength test results is equal to or greater than the design strength at 28 days. The engineer of record shall evaluate and approve acceptance of deviations below design strength.

1052.40.2.5 Absorption. The manufacturer shall sample and test units based on production lots for absorption in accordance with ASTM C140.

1052.40.2.6 Dimensional Tolerances. Concrete blocks shall be manufactured within the following tolerances:

a) The length and width of each concrete block shall be within 1/8 inch of the specified dimension.

b) The height of each concrete block shall be within 1/16 inch of the specified dimension.

c) When a broken face finish is used, the dimension of the front face shall be within one inch of the theoretical dimension of the concrete block.

1052.40.2.7 Other Criteria. All concrete blocks shall be sound and free of cracks or other defects that would interfere with the proper placement of the blocks or significantly impair the strength or permanence of the construction. At the time of the delivery to the work site the concrete blocks shall:

a) A maximum water absorption of 5 percent

b) Minor cracks incidental to the usual method of manufacture or minor chipping resulting from shipment and delivery will not be grounds for rejection. Minor cracks will be defined as cracks that are no wider than 1/64 inch and no longer than 25 percent of the block height.

c) Any exposed face of a concrete block shall be free of chips, cracks or other imperfections when viewed from a distance of 30 feet under diffused lighting. Up to 5 percent of a shipment may contain slight cracks or small chips no larger than one inch.

1052.40.2.8 Concrete blocks shall not be accepted if any of the requirements specified above or the following defects in physical characteristics are found:

a) Defects indicating imperfect molding.

b) Defects indicating honeycomb or open texture concrete.

c) Cracked or severely chipped blocks.

d) Color variation on front face of blocks.

1052.40.3 Material.

1052.40.3.1 Concrete. Concrete material, proportioning, air entraining, mixing, slump and transporting of concrete shall be in accordance with Sec 501, except as noted in this section. Coloring pigments, integral water repellants, finely ground silica and other constituents shall be previously directed as suitable for use and shall be in accordance with applicable ASTM standards, or evidence shall be provided to prove the product is not detrimental to the durability of the concrete blocks or any material customarily used in masonry construction.

1052.40.3.2 Aggregate. Fine and coarse aggregate for the concrete mixture shall be in accordance with Sec 1005, except that the requirements for gradation and percent passing the No. 200 sieve will not apply.

1052.40.4 Design. The concrete mixture shall have a minimum compressive strength of 4,000 psi at 28 days. The design including all contents of the mixture and curing method shall be submitted to the engineer for approval prior to use.

1052.40.5 Manufacturing

1052.40.5.1 Finish Color. Color and finish shall be as shown on the plans. If no color or finish is specified on the plans, the contractor shall provide a color and finish to the engineer for approval.

1052.40.6 Certification. The manufacturer of the concrete blocks shall certify that the concrete blocks are in accordance with this specification. This certification, copies of test results for all required tests, and any other supporting documentation shall be provided to the engineer prior to the material being shipped to the construction site.

NOTE: EPG articles or portions of articles without changes have been omitted.

321.2.4.4 Light Towers

Cohesive soils

1. Undrained Shear Strength- USS or C from Bowles 1977 using uncorrected blow count N60, preferably Qu/2.

2. Friction Angle from correlation of PI to angle of internal friction minus one standard deviation as published in Navdocks DM-7.

P-Y Curve Parameters

1. K(f) = slope (variation) of linear subgrade modulus. From EPG 751.9 ~~LFD~~Bridge Seismic Design or "Soil Properties (Lpile~~ & Com624P~~)"

2. K(f)cyclic = for cyclic loading

3. E50 = strain at 50 % of the maximum difference in principal stresses, unitless, from Qu test and EPG 751.9 ~~LFD~~ Bridge Seismic Design or "Soil Properties (Lpile~~ & Com624P~~)"

Electro Chemical Parameters

Resistivity is a function of the chloride ion and sulfate ion content and most of the time we will not run this test. To run the test we need about half a materials sack and the sample is entered into site manager.

720.1 Materials Guidance for Sec 720

This guidance establishes procedures for inspection and reporting of drycast modular block wall (DMBW-MSE), wetcast modular block wall (WMBW-MSE) and precast modular panel wall (PMPW-MSE) ~~small and large block~~ mechanically stabilized earth ~~(MSE)~~ wall systems. Inspection of these items covers aggregate, geotextiles, blocks, face panels, reinforcing grids, and other miscellaneous hardware necessary as show on the wall system drawings.

747.2.6.2 Mechanically Stabilized Earth (MSE) Wall Systems

Description. Mechanically stabilized earth wall systems consist of a reinforced soil mass placed behind facing units. Types of MSE wall systems include drycast modular block wall (DMBW-MSE), wetcast modular block wall (WMBW-MSE) and precast modular panel wall (PMPW-MSE)~~small block and large block (panel)~~. Information concerning the types, appropriate uses and design of MSE walls can be found in EPG 751.24.2

Mechanically Stabilized Earth (MSE) Walls. Contractors are responsible for performing the design of MSE walls. Only the wall systems shown in the Bridge Pre-qualified Products listing will be available for use by the contractor.

When NOT to Use MSE Walls. You must have adequate room behind the wall for the reinforcing straps (need horizontal clearance behind the wall of approximately 0.7 times the height or more if seismic loading is considered). You also can NOT use MSE walls in locations where the underlying soil cannot support the weight of the fill and the wall (rare occurrence). This is determined by the District Geologist/Geotechnical Director.

Plans Developed by the District

Plans for MSE walls will be developed by the district unless they go under a bridge, in which case the Bridge Division will develop the plans.

The following table provides an overview of MSE wall design procedure:

Question	Answer
Exceptions	The Bridge Division will still be responsible for producing the plans for any MSE walls that go under a bridge or act as wingwalls for a bridge.
Plans	District will prepare plans for each wall. (See Bridge Standard Drawings – MSE Wall.) The latest notes can be found in EPG 751.50 Standard Detailing Notes~~.~~ and ~~EPG 751.50~~ should be checked often to ensure you are using the most up-to-date notes.
MSE Wall Nos.	District will assign each wall a number using the following system (Dx-000x). Each district will need to keep a log of the wall nos. used. This log should include the beginning station and job no. for each wall no. assigned.
Soundings/Borings	District will submit the Request for Final Soundings for Structure for each wall to the Geotechnical Director in Central Office. The District Geologist should be copied on this request. . For MSE wall (retaining wall) example See Guidance for Request for Final Soundings for Structure Form.
Excavation and Fill Behind the Wall	In Cut walls: The excavation behind the walls shall be included in the roadway excavation quantities and identified with the MSE wall. The quantity and cost of select granular backfill behind the walls is included with the MSE wall pay item. In Fill walls: The quantity and cost of select granular backfill behind the walls is included with the MSE wall pay item. Retained fill beyond the granular select fill shall be included in the roadway excavation quantities. For estimating excavation, see EPG 751.6.2.17 Excavation.
Excavation and Fill Below the Wall	In Cut walls and In Fill walls: If required, the excavation and fill below the walls shall be included in the roadway excavation quantities and identified with the MSE wall. Excavation and fill requirements below the walls is given in the Foundation Investigation Geotechnical Report an identified as “ground improvement” (also

	referred to as "soil improvement", "ground [or soil] mitigation", "foundation replacement" or "foundation excavation"). For estimating excavation, see EPG 751.6.2.17 Excavation.
Seismic	Show seismic ~~performance~~ design category (SDC) and acceleration coefficient (effective peak ground acceleration coefficient), A_s on MSE wall plans. ~~See EPG 751.9.1.3 Seismic Design Force Concepts and EPG 751.9.1.4 for this information or contact the Bridge Division. This is only required for the St. Louis District and Northeast District counties of Bollinger, Butler, Cape Girardeau, Carter, Dunklin, Iron, Jefferson, New Madrid, Madison, Mississippi, Pemiscot, Perry, Ripley, Scott, St. Francois, Ste. Genevieve, St. Louis, Stoddard and Wayne.~~ For LRFD design, The Foundation Investigation Geotechnical Report (FIGR) will provide these values. If A_S > 0.75 then use A_S = 0.75. For LRFD, seismic analysis is determined based on SDC and/or supporting other structure condition. For District MSE walls that do not support another structure (i.e. Not supporting abutment fill or building) in SDC B or C (seismic zone 2 or 3), No-Seismic-Analysis provisions may be considered in accordance with the AASHTO LRFD Bridge Design Specifications 11.5.4.2, and EPG 751.50 J1.5 note shall be shown on the plan details. For MSE walls that support another structure in SDC B or C (seismic zone 2 or 3), Seismic analysis provisions shall not be ignored, and EPG 751.50 J1.4 note shall be shown on the plan details. SDC D retaining walls shall be designed for seismic load and EPG 751.50 J1.4 note shall be shown on the plan details. For SDC B, C, and D (seismic zone 2, 3, and 4) retaining walls EPG 751.50 J1.30 and EPG 751.50 J1.40 note shall be shown on the plan details. Note: The minimum strap length used for estimating excavation quantities for a s~~S~~eismic design wall (0.95H) is greater than Nonseismic (0.7H). For a seismic design wall minimum soil reinforcement length shall be ≥ 0.8H by design. For No-Seismic-Analysis provisions wall use minimum soil reinforcement length = 0.8H to estimate excavation quantities. See EPG 751.6.2.17 Excavation.
Special Provisions	A special provision, "Form Liners", needs to be included as a Design Special Provision for MSE walls. Other information needed is in Sec 720 of the Standard Specifications.
Pay Items	MSE walls typically only have one pay item: 720-10.00 Mechanically Stabilized Earth Wall Systems. This is bid per square foot and will now be a Roadway Item when the districts do the plans and a Bridge Item when the Bridge Division does the plans. Other pay items may include form liners, color stain, masonry protector and graffiti protector.
Shop Drawings	Do NOT send to the Bridge Division. Shop drawings will be signed and sealed by a Missouri PE and the Resident Engineer will handle them like other shop drawings that aren't submitted to Central Office.
Engineering Policy Guidelines (EPG)	The Bridge Division will continue to maintain EPG 751.24 ~~LFD~~ Retaining Walls. Districts have access to this on the internet.

Approved Systems	The Bridge Division will continue to be responsible for reviewing and approving systems from manufacturers.
Historical Plans	The MSE wall plans will be part of the roadway plans so they will be scanned and saved in the same manner.
Drainage	For longitudinal drain pipes use two-6" (min.) diameter perforated PVC or PE pipes (Sec 1013) unless larger diameter pipes required by design which shall be the responsibility of the district Design division. Lateral drain pipes permitted by specification shall be sized by the district Design division. See EPG 751.24.2.1 Mechanically Stabilized Earth Walls (MSE).
Aesthetics	For ~~large block~~ precast modular panel wall systems only, form liners are required to produce all panels. Standard form liners are specified on the Bridge Standard Drawings - MSE Wall Concrete staining is another aesthetic treatment available for any type MSE wall. Be specific regarding names, types and colors of staining, and names and types of form liner.
Help	Contact the Bridge Division. The Bridge Division contact person for any questions or concerns about MSE walls is Structural Resource Manager or Structural Development and Support Engineer.

For estimating excavation, see EPG 751.6.2.17 Excavation.

The table below shows division responsibilities for preparing MSE wall plans, computing excavation class, quantities and locations, and drainage design.

Responsibilities	**MSE Wall Plans Preparer**		**Excavation Class, Quantities and Locations, Sec 203 (behind wall)**		**Ground Improvement Excavation Class, Quantities and Locations, Sec 203 (below wall)**		**Drainage Design: Top of Wall and Bottom of Wall**	
Division MSE Wall	**District Design**	**Bridge Division**	**District Design[1]**	**Bridge Division**	**District Design[2]**	**Bridge Division[3]**	**District Design[4]**	**Bridge Division**
District Design Division	√	---	√	---	√	---	√	---
Bridge Division	---	√	√	---	√	Locations only	√	---

1 Class and Quantities shown on 2B sheets and identified with MSE wall and excavation locations along wall shown on roadway plans.	
2 Class and Quantities shown on 2B sheets and identified with MSE wall and excavation locations along wall shown on MSE wall plans with associated allowable bearing pressure.	
3 Locations along wall shown on MSE wall plans with associated allowable bearing pressure.	
4 See EPG 751.24.2.1 Mechanically Stabilized Earth Walls (MSE).	

Minimum Embedment Depth of MSEW - Minimum embedment is defined as the distance between the finished ground line and the top of the leveling pad. It is based on this table (FHWA--NHI-10-024, Table 2-1 and LRFD 11.10.2.2 Demo. #82):

Slope in Front of Wall	Minimum Embedment Depth to Top of Leveling Pad
All Geometries	2 ft minimum
Horizontal (walls)	H/20
Horizontal (abutments)	H/10
3H:1V:3H	H/10
2H:1V:2H	H/7
1.5H:1V	H/5

Where,

H:V = Horizontal to vertical slope in front of the wall

H = Height of the wall as measured from the top of the leveling pad to the top of the wall

The absolute minimum embedment is 2 ft except when rock is found near surface. When the soundings are returned from the Geotechnical Director, they will include a minimum embedment depth to the top of leveling pad, minimum soil reinforcement length necessary for global stability, bearing resistance and settlement requirements. If rock is encountered during excavation then the contractor shall immediately cease excavating and notify the engineer and contact Geotechnical Section to perform global stability and suggest a required minimum embedment depth to the top of leveling pad and required minimum soil reinforcement length.

Category:751 LRFD Bridge Design Guidelines

Bridge Design Guidelines assist MoDOT's internal staff and outside consultants in performing design work for the department. It is intended to disseminate information regarding practices and policies to be applied to the design of Missouri structures on the state maintained system.

It is the users responsibility to verify the design information presented is applicable to their particular project or situation.

These guidelines are not intended to limit the designer or consultant from applying innovations which will lead to a more cost effective and technically sound solution as appropriate for the situation at hand. The evaluation of alternate solutions include such innovations is both expected and encouraged. However, any variations to EPG 751 or Standard Plan Sheets should be discussed in advance with the appropriate Structural Liaison Engineer or Structural Project Manager.

The following notation is used throughout these guidelines:

"LRFD XXX" refers to AASHTO LRFD Bridge Design Specifications.
"SGS XXX" refers to AASHTO Guide Specifications for LRFD Seismic Bridge Design.

"LFD XXX" refers to AASHTO Standard Specifications for Highway Bridges, 17th Ed. - 2002.

"Sec" refers to Missouri Standard Specifications for Highway Construction.

It should be noted that the Federal Highway Administration has mandated for state owned structures:

- All new and replacement bridges, culverts, retaining walls and other structures on which states initiate preliminary engineering shall be designed in accordance with ~~after October 1, 2007, shall be designed by the~~ LRFD and SGS~~Specifications~~.
- ~~All new culverts and other standard structures on which states initiate preliminary engineering after October 1, 2010, shall be designed by LRFD (Load and Resistance Factor Design) Specifications, with the assumption that the specifications and software for these structures are "mature" at this time.~~
- ~~All new retaining walls shall be designed using 2002 AASHTO LFD (17th Edition) standard specifications.~~

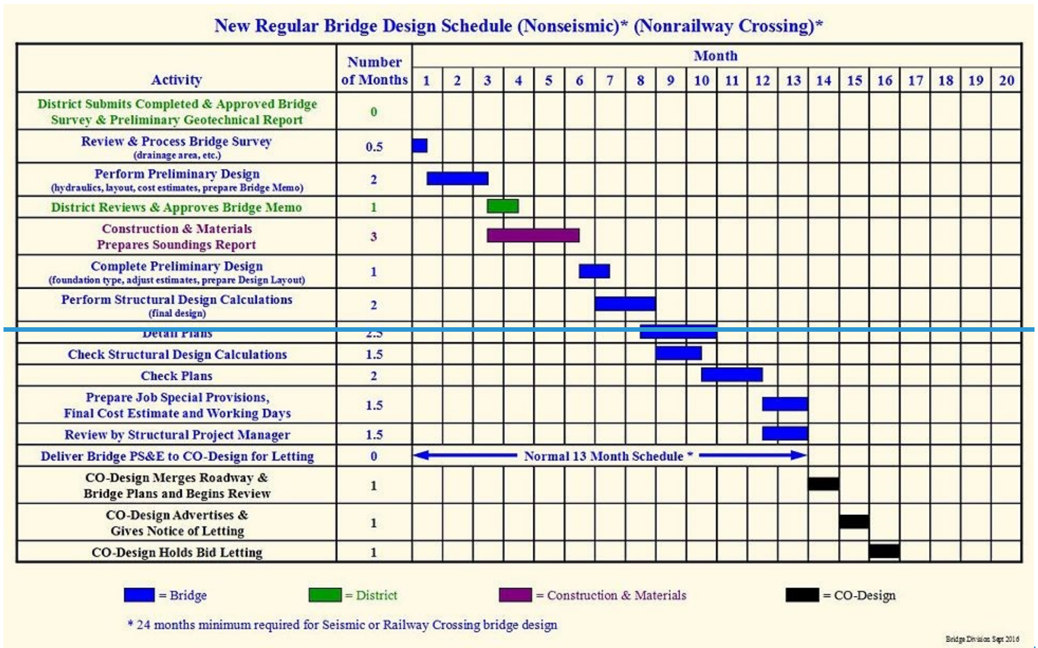
- For modifications to existing structures, states ~~would~~ have the option of using LRFD and SGS Specifications or the specifications that ~~which~~ were used for the original design. Generally modifications to bridge projects on the state system include but are not limited to rehabs, redecks, superstructure replacements and widenings. If widening require additional substructure or modification to existing substructure than whole structure shall be analyzed in accordance with LRFD and SGS specification.

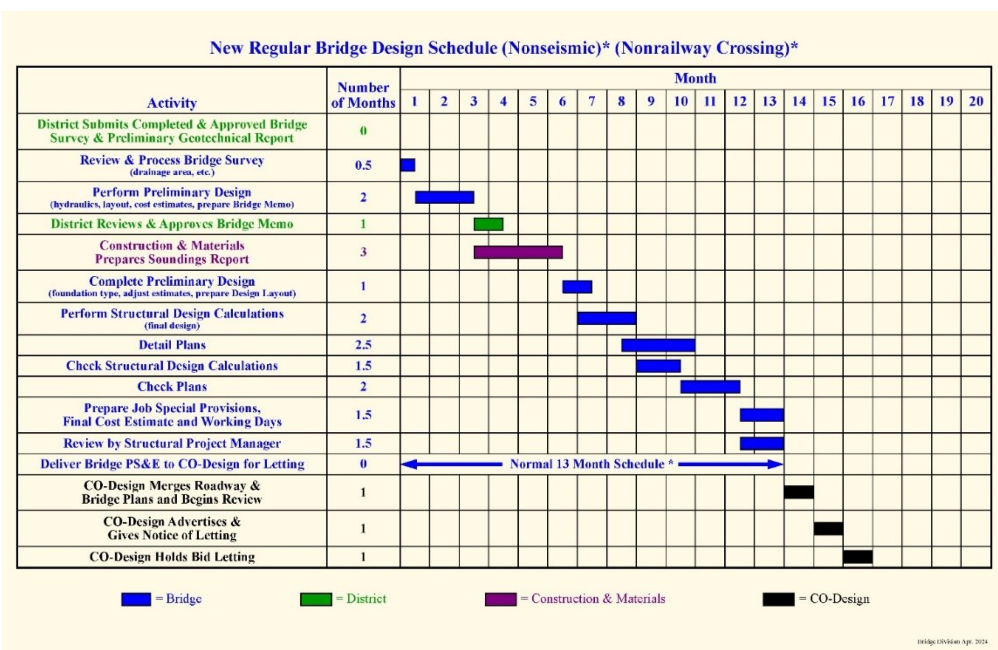
~~The following notation is used throughout these guidelines:~~

~~"LRFD XXX" refers to AASHTO LRFD Bridge Design Specifications.~~

~~"Sec" refers to Missouri Standard Specifications for Highway Construction.~~

751.1.1.5 New Regular Bridge Design Schedule (Nonseismic) (Nonrailway Crossing)





*13 months minimum required for multi-span bridge design with seismic details or seismic details and abutment seismic design. 13 months minimum required for single-span bridge design with abutment seismic design or seismic details. 24 months minimum required for complete seismic analysis of multi-span bridge design. 24 months minimum required for Railway Crossing bridge design.

751.1.2.2 Wing Lengths

The purpose of wings is to contain and stabilize the abutment fill as the roadway transitions to the bridge. For stream crossings in particular, the wings also protect the abutment during extreme hydraulic events.

The lengths of the wings at the end bents are to be determined prior to the issuance of the Bridge Memorandum. There are two reasons for this. First, the district will use these lengths to determine the placement of their guardrail (bridge anchor section). Second, if the lengths of the wings exceed 22 ft. for seismic design category A or 17 ft. for seismic design category B, C or D, they will have to be broken into a stub wing and a detached wing wall. If this happens, then you will need to include this extra cost in your Preliminary Cost Estimate and request soundings for the wall. The request for soundings for the wall should include a request for the determination of the allowable bearing of the soil (if in cut - assume piling if it is in fill) and the angle of internal friction for the material retained by the detached wing wall. Also include the bottom of wing footing elevation.

In order to use a standard end section for Type D barrier on a short turned-back wing, consider increasing the wing length so that the barrier end section is at least 8 feet long.

751.1.2.13 Seismic (Earthquake ~~(Seismic~~) Design Category A, B, C and D Considerations

See EPG 751.9 Bridge ~~756~~ Seismic Design for ~~flowcharted~~ seismic design and detail requirements in accordance with SGS and LRFD. Utilize provided flow charts.

All new or replacement bridge/wall designs, either nonseismic (meaning a regular static design) or seismic design or detail, must meet Seismic Design Category (SDC) A requirements in accordance with SGS (Seismic Zone 1 of LRFD). Additionally, where applicable, bridge seismic ~~which includes nonseismic (or static)~~ designs/details/analysis must meet requirements of ~~unless~~ the ~~seismic design category is B, C, or D. If the structure you are laying out falls in~~ Seismic Design Category B, C or D~~,~~ in accordance with Bridge Seismic Design Flowchart ~~there are a few items to keep in mind~~.

For laying out new or replacement bridges in SDC A, B, C or D (per SGS), the following is important.

- Box culverts are preferable to bridges on stream crossings because they are exempt from seismic design unless crossing a known exposed fault.
- Pile cap intermediate bents and drilled shafts are preferable to open column bents on footings because footings can grow quite large due to seismic forces.
- Minimize the number of expansion joints in the deck because each of these locations may require earthquake restrainers which are very costly.
- Make the superstructure as light as possible, which usually means use steel plate girders or wide flanges instead of prestressed concrete girders where possible.

~~Go to https://earthquake.usgs.gov/designmaps/us/application.php and use the following instructions to determine the LRFD Seismic Design Category:~~

~~Instructions:~~
~~1. For "Design Code Reference Document", **select** "Derived from USGS hazard data available in 2002" followed by "2009 AASHTO".~~
~~2. For "Site Soil Classification", **select** "Site Soil Classification" (Select Site Class "A, B, C, D or E" for preliminary design per Geotechnical Section recommendation or for final design as given on Foundation Investigation Geotechnical Report.~~
~~3. For "Site Latitude" and "Site Longitude", **input** coordinates or alternatively **input** address or zip code in the map area.~~

The new or replacement bridge design schedule for a complete seismic bridge requires 24 months minimum and bridge design schedule for seismic details and/or abutment seismic design requires 13 months minimum. Additional 2 - 3 months is required for review and letting process before the schedule letting. See EPG 751.1.1.5 New Regular Bridge Design Schedule (Nonseismic) (Nonrailway Crossing).

751.1.2.17 Preliminary Cost Estimate

- **Box Culverts –** A new or replaced box culvert is exempt from seismic design unless crossing a known exposed fault. Submit "Request for soil properties Form A" to Geotech Section and design as a SDC A. If box culvert is crossing a known exposed fault then discuss with Structural Project Manager (SPM) for alternate option.
- **Bridges and Retaining Walls –** For a new or replaced retaining wall or bridge, review Bridge Seismic Planning Flowchart, Bridge Seismic Design Flowchart, preliminary seismic design map and following information.

  Seismic design of overpass should be considered when overpass bridge collapse would greatly impede emergency traffic for the main route. (i.e., No access ramps on a major route or a 1st or 2nd priority earthquake emergency route).

  - For preliminary planning and cost estimate use the SDC values shown on preliminary seismic design map . SDC boundaries are shown for soil site class D.
  - Site class verification is not required for bridges located in regions SDC A1 or A2, so the preliminary SDC shall be used for plans reporting.
  - In the normal design schedule, the Geotechnical section will determine the site class and an accurate SDC, S_{D1}, A_s for bridges located in the regions encompassed by SDC B, C and D on the preliminary seismic design map. Typically, the SDC will remain the same as shown on the map or get dropped to a lower SDC (e.g., D to C, C to B, B to A2).
  - If a bridge gets downgraded to SDC A2 after Geotech analysis and carry a 1st or 2nd priority earthquake emergency route, the bridge shall receive seismic details similar to SDC B. If a bridge gets downgraded to SDC A2 after Geotech analysis and does not carry a 1st or 2nd priority route, it will not require seismic details. If a bridge gets downgraded to SDC A1 after Geotech analysis, it will not require seismic details. Typically, downgrades may result in a reduced project schedule and/or a reduced cost estimate for the bridge.
  - Geotechnical section will perform a liquefaction assessment for bridges with a final SDC of C or D and carry a major route or 1st or 2nd priority earthquake emergency route.

Seismic design category (SDC) is divided in SDC A (S_{D1} < 0.15), SDC B (0.15 ≤ S_{D1} < 0.30), SDC C (0.30 ≤ S_{D1} < 0.50) and SDC D (S_{D1} ≥ 0.50). SDC A is subdivided into SDC A1 (S_{D1} < 0.10) and SDC A2 (0.10 ≤ S_{D1} < 0.15). Submit "Soil properties Form A" to Geotech Section for SDC A1 and SDC A2 area bridges, retaining walls and box culverts. Submit "Soil properties Form A" and "Soil properties Form B" to Geotech Section for SDC B, C and D area bridges and retaining walls. For soil properties form, see EPG 751.1.2.19 Soundings (Borings).

The Preliminary Cost Estimate should be neat, legible and dated since a copy of it is included with the Bridge Memo. It should also be rounded to the nearest thousand dollars.

The accepted method of calculating the Preliminary Cost Estimate is to calculate some approximate quantities for the bridge and then multiply them by the unit prices supplied by the Bridge Division Preliminary and Review Section. A spreadsheet should be used to calculate these quantities. To estimate the pounds of reinforcing steel in a structure, multiply the number of cubic yards of concrete in the structure by 125 for bridges. See table below for Box Culverts.

Table 751.1.2.17, Box Culvert Reinforcing Steel (lbs.) Estimate	
Design Fill (ft.)	Concrete (lbs/cy) Multiplier
2.00	225
6.00	168
10.00	116
25.00	96
32.00	84

The Preliminary Cost Estimate should be increased for the following items: Cost Estimate Guide for rural preliminary design (do not compound all ~~the~~ increases ~~by~~ using your judgment).

Bridge in SDC boundaries on preliminary seismic design map	% Cost increase	Comments for final SDC
SDC A1 SDC A2 (nonseismic) SDC A2 (seismic details)	0 0 10	No cost increase for SDC A1 area bridges and most of the bridges in SDC A2 area. If a bridge carry a 1st or 2nd priority earthquake emergency route and located in SDC A2 area, it will receive seismic details similar to SDC B (i.e. 10% increase).
SDC B (single span, seismic details) SDC B (single span, abutment seismic design) SDC B (multi-span)	0 5 10	Cost increase is for seismic details in accordance with the 2023 AASHTO Guide Specifications for LRFD Seismic Bridge Design. If bridge receives a final SDC B and carries a major route or 1st or 2nd priority earthquake emergency route then abutments will be designed for mass inertial forces per SEG 24-02. (i.e. 0 to 5% increase for single span bridges). If a bridge gets downgraded to SDC A2 and does not carry a 1st or 2nd priority route, it will not require seismic details. If a bridge gets downgraded to SDC A1 after Geotech analysis, it will not require seismic details (i.e. no cost increase).
SDC C (single span, seismic details) SDC C (single span, abutment seismic design)	0 5 10	25% cost increase is for complete seismic analysis. All bridges receiving a final SDC C and not carrying a major or 1st or 2nd priority earthquake emergency route will only receive seismic details (i.e. 10% increase). If a bridge carry a major route or 1st or 2nd priority earthquake emergency route, gets downgraded to SDC B, it will only receive seismic details and abutments will be designed for mass inertial forces per SEG 24-02 (i.e. 10% increase).If single span bridge receives a final SDC C and carries a major route or 1st or 2nd priority earthquake emergency route

SDC C (multi-span, seismic details) SDC C (multi-span, complete seismic analysis)	25	then abutments will be designed for mass inertial forces per SEG 24-02 (i.e. 0 to 5% increase).
SDC D (single span, seismic details) SDC D (single span, abutment seismic design) SDC D (multi-span, seismic details) SDC D (multi-span, complete seismic analysis)	0 10 10 40	40 % cost increase is for complete seismic analysis. All bridges receiving a final SDC D after Geotech analysis and do not carry a major or 1st or 2nd priority earthquake emergency route will only receive seismic details (i.e. 10% increase). If a bridge carry a major route or 1st or 2nd priority earthquake emergency route, gets downgraded to SDC B, it will only receive seismic details and abutments will be designed for mass inertial forces per SEG 24-02 (i.e. 10% increase). If a bridge carry a major route or 1st or 2nd priority earthquake emergency route, gets downgraded to SDC C, it will receive a complete seismic analysis (i.e. 25% increase). If single span bridge receives a final SDC C or D and carries a major route or 1st or 2nd priority earthquake emergency route then abutments will be designed for mass inertial forces per SEG 24-02 (i.e. 5 to 10% increase).

Item	% Cost iIncrease
Staged Construction (SDC A)	10
Horizontally Curved (SDC A)	5
Seismic Performance Cat B	10 *
Seismic Performance Cat C	25 *
Seismic Performance Cat D	40 *
Tight Site/Limited Access	3

*These factors assume estimated quantities have not been increased due to seismic forces.

The following are some guidelines for estimating the cost of the removal of existing bridges include:

Type of Bridge Removal	Cost per Square Foot
Simple Structures Over Streams	**
Girder Structures Over Roads	**

Conc. Slab Structures Over Interstates **

(qQuick opening of lanes to traffic)

** Consult Bid Tabs for an analysis of the latest bridge removal costs. Bridge Division staff may consult the Pay Item Spreadsheet maintained by the Structural Preliminary and Review Engineer or see EPG 751.6.1 Index of Quantities.

751.1.2.18.2 Content

Sample listing of what to include on the Bridge Memorandum:

1. Identify the following classifications if applicable: (*Design Implications*)

- All routes involved shall be classified as either:

o (major), as shown in link.
o (minor), not a major route and ADT ≥ 400.
o (low volume), not a major route and ADT < 400.

- Major bridges with a total length ≥ 1000 feet shall be classified by specifying "(major)" behind the specified bridge number.
- Priority 1 or 2 earthquake emergency routes shall be classified by specifying "(priority 1 2 EQ)" behind the route classification.

2. Identify type of structure, span lengths, skew, loading, roadway width, wing lengths and special end fill considerations. For curved structures, specify how the design span lengths are to be measured i.e., "measured along the CL of Roadway". If plate girder or wide flange beam, further identify them as either weathering or painted steel.

3. Indicate all pertinent profile grade, alignment and superelevation transition information.

24. Form liners are standard for MSE precast modular panel wall systems large block walls. Be specific regarding names, types and colors of staining, and names and types of form liner. See Bridge Standard Drawings – MSE Wall - MSEW.

25. For MSE wall supporting abutments fill: Identify gutter type, fencing, lower longitudinal and lateral drain pipe sizes (type and sizes to be determined by district Design division). (Lateral drain pipes are only required as determined by district Design division.)

26. OPTIONAL Seismic Information for new bridge or wall on Memo: Note "Preliminary Seismic Description: Site Class _, Seismic Design Category _, A_s = __, S_{D1} = _," _____". The last blank should be filled with "non-seismic", "seismic details", "abutment seismic design", "seismic details with abutment seismic design" or "complete seismic analysis". The provided information is subject to change that would require Geotechnical Section input regarding the Site Class and Seismic Design Category used for cost estimating after Geotechnical Report is released. See Bridge Seismic Planning Flowchart. (This is similar to item no. 9 under EPG 751.1.2.31 Finishing Up Design Layout.)

27. For rehabs, redecks, widenings, recoatings and new replacement structures, see EPG 751.1.3.9 Environmental Considerations: Asbestos and Lead for notes to include.

751.1.2.**19**.3 Required Documents

Request for Soil Properties – The request for soil properties is located on a separate tab in the Request for Final Soundings for Structures form.

Bridges – If there is a possibility that drilled shafts will be used, request borings based on using drilled shafts so the appropriate lab work can be done the first time.

MSE Walls – The request for soundings for MSE walls should include requests for the angle of internal frictions (Ø) for both the foundation (improved and unimproved) and the retained material.

751.1.2.19.4 Submittal

The completed Request for Final Soundings ~~o~~for Structures F~~f~~orm and the other supporting documents listed above should be stored ~~on the Bridge Division SharePoint page in the Projects-Inwork directory under the structure's subfolder~~in the project's corresponding eProjects folder. (Consultants should contact the Structural Liaison Engineer).

A request for soundings should be sent by email to the Construction and Materials Division. The email shall be addressed to the Geotechnical Engineer and copied to the Geotechnical Director and the Structural Project Manager (or the Structural Liaison Engineer). It should include at a minimum, a link to the SharePoint folder that contains the completed Request for Final Soundings ~~o~~for Structures Form and supporting documents. In addition to the SharePoint link, any relevant information that may aid the Geotechnical Section in providing the requested borings should be included.

The request for soundings is typically done at the same time that the Bridge Memorandum is sent to the district.

751.1.2.19.4.1 Sounding Information for Seismic Category A, B, C and D

For all new or replacement bridges or walls or structure modification for widening submit Request for Final Soundings for Structures Form **(Soil Properties Form A and AASHTO LRFD (SGS) Form B**) for LRFD projects. Based on following procedure Geotechnical Section will determine SDC for structures located in SDC B, C and D on Preliminary Seismic Design Map. For all new or replacement box culverts on rock submit Request for Final Soundings for Structures Form (Soil Properties Form A)**.**

Geotechnical Section will determine S_{D1} = _, A_S = _, and SDC = _ using (NSHMP Static Data Services (usgs.gov) website. The risk-targeted design spectra returned by this web service are derived from the USGS 2018 National Seismic Hazard Model for the conterminous United States. Designer should use same procedure to create response spectra for bridge seismic design or verifying SDC using Geotechnical section reported site class.

For example see: Example 1_SDC_Response_Spectra

751.1.2.31 Finishing Up Design Layout

Design Layouts shall be generated for new bridges, retaining walls and when foundation work is required for bridge widenings. Otherwise, Design Layouts are not utilized for conveyance of information related to rehabilitation projects, or work on existing bridges or, more generally, on structures.

Once the Preliminary Detailer has created the Design Layout Sheet and added the borings and details of the proposed bridge to the plat and profile sheets, they should be checked by the Preliminary Designer. These sheets are the end product of the Preliminary Design process and will be used to perform the structural calculations for the Final Design phase of the bridge, which results in the production of the contract plans. Here is a list of items to include.

1.) General Information

a. Route and structure classifications

b. Live load designation

c. Traffic counts for the design year (AADT and AADTT).

d. Tie station (if applicable).

e. Beginning station.

f. Horizontal curve data.

g. Profile grade information (including offset from CL of roadway or median).

h. Excavation datum.

2.) Superstructure

9.) Seismic Information (New or Replacement Bridge, substructure widening or Wall) (Applies to both seismic ~~dynamic~~ and ~~static~~ nonseismic designs):

a. Provide Site Class, Seismic Design Category, A_S~~,~~ and S_{D1} for SDC B, C and D bridge/wall, and Liquefaction Potential information for SDC C and D (All available information from Geotechnical report). When A_s is greater than 0.75 then show A_s = 0.75. For SDC A area bridge/wall indicate SDC A, S_{D1} < 0.15 and A_s = N/A. Use N/A if not reported in Geotech report. ~~.~~

b. Indicate e~~E~~ither "Nonseismic", "~~LRFD~~ Seismic Details ~~Only~~" ~~or "LRFD Complete Seismic Analysis"~~, "Abutment Seismic Design", "Seismic Details plus -Abutment Seismic Design" or "Complete Seismic Analysis" for a bridge structure based on Geotechnical Section provided SDC and Bridge Seismic Design Flowchart (EPG 751.9.1 Seismic Analysis and Design Specifications).

- For final SDC A2 from Geotechnical report, indicate "Seismic Details" if bridge carries a 1st or 2nd priority earthquake emergency route. For final SDC A2 bridge indicate SDC A on design layout.
- For final SDC B from Geotechnical report, indicate "Seismic Details plus Abutment Seismic Design" if bridge carries a major or 1st or 2nd priority earthquake emergency route otherwise indicate "Seismic details".

- For final SDC C or D from Geotechnical report, indicate "Complete seismic analysis" if multi-span bridge carries a major or 1st or 2nd priority earthquake emergency route otherwise indicate "Seismic details". For final SDC C or D from Geotechnical report, indicate "Abutment Seismic Design" if single-span bridge carry a major or 1st or 2nd priority earthquake emergency route otherwise indicate "Seismic details ".

c. For a wall structure in SDC B, or C seismic analysis provisions shall not be ignored for walls that support another structure (i.e. abutment fill or building) in accordance with LRFD 11.5.4.2. Based on wall supporting information and Geotech report indicate "seismic analysis not required" or "seismic analysis required". SDC D retaining walls shall be designed for seismic load.

dc. For Nonseismic (or static) designs, Seismic Design Category A, A_s, S_{D1} (All new or replacement bridge/wall designs, either nonseismic (meaning a regular static design) or seismic design or detail, must meet Seismic Design Category (SDC) A requirements in accordance with SGS (Seismic Zone 1 of LRFD). Additionally, bridge/wall seismic designs/details must meet requirements of the Seismic Design Category B, C, or D where applicable. See EPG 751.1.2.13 Seismic (Earthquake (Seismic) Considerations.)

10.) Miscellaneous

-

1 Drain basins can be included with concrete approach pavement per district. (Rdwy. Item)

2 Show maximum of total scour depths estimated for multiple return periods in years from Preliminary design which should be given on the Design Layout. Show the controlling return period (e.g. 100, 200, 500) in Foundation Data. If return periods are different for different bents, add a new line in Foundation Data. On the plans report note EPG 751.50 E2.22 for CIP pile.

3 Show for open ended CIP piles. For scour condition, minimum cleanout elevation shall be at least 3 feet below maximum estimated scour depth. For non scour condition, minimum cleanout elevation shall be at least 10 feet below natural ground line.

751.1.4.2 Types of Walls

For walls on rock or very competent foundation soil, e.i., SPT > 50, the Bottom reinforcements may be shortened to a minimum of (greater of 0.4H or 5 ft) with the Upper reinforcements lengthened to compensate for external stability issues in lieu of removing rock or competent soil for construction. Design Guidelines for this case are provided in FHWA Publications No. FHWA-NHI-00-04310-024 (Elias et al. 2001).

For conditions of marginal stability, consideration must be given to ground improvement techniques to improve foundation stability, or to lengthening of reinforcement.

MSE walls are pre-qualified and listed on the internet in two three categories:

- Drycast modular block wall (DMBW-MSE) systems~~Small block walls~~
- Wetcast modular block wall (WMBW-MSE) systems
- Precast modular panel wall (PMPW-MSE) systems ~~Large block walls~~

Drycast modular block wall systems~~Small block walls~~ are battered walls with a maximum height of 10 feet. Drycast modular block wall systems have five major components: Dry cast modular blocks, pre-approved geogrid soil reinforcements, select granular backfill, unit fill and nonreinforced concrete leveling pad.

Wetcast modular block wall systems are battered walls with a maximum height of 15 feet. Wetcast modular block wall systems have five major components: Wetcast modular blocks, pre-approved geogrid soil reinforcements, select granular backfill, unit fill and nonreinforced concrete leveling pad.

Precast modular panel wall systems ~~Large block walls~~ are vertical walls with heights that may exceed 10 feet. Precast modular panel wall systems have five major components: Precast modular panels, pre-approved soil reinforcements, anchorage devices, select granular backfill, and nonreinforced concrete leveling pad.

~~Combination wall systems are considered small block wall system and shall be battered with a maximum height of 10 feet.~~

Aesthetic enhancements may be used for either CIP or MSE walls. If EPG 751.1.2.33 A~~a~~esthetic ~~e~~Enhancements are required by the district, form liners and concrete stains are encouraged rather than actual brickwork and stonework since form liners and concrete stains typically need less maintenance, less loading, less detailing, no extra support ledge and produce no risk of delaminations or falling work. However, for MSE precast modular panel wall systems~~large block walls~~ only, form liners are required for all panels. For additional information, see EPG 751.24.2 Mechanically Stabilized Earth (MSE) Walls.

Any deviation from the criteria listed shall be discussed with Structural Project Manager.

751.1.4.3 MSE Walls

Generally, both the horizontal alignment and the top of wall elevations are supplied by the district in the Bridge Survey. You do need to check the top of wall elevations to make sure the district accounted for any concrete gutters placed behind the top of the wall (Gutters are necessary if the slope of the fill can direct water towards the top of the wall, i.e., positive sloping and flat backfills). The district should decide whether to use Type A or Type B gutters (Standard Plan 609.00), or Modified Type A or Modified Type B gutters (Standard Plan 607.11) if fencing is required, and where they should drain (to be shown on roadway plans). For general guidelines, see EPG 751.24.2 Mechanically Stabilized Earth (MSE) Walls.

You will also need to set the elevations for the top of the leveling pad. The minimum embedment depth of MSEW, which is the distance between the finished ground line and the top of the leveling pad, is based on this table: (FHWA-NHI-10-024, Table 2-1 and LRFD 11.10.2.2~~ Demonstration Project 82~~)

Slope in Front of Wall	**Minimum Embedment Depth to Top of Leveling Pad**
All Geometries	2 ft minimum
Horizontal (walls)	H/20
Horizontal (abutments)	H/10

3H:1V	H/10
2H:1V	H/7
1.5H:1V	H/5

Where,

H:V = Horizontal to vertical slope in the front of the wall
H = Height of the wall as measured from the top of the leveling pad to the top of the wall

The absolute minimum embedment is 2 ft except when rock is found near surface. When the soundings are returned from the Geotechnical Director, they will include a minimum embedment depth to the top of leveling pad, minimum soil reinforcement length necessary for global stability, bearing resistance and settlement requirements. If rock is encountered during excavation then the contractor shall immediately cease excavating and notify the engineer and contact Geotechnical Section to perform global stability and suggest a required minimum embedment depth to the top of leveling pad and required minimum soil reinforcement length.

Preliminary cost estimating MSE walls is based on the unit price bid history and on the square footage of the area of the face of the wall. The unit price per square foot of wall includes wall elements, leveling pad and backfill. Excavation and retained fill are not included.

751.1.4.4 CIP Concrete Walls

For details on requesting soundings, see EPG 751.1.2.20 19 Soundings (Borings).

If you have indications that the foundation material is very poor in quality (less than 1 ton per sq. ft. allowable bearing), consider piling and include in the Preliminary Cost Estimate. Preliminary cost estimating should follow EPG 751.1.2.18 17 Preliminary Cost Estimate and be based upon unit price bid history. More refined cost estimating should follow cost-basing estimating.

751.2.2.6 Other Loads

Earthquake, EQ EQ

See EPG 751.9 BridgeLFD Seismic Design. Ffor seismic design concepts and guidance for earthquake loads follow LFD seismic process and modify as necessary for SGS/LRFD seismic. SeeEPG 756 Seismic Design.

All new bridge/wall designs including nonseismic (or static) and seismic new or replacement bridge designs mustshall be required to meet the Seismic Design Category (SDC) A requirements in accordance with SGS (Seismic Zone 1 of LRFD) in accordance with AASHTO Guide Specifications for LRFD requirements. Additionally, provide seismic details only or perform seismic design of the abutments for SDC B, C and D region bridges or perform complete seismic analysis for SDC C and D region bridges in accordance with Bridge Seismic Design Flowchart. Seismic Bridge Design.

Vehicular Collision Force, CT

751.2.4.2 Live Load Deflection

The following recommendations are for new LRFD bridges. Existing bBridges currently designed by the LFD method should be discussed with the Structural Project Manager or Liaison Engineer as to the appropriate approach. Widenings and rehabs will be handled on a case-by-case basis.

Live Load Deflection criteria shall be according to AASHTO LRFD 2.5.2.6.2..

751.5.5 Culvert Sheets

Detailing Guidance
EPG 751.8 ~~LRFD~~ Concrete Box Culverts

Bridge Standard Drawings
~~New~~ Box Culverts ~~and Extension Details~~

751.5.6 Retaining Wall Sheets

Detailing Guidance
EPG 751.24 ~~LFD~~ Retaining Walls

Bridge Standard Drawings

MSE Wall

751.5.9.2.5 Spacing Limits

Minimum & Maximum Pitch- Spiral Reinforcement for Compression Members (Seismic)
See EPG 751.9 ~~LFD~~ Bridge Seismic Design

751.6.2.17 Excavation

Excavation Limits: Mechanically Stabilized Earth Walls (MSEW)

Excavation behind and below MSEWs are roadway pay items and based on information given in the Foundation Investigation Geotechnical Report (FIGR). Included may be a minimum soil reinforcement length, minimum embedment of the bottom of wall (top of leveling pad), global stability confirmation and angle of retained backfill which are used to estimate the excavation quantities. Use greatest of recommended minimum soil reinforcement length from

- FIGR, or
- the following table, or
- 8 ft. minimum.

One additional foot must be added to the selected length to determine estimated excavation quantities.

	MoDOT (USE)	**Table 2-1 (FHWA NHI-10-024) (REFERENCE)**
Case	**Minimum Length of Soil Reinforcement, L**	**Minimum Length of Soil Reinforcement, L**
Static loading with or without traffic surcharge	0.7H	0.7H
Sloping backfill surcharge	0.8H	0.8H
Seismic loading	0.95H[1]	0.8H to 1.1H

[1] For a seismic design wall use 0.95H to estimate excavation quantities. For a seismic design wall minimum soil reinforcement length shall be ≥ 0.8H by design. For No-Seismic-Analysis provisions wall use minimum soil reinforcement length = 0.8H to estimate excavation quantities.

Where,

H = Height of the wall as measured from the top of the leveling pad to the top of the wall

Note: For seismic requirement uUpper two layers of soil reinforcement shall be extended 3 feet to 5 feet beyond the lower layers when wall height is greater than or equal to 10 feetfor seismic requirement. (FHWA NHI-10-024 section 4.4.3)

Minimum soil reinforcement length shall be greater than or equal to as required for a stable feature wall for strong/stable rock as shown in following cases 5 through 7.

Minimum Embedment Depth of MSEW- Minimum embedment is defined as the distance between the finished ground line and the top of the leveling pad. It is based on this table (FHWA-NHI-10-024, Table 2-1 and LRFD 11.10.2.2):

Slope in Front of Wall	**Minimum Embedment Depth to Top of Leveling Pad**
All Geometries	2 ft minimum
Horizontal (walls)	H/20
Horizontal (abutments)	H/10
3H:1V	H/10
2H:1V	H/7
1.5H:1V	H/5

Where,

H:V = Horizontal to vertical slope in front of the wall

H = Height of the wall as measured from the top of the leveling pad to the top of the wall

The absolute minimum embedment is 2 ft except when rock is found near surface. When the soundings are returned from the Geotechnical Director they will include a minimum embedment depth to the top of leveling pad, minimum soil reinforcement length necessary for global stability, bearing resistance and settlement requirements. If rock is encountered during excavation then the contractor shall immediately cease excavating and notify the engineer and contact Geotechnical Section to perform global stability and suggest a required minimum embedment depth to the top of leveling pad and required minimum soil reinforcement length.

751.8 ~~LRFD~~ Concrete Box Culverts

751.9 ~~LFD~~ Bridge Seismic Design

751.9.1 Seismic Analysis and~~&~~ Design Specifications

Additional Information

Bridge Seismic Design Flowchart

All new or replacement bridges on the state system shall include seismic design and/or detailing to resist an expected seismic event per the Bridge Seismic Design Flowchart. For example, for a bridge in Seismic Design Categories A, B, C or D, complete seismic analysis or seismic detailing only may be determined as per “Bridge Seismic Design Flowchart”.

Missouri is divided into four Seismic Design Categories. Most of the state is SDC A which requires minimal seismic design and/or detailing in accordance with SGS (Seismic Zone 1 of LRFD) and “Bridge Seismic Design Flowchart”. The other seismic design categories will require a greater amount of seismic design and/or detailing.

For seismic detailing only:

When A_S is greater than 0.75 then use A_S = 0.75 for abutment design where required per “Bridge Seismic Design Flowchart” and SEG 24-01

For complete seismic analysis:

When A_S is greater than 0.75 then use A_S = 0.75 at zero second for seismic analysis and response spectrum curve. See Example 1_SDC_Response_Spectra. The other data points on the response spectrum curve shall not be modified.

Additional Information

Bridge Seismic Retrofit Flowchart

When existing bridges are identified as needing repairs or maintenance, a decision on whether to include seismic retrofitting in the scope of the project shall be determined per the “Bridge Seismic Retrofit Flowchart”, the extent of the rehabilitation work and the expected life of the bridge after the work. For example, if the bridge needs painting or deck patching, no retrofitting is recommended. However, redecking or widening the bridge indicates that MoDOT is planning to keep the bridge in the state system with an expected life of at least 30 more years. In these instances, the project core team should consider cost effective methods of retrofitting the existing bridge. Superstructure replacement requires a good substructure and the core team shall decide whether there is sufficient seismic capacity. Follow the design procedures for new or replacement bridges in forming logical comparisons and assessing risk in a rational determination of the scope of a superstructure replacement project specific to the substructure. For example, based on SPC and route, retrofit of the substructure could include seismic detailing only or a complete seismic analysis may be required determine sufficient seismic capacity. Economic analysis should be considered as part of the decision to re-use and retrofit, or re-build. Where practical, make end bents integral and eliminate expansion joints.

Additional Information
Bridge Seismic Retrofit Design Process Flowchart

Bridge Sseismic retrofit design of bridges shall be in accordance with Bridge Seismic Retrofit Flowchart conform to AASHTO Division I-A, 1996 and Interims thru 1998. (Refer also to the 1998 Commentary for Division I-A.) Seismic retrofitting of existing bridges shall conform to the Seismic Retrofitting Manual for Highway Bridges, FHWA-RD-94-052, May 1995. Seismic isolation systems shall conform to AASHTO Guide Specifications for Seismic Isolation Design 4th Ed. 2023, 1999.

751.9.1.1 Applicability of Guidelines **and Seismic Design Philosophy**

SGS 3.1, 3.2, LRFD 3.4 and LRFD C3.4.1

EPG 751.9 supplements the above documentation for typical bridges in accordance with SGS 3.1. It does not apply to movable bridges, bridges with spans greater than 500 ft., suspension bridges, cable-stayed bridges, truss bridges or arch-type bridges. The State Bridge Engineer shall specify and/or approve appropriate provisions or specifications. There are special considerations for single-span bridges, temporary bridges and bridges with stage construction.

Critical and Recovery Bridges are not specifically addressed in SGS specification, SGS 3.1. Operational classification shall be in accordance with SGS 3.1 and SGS 3.2. Bridges shall be designed for the life safety performance objective using at a minimum the limit state of incipient collapse or unacceptable performance for geotechnical failure modes at a targeted risk of approximately 1.5 percent over 75 years in accordance with SGS 3.2 Higher levels of performance, such as the operational objective, may be established and authorized by the bridge owner. Critical and Recovery bridges shall be designed in accordance with AASHTO Guidelines for Performance-Based Seismic Design of Highway Bridges, 1st ed.

and does not apply to culverts, movable bridges, bridges with spans greater than 500 ft., suspension bridges, cable-stayed bridges, or arch-type bridges. There are special considerations for single-span bridges, temporary bridges and bridges with stage construction.

Additional Information
AASHTO Div. I-A, 3.1

The following categories are used throughout EPG:

Nonseismic = Bridges requiring a static design only. Minimal seismic details in accordance with SDC A are still required.

Seismic Details = This category refers to SDC A (S_{D1} ≥ 0.1), B, C and CD bridges that do not require a seismic design, but do require higher levels of seismic detailing.

Complete Seismic Analysis = Bridges requiring a full seismic analysis. SDC C or D bridges may be applicable based on the importance of the route.

Life safety for the design event shall be taken to imply that the bridge has a low probability of collapse but may suffer significant damage, and significant disruption to service is possible. Partial or complete replacement may be required in accordance with SGS 3.2. Hazard to human life should be minimized, and essential bridges should continue to function after an earthquake. Bridges are designed for good ductility and displacement control and are allowed to suffer minor, acceptable damage in order to prevent major, unacceptable damage.

Note: For seismic design force concepts and guidance, follow the seismic design process (EPG 751.9.1.3 thru 751.9.4) and modify design/details of LFD as necessary to meet SGS and LRFD seismic requirements until LRFD seismic section is created (modified EPG 751.9.1.3 thru 751.9.4).

All new or replacement bridges on the state system shall include seismic design and/or detailing to resist an expected seismic event for a given return period per the Bridge Seismic Design Flowchart.

- For a major bridge, the State Bridge Engineer will decide the design as a life safety or critical/essential or recovery bridge in accordance with SGS 3.1, SGS 3.2 and SGS C3.2.
- Except for section 7 of the AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS) is based on Displacement Based Design. The AASHTO LRFD Bridge Design Specifications (LRFD) -is based on Force Based Design. For seismic details and design concept use the SGS when information is available otherwise use LRFD. Seismic analysis shall be performed using displacement-based design (for exception see SGS 7).

Seismic Design Category/Seismic Zone by Code		
Value of design spectral acceleration coefficient at 1.0 second period, S_{D1} SGS 3.4.1 and 3.5	[1]AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS) SGS table 3.5-1 **Seismic Design Category (SDC)**	[2]AASHTO LRFD Bridge Design Specifications (LRFD) LRFD Table 3.10.6-1 **Seismic Zones**
$S_{D1} < 0.10$	A1	1
$0.10 \le S_{D1} < 0.15$	A2[3]	1[3]
$0.15 \le S_{D1} < 0.30$	B	2
$0.30 \le S_{D1} < 0.50$	C	3
$0.50 \le S_{D1}$	D	4

[1]SGS is required for seismic design. LRFD is shown because SGS refers to LRFD for support, and understanding the equivalency category and zone may be important. In accordance with SGS, all bridge designs must meet the requirements for SDC A (Seismic Zone 1). Additional seismic details are typically required for higher seismic design categories-.

[2]LRFD inequalities are different. Use SGS as shown.
[3]Structural member shall be detailed in accordance with SDC B (SGS 8.2) if bridge carry a 1st or 2nd priority earthquake emergency route.

751.9.1.2 Seismic Design PhilosophyNot used

Bridges may suffer damage but should have a low probability of collapse. Hazard to human life should be minimized, and essential bridges should continue to function after an earthquake. Bridges are designed for good ductility and displacement control and are allowed to suffer minor, acceptable damage in order to prevent major, unacceptable damage.

Additional Information

AASHTO Div. I-A, 3.11 and 3.12

751.9.3.1.1 Anchor Bolts

For LRFD, see EPG 751.11.2 Design for anchor bolt design.

Anchor bolts are used on bearings with sole plates. Design anchor bolts for flexure, shear and axial forces. Design forces are specified in AASHTO Div. I-A, Sections 3.6, 3.7, 5.2, 6.2 or 7.2. Anchor bolts shall be ASTM F1554 Grade 55, unless higher grade anchor bolts are required to meet design requirements. Grade 105 bolts shall not be used in applications where welding is required.

Flexural Stress

For flexural stress, design the bolt diameter to satisfy the allowable stress as shown below. Limit the number of bolts per bearing to four by adding concrete shear blocks when required.

M = PL/2 = maximum moment per bolt, inch*kips

L = moment arm from center of sole plate to top of the beam cap, inches

= Horizontal seismic design force per bolt, kips

F_H = Horizontal seismic force per girder as shown below, kips.

FH in Seismic Performance Category A

For expansion bearings, transverse F_T = 0.2(DL) & longitudinal F_L = 0.
Where DL = maximum dead load girder reaction at the bent, kips.
For fixed bearings, transverse F_T = 0.2(DL) per girder &

longitudinal F_L = (0.2)(segment weight)/(# of girders).
Segment weight should be distributed appropriately among fixed bents.
See also AASHTO Division I-A, Section 5.2.

FH in Seismic Performance Categories B, C and D

At intermediate bents, F_H = , where:

= summation of top of column longitudinal shears at bent

= summation of top of column transverse shears at bent

At end bents, use the same formula as above, except substitute the abutment shears in place of the top of column shears.

n_b = the number of bolts per girder

N_G = the number of girders at the bent

R = 1.0 for Seismic Performance Category A,

0.8 for Seismic Performance Categories B, C and D

S = Section modulus for the bolt = , cubic inches.

D = minimum body diameter, inches. For F1554 bolts use D = 0.92 x nominal bolt diameter. Alternately, the minimum body diameter can be retrieved from ASTM F1554 Table 4. For all other bolt types the nominal bolt diameter may be used because the bolt is unthreaded in the flexural zone and the minimum body diameter is similar to the nominal diameter.

F_b (Grade 55) = (overstress factor=1.5)*0.55*(F_y=55 ksi) = 45.4 ksi

Shear Stress

For shear stress, design the bolt diameter to satisfy the allowable stress as shown below ($f_v < F_v$). Limit the number of bolts per bearing to four by adding concrete shear blocks when required.

f_v = actual shear stress on the bolt, ksi

P = the design shear force per bolt, kips/bolt

= ,

where the definitions are the same as in the flexural stress section.

F_v= allowable shear stress per bolt, ksi = 1.5*(0.17F_u)*(f1)

where:

1.5 = overstress factor for seismic loads

0.17F_u = allowable shear stress when threads are included in shear plane per AISC, 9th Ed. Table J3.2 and Numerical Values Table 2 for A36, A307 and A449 bolts and applied here for F1554 anchor bolts. For A325 and A490 bolts refer to the values listed in AASHTO Table 10.32.3B.

f1 = 1.0 for F1554 bolts (all grades)

f1 = 1.0 for threads in the shear plane (A36, A307, A449, A325, A490)

f1 = 1.25 for threads not in the shear plane (A36, A307, A449, A325, A490)

For F1554 Grade 55 anchor bolts, F_v = 1.5*0.17*75*1.0 = 19.13 ksi.

A = = Nominal area of bolt, square inches

D = nominal bolt diameter.

Note: Do not apply the 0.875 factor for new A325 bolts as shown in footnote d under AASHTO Table 10.32.3b. A325 bolts no longer come in different grades (tensile strengths).

Note: ASTM F1554 allows the body diameter of the bolt to be reduced to provide an area not less than the stress area of the threaded portion of the bolt. For this reason, the allowable stress is similar for threads beings included or excluded from the shear plane.

Axial Stress

For axial stress, design the bolt diameter to satisfy the allowable tensile stress as shown below. For further information about vertical restrainers (hold-down devices), see EPG 751.9.3.1.3.

where

f_t = applied tensile stress, ksi
T = the maximum seismic tensile (uplift) force (DL ± EQ) per bolt from the seismic analysis, kips. If (DL+EQ) and (DL-EQ) are both compressive, then there is no need to design the bolts for axial stress.
A_t = normal area of bolt, square inches
F_t = allowable tensile stress = 1.5(0.33Fu) =37.13 ksi for Grade 55

where:

0.33Fu = allowable tensile stress per AISC, 9th Ed. Table J3.2 and Numerical Values Table 2 for A36, A307 and A449 bolts and applied here for F1554 anchor bolts. For A325 and A490 bolts refer to the values listed in AASHTO Table 10.32.3B.

Note: Do not apply the 0.875 factor for new A325 bolts as shown in footnote d under AASHTO Table 10.32.3b. A325 bolts no longer come in different grades (tensile strengths).

751.9.3.1.2 Dowel Bars

For LRFD, see EPG 751.22.2.7 Dowel Bars for dowel bar design.

Dowel bars connect standard concrete diaphragms and beams on concrete girder bridges (standard fixed diaphragms are those with beam stirrups NOT extending up into the diaphragm). Dowel bars are standard rebars designed using Allowable Stress Design and an allowable overstress of 33%. Design forces are as specified in AASHTO Div. I-A, Sections 3.6, 3.7, 5.2, 6.2 or 7.2. The length of dowel bars is as shown in EPG 751.22.2.7 Dowel Bars. For a calculated seismic vertical reaction or an anticipated foundation settlement resulting in a net tensile reaction, use the development length of dowel bars into beam and into diaphragm based on dowel bar size.

Shear Stress

For shear stress, design the size and number of dowel bars to satisfy the allowable stress as shown below (f_v < F_v). The number of dowels must also fit into the space available on the key:

min. bar size = #6; max. bar size = #11
min. spacing = 6"; max. spacing = 18"

min. end distance=3"; max. end distance=9" (half the spacing)

f_v = actual shear stress on the dowel, ksi

P = the design shear force per dowel, kips/dowel =
where:

F_H = Horizontal seismic force as shown below, kips =
F_H in Seismic Performance Category A
Transverse F_T = 0.2(DL)
where: DL = the summation of dead load reactions at the bent, kips
Longitudinal F_L = 0.2(segment wt.) where segment weight should be distributed appropriately among fixed bents.
FH in Seismic Performance Categories B, C and D

Additional Information

AASHTO Div. I-A, 5.2

~~F_H =~~

~~where:~~

~~= summation of top of column longitudinal shears at all columns~~

~~= summation of top of column transverse shears at all columns~~

~~If columns are designed for plastic hinging, use the plastic hinging shear.~~

~~n_d = the number of dowels at the bent~~

~~R =1.0 for Seismic Performance Category A,~~

~~0.8 for Seismic Performance Categories B, C and D~~

~~A = the cross-sectional area of the bar, sq. inches~~

~~F_v = allowable shear stress per dowel = 1.33*0.4*f_y = 31.9 ksi / dowel~~

~~f_y = yield stress of the rebar, ksi~~

~~**Axial Stress**~~

~~For axial stress, design the total area of bars to satisfy the tensile stress as shown below.~~

~~where:~~

~~f_t = applied tensile stress, ksi / dowel T = seismic tensile (uplift) force (DL - EQ) at bent, kips. If both (DL + EQ) and (DL - EQ) are compressive, then there is no need to design the dowels for axial stress.~~

~~n_d = the number of dowels at the bent~~

~~A_d = cross-sectional area of one bar, sq. inches~~

~~F_t = allowable tensile stress per dowel = 1.33*0.55*fy = 43.9 ksi / dowel~~

***751.9.3.1.3* Restrainers**

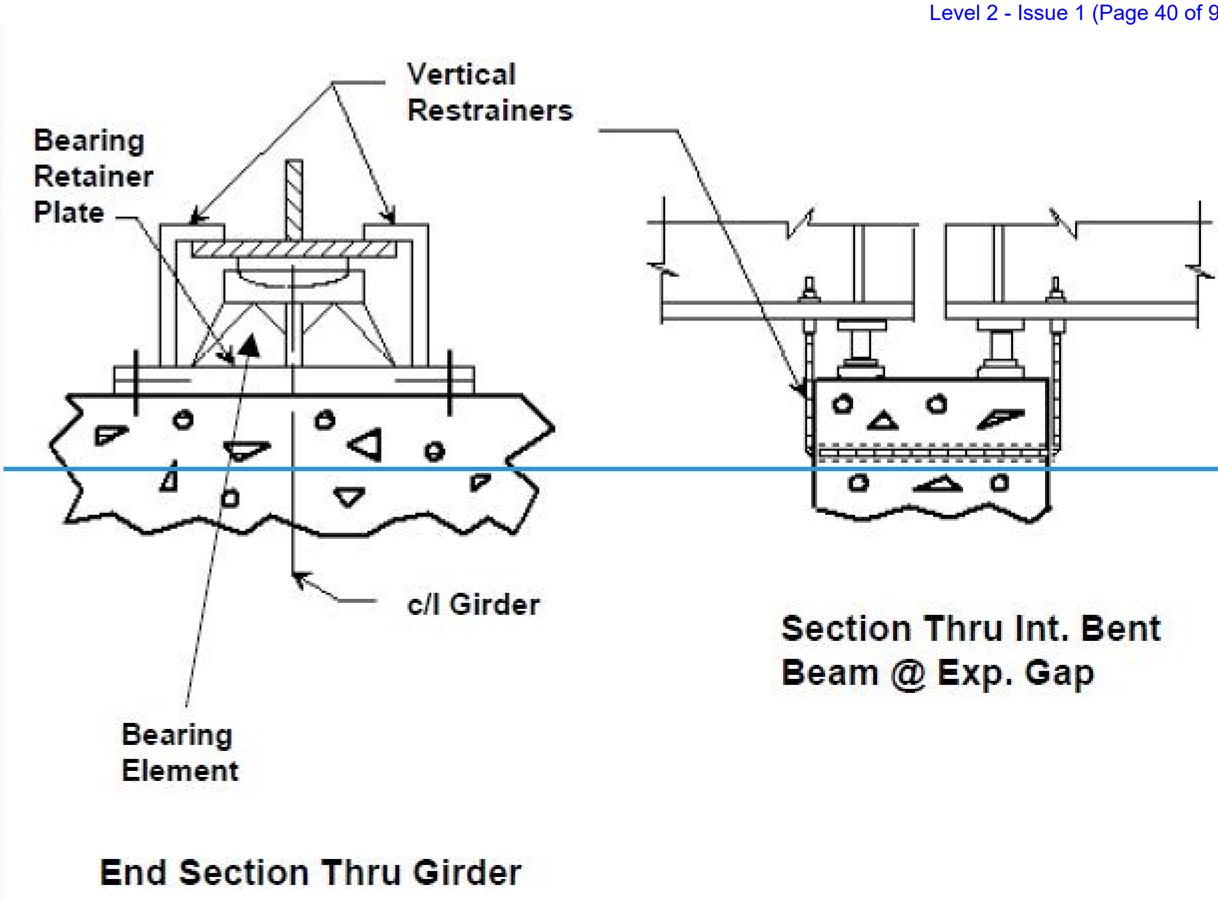
Vertical Restrainers (Hold-down Devices)

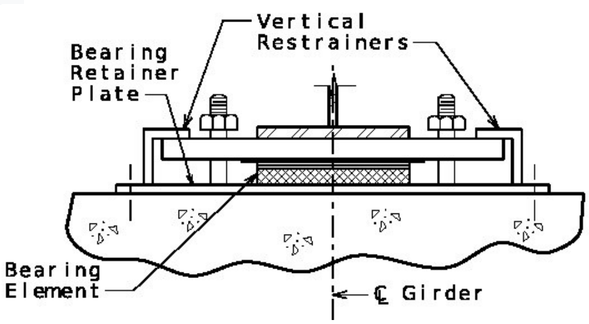
Vertical restrainers are only required in Seismic Performance Categories C and D (AASHTO Div. I-A, 7.2.5(B)), but they may also be used on important structures in SPC B. Vertical restrainers shall be used at all supports or hinges in continuous structures when the vertical seismic force (EQ) exceeds 50% of the dead load reaction (DR).

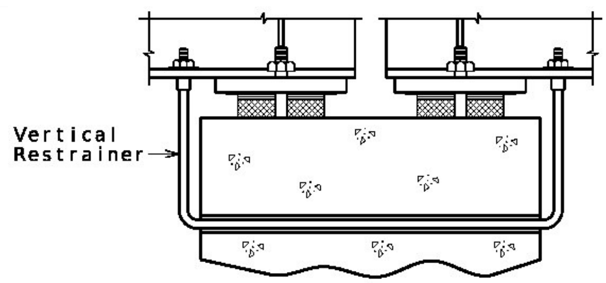
When 0.5(DR) < EQ < 1.0(DR), then the minimum net uplift force = 10% of the dead load downward force that would be exerted if the span were simply supported.

When EQ > 1.0(DR), then the net uplift force = 1.2*(EQ-DR), but not less than 10% of the dead load downward force that would be exerted if the span were simply supported.

Vertical restrainers can take several forms: (a) using existing anchor bolts, (b) adding threaded rods, (c) adding vertical restraining plates, or (d) adding prestressing strands. If vertical restrainers are required, see the Structural Project Manager to determine which vertical restrainer system should be used.



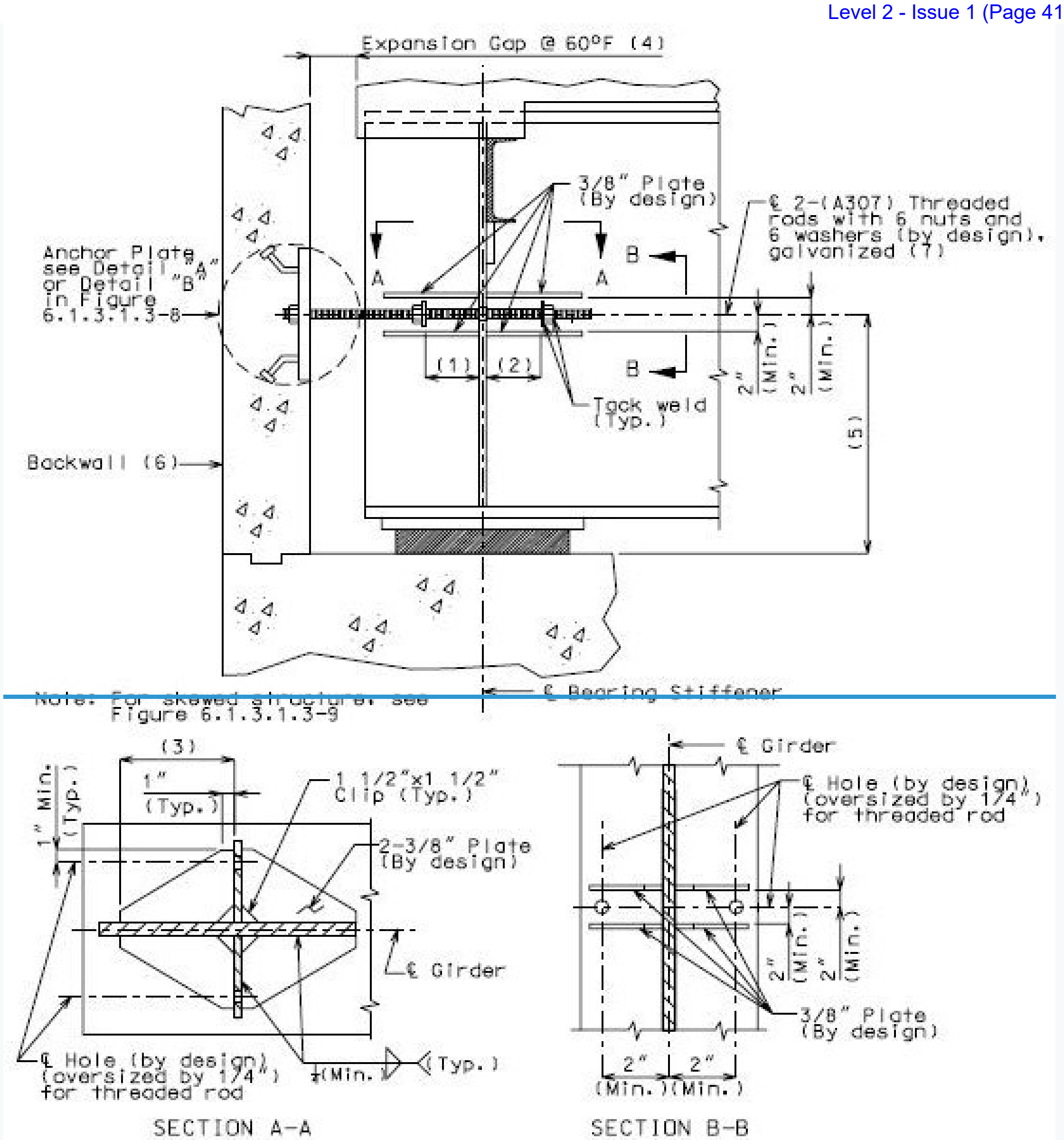




End Section thru Girder

Section thru Intermediate Bent Beam at Expansion Gap

Fig. 751.9.3.1.3.2 Examples of Vertical Restrainers



(1) (Expansion Gap @ 60° F) + 1/2".

(2) Expansion Gap @ 60° F.

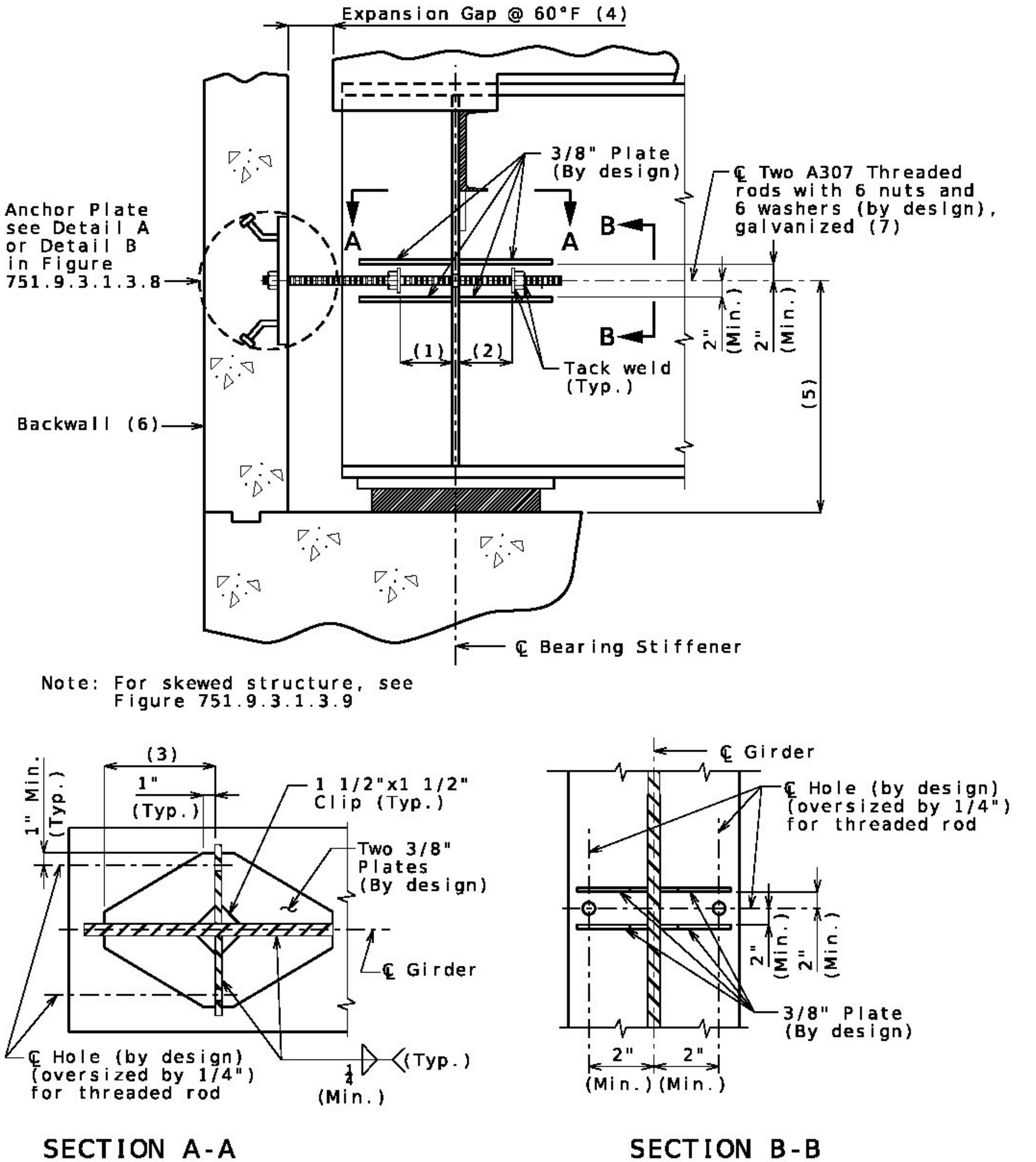
(3) Design length as required for the weld to develop the seismic force.

(4) On skewed structures, adjust this distance parallel to the C/L of roadway.

(5) Locate the restrainer as close as possible to the neutral axis of the superstructure and as close as possible to the bottom of the diaphragm.

(6) End bent backwalls are to be designed for active seismic soil pressure as described in Section 6.1.3.2.

(7) Omit restrainers on exterior faces of exterior girders.



(1) (Expansion Gap @ 60°F) + 1/2"

(2) Expansion Gap @ 60°F

(3) Design length as required for the weld to develop the seismic force.

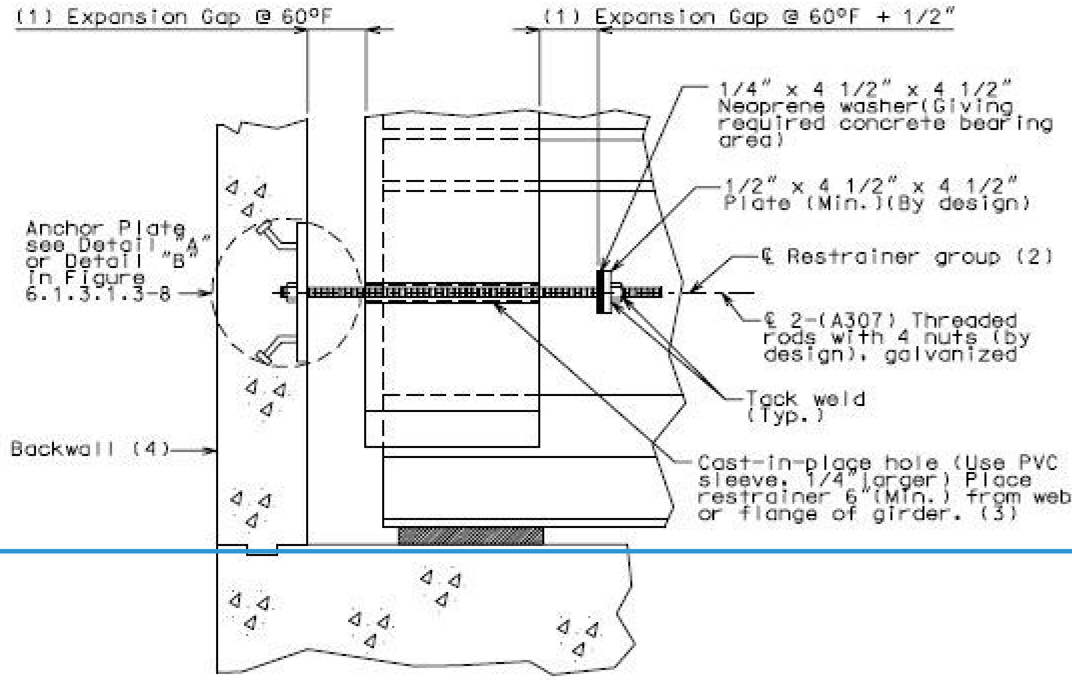
(4) On skewed structures, adjust this distance parallel to the centerline of roadway.

(5) Locate the restrainer as close as possible to the neutral axis of the superstructure and as close as possible to the bottom of the diaphragm.

(6) End bent backwalls are to be designed for active seismic soil pressure as described in EPG 751.9.3.2.

(7) Omit restrainers on exterior faces of exterior girders.

Fig. 751.9.3.1.3.3 Longitudinal Restrainers (End Bents - Steel Girders)



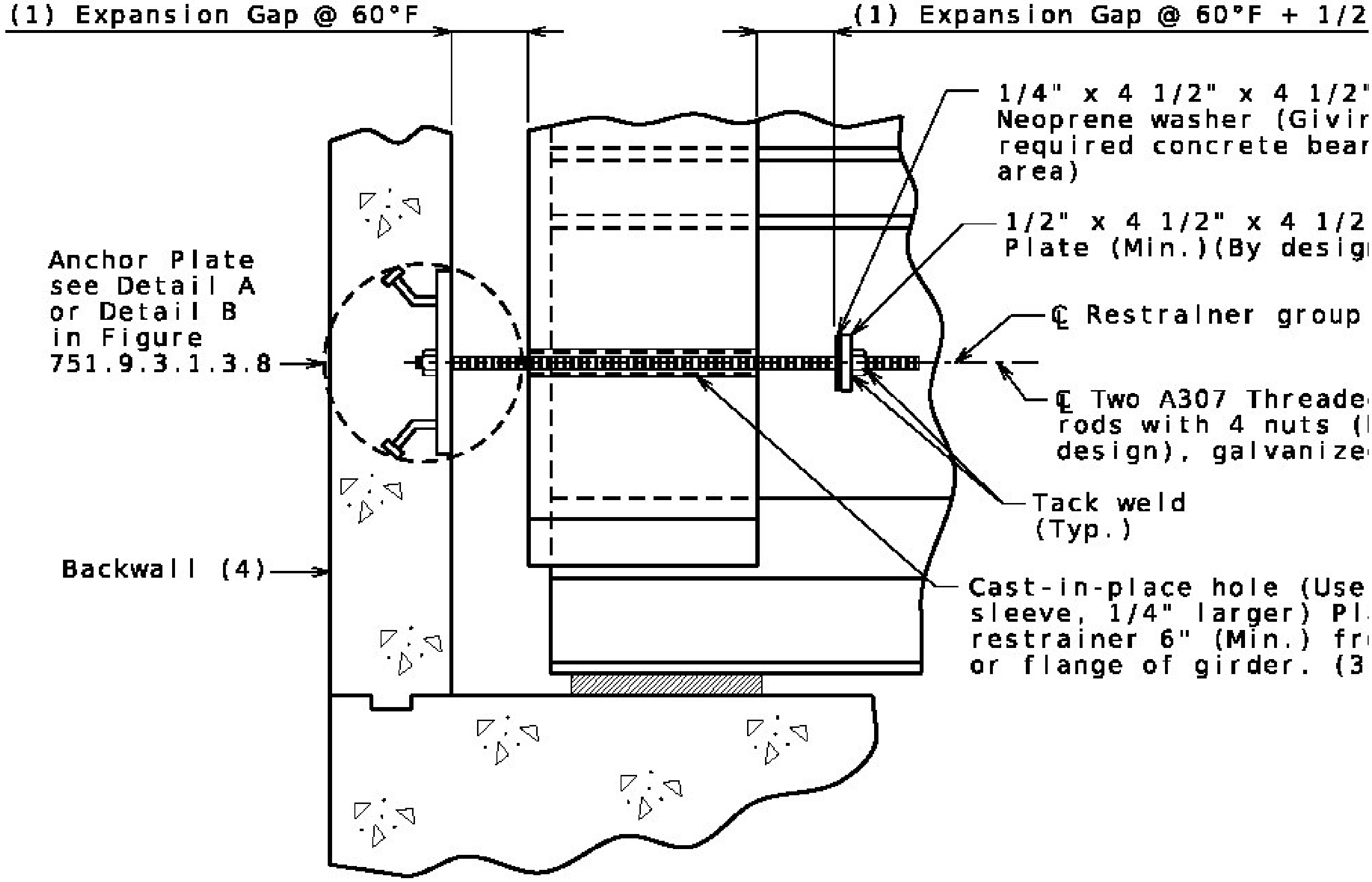
Note: For skewed structure, see Figure 6.1.3.1.3-9

(1) On skewed structures, adjust this distance parallel to the C/L of roadway.

(2) Locate at the center of gravity of the superstructure, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. May adjust for clearance.

(3) Omit restrainers on exterior faces of exterior girders.

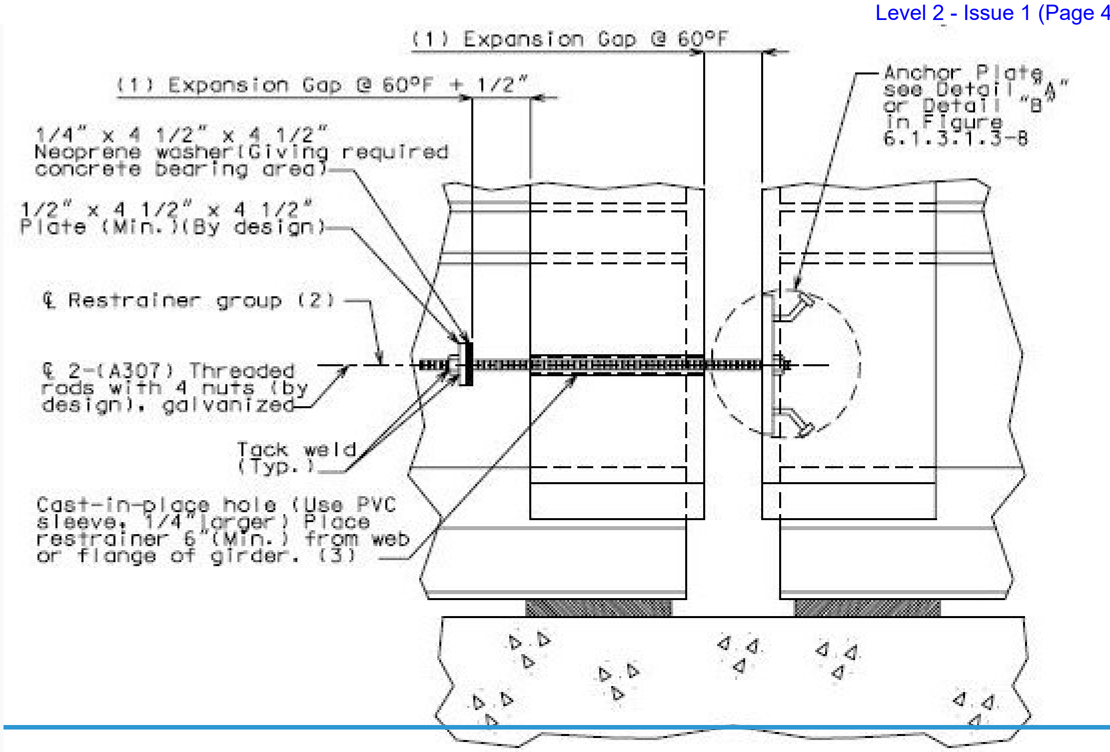
(4) End bent backwalls are to be designed for active seismic soil pressure as described in Section 6.1.3.2.



Note: For skewed structures, see Figure 751.9.3.1.3.9.

(1) On skewed structures, adjust this distance parallel to the centerline of roadway.
(2) Locate at the center of gravity for the superstructure, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. May adjust for clearance.
(3) Omit restrainers on exterior faces of exterior girders.
(4) End bent backwalls are to be designed for active seismic soil pressure as described in EPG 751.9.3.2

Fig. 751.9.3.1.3.4 Longitudinal Restrainers (End Bents - Concrete Girders)



Note: For skewed structure, see Figure 6.1.3.1.3-9

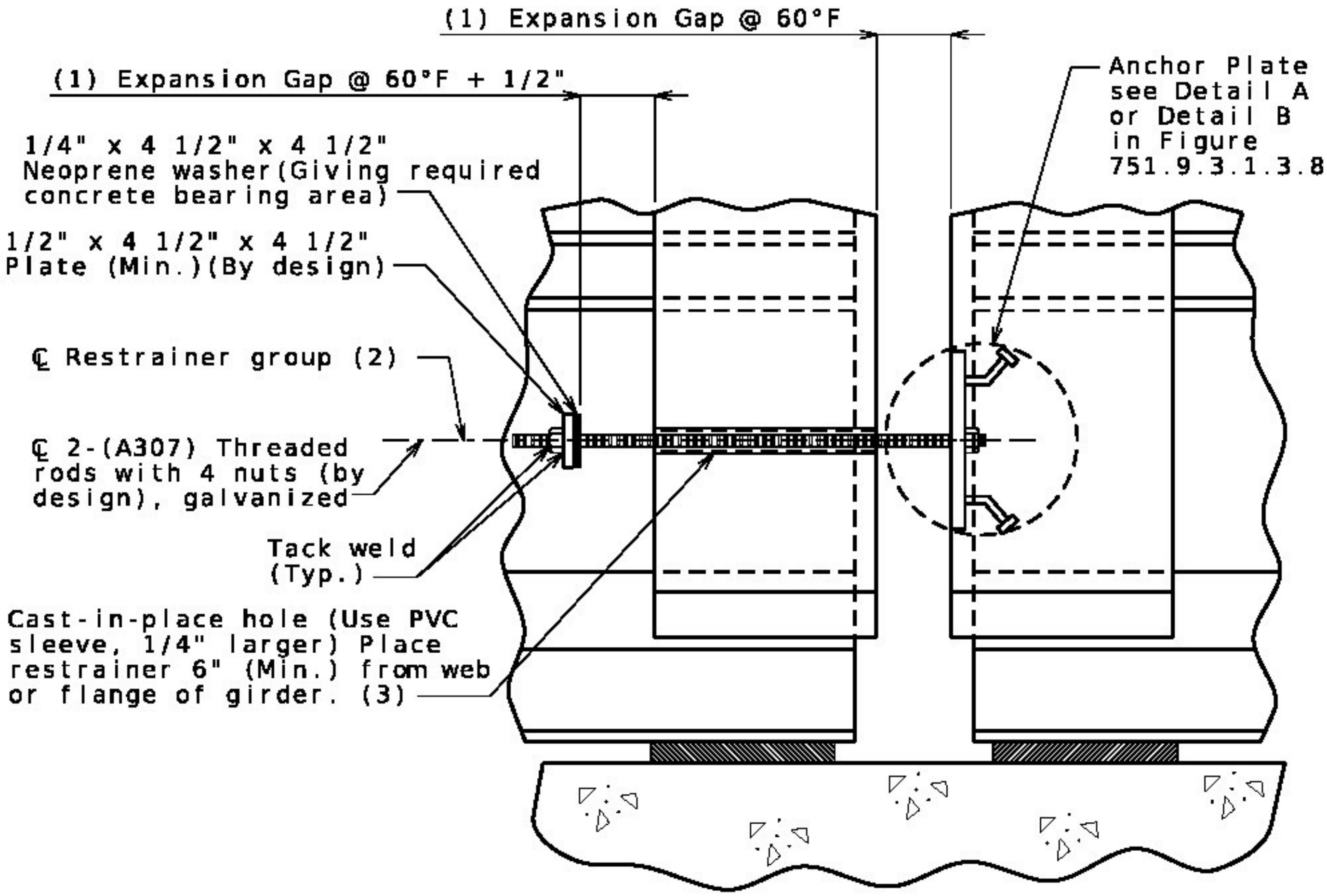
Y_b = GRAVITY NEUTRAL AXIS OF PRESTRESSED I-GIRDERS (✱)					
ROADWAY	GIRDER SPACING	GIRDER TYPE			
		III	IV	VI	VII
26'-0"	7'-6"	32.7	36.5	41.1	54.2
28'-0"	8'-2"	33.2	37.0	41.6	54.9
30'-0"	8'-8"	33.6	37.5	42.1	55.5
32'-0"	9'-2"	33.9	37.9	42.6	56.1
36'-0"	8'-2"	33.2	37.1	41.7	55.0
38'-0"	8'-8"	33.5	37.4	42.1	55.5
40'-0"	9'-0"	33.8	37.8	42.5	55.9
44'-0"	9'-9"	34.4	38.4	43.2	56.8

✱ Y_b = Inches from bottom of beam, based on an 8 1/2" slab.

(1) On skewed structures, adjust this distance parallel to the C/L of roadway.

(2) Locate at the center of gravity of the superstructure. Use the gravity neutral axis of the composite section, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. May adjust for clearance.

(3) Omit restrainers on exterior faces of exterior girders.



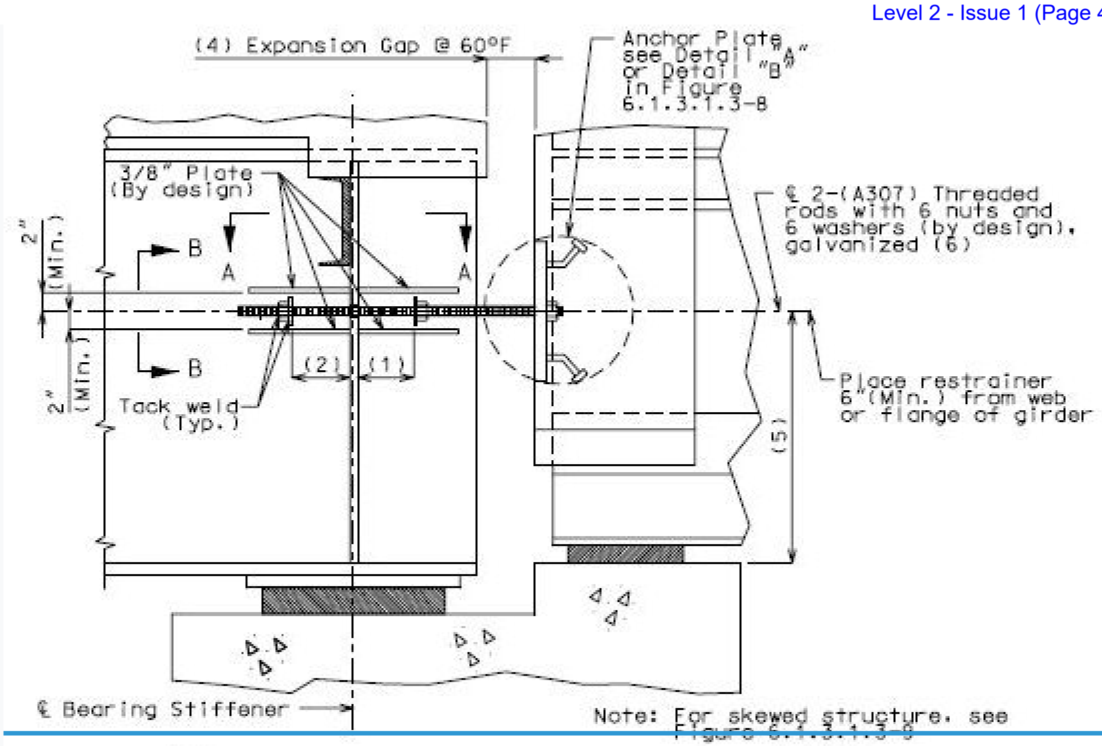
Note: For skewed structures, see Figure 751.9.3.1.3.9.

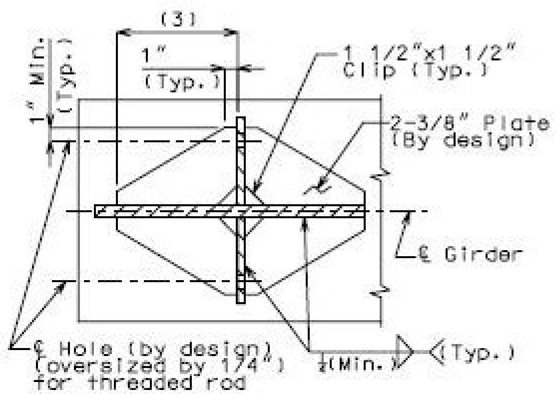
Yb = GRAVITY NEUTRAL AXIS OF PRESTRESSED I-GIRDERS *					
ROADWAY	GIRDER SPACING	GIRDER TYPE			
		III	IV	VI	VII
26’-0”	7’-6”	32.7	36.5	41.1	54.2
28’-0”	8’-2”	33.2	37.0	41.6	54.9
30’-0”	8’-8”	33.6	37.5	42.1	55.5
32’-0”	9’-2”	33.9	37.9	42.6	56.1
36’-0”	8’-2”	33.2	37.1	41.7	55.0
38’-0”	8’-8”	33.5	37.4	42.1	55.5
40’-0”	9’-0”	33.8	37.8	42.5	55.9
44’-0”	9’-9”	34.4	38.4	43.2	56.8

* Yb = Inches from bottom of beam, based on an 8½” slab.

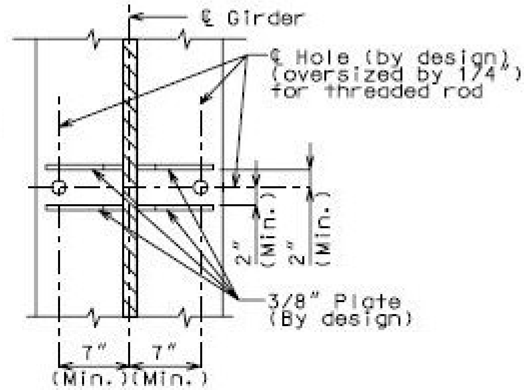
(1) On skewed structures, adjust this distance parallel to the centerline of roadway.
(2) Locate at the center of gravity for the superstructure. Use the gravity neutral axis of the composite section, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. May adjust for clearance.
(3) Omit restrainers on exterior faces of exterior girders.

Fig. 751.9.3.1.3.5 Longitudinal Restrainers (Intermediate Bents - Concrete Girders)





SECTION A-A



SECTION B-B

(1) (Expansion Gap @ 60° F) + 1/2".

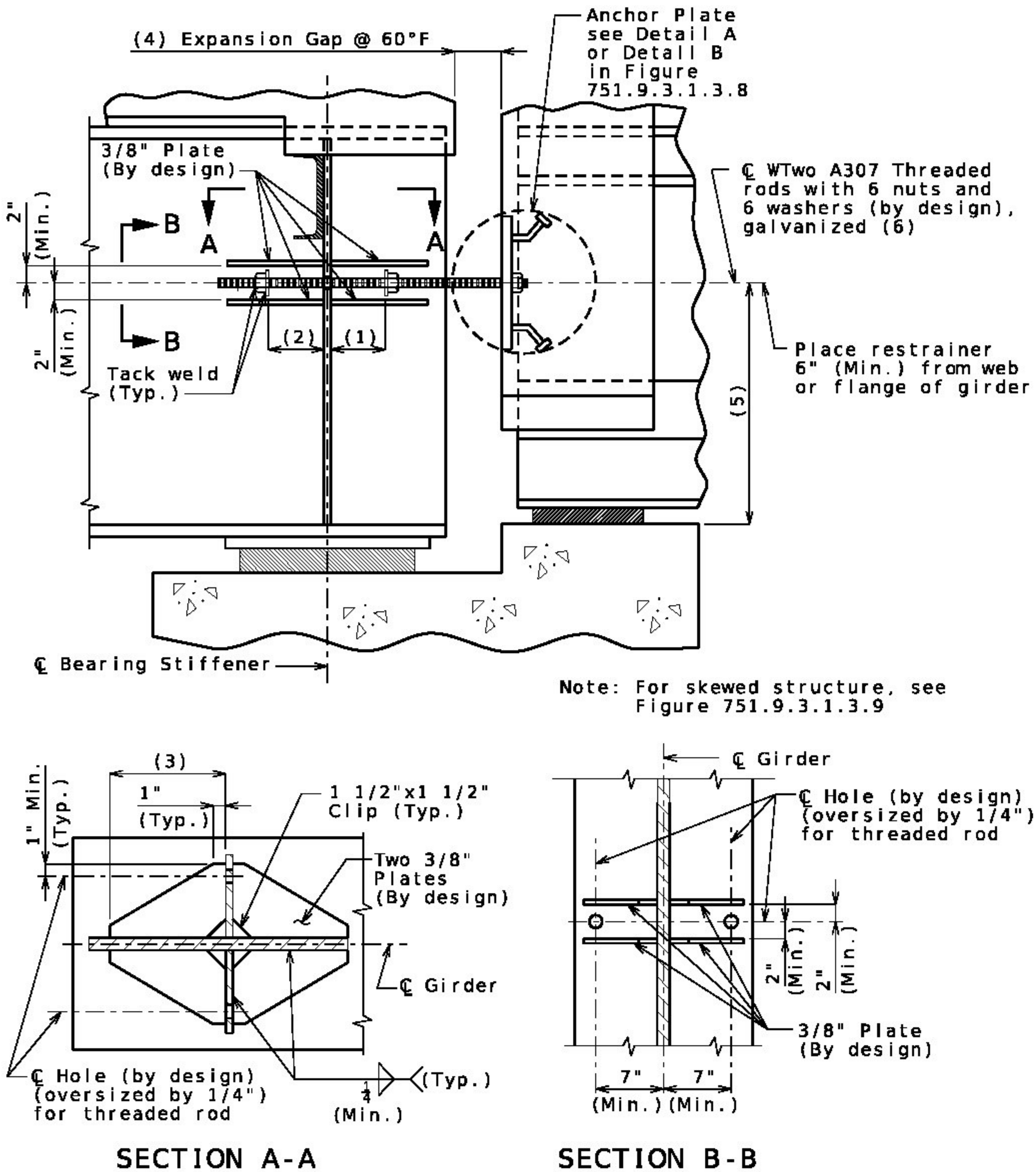
(2) Expansion Gap @ 60° F.

(3) Design length as required for the weld to develop the seismic force.

(4) On skewed structures, adjust this distance parallel to the C/L of roadway.

(5) Locate the restrainer as close as possible to the neutral axis of the superstructure. Use the gravity neutral axis of the composite section, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. Adjust the restrainer to clear channel and shop weld. Larger bracing is required for P/S to Steel beam restrainers.

(6) Omit restrainers on exterior faces of exterior girders.



(1) (Expansion Gap @ 60°F) + 1/2"

(2) Expansion Gap @ 60°F

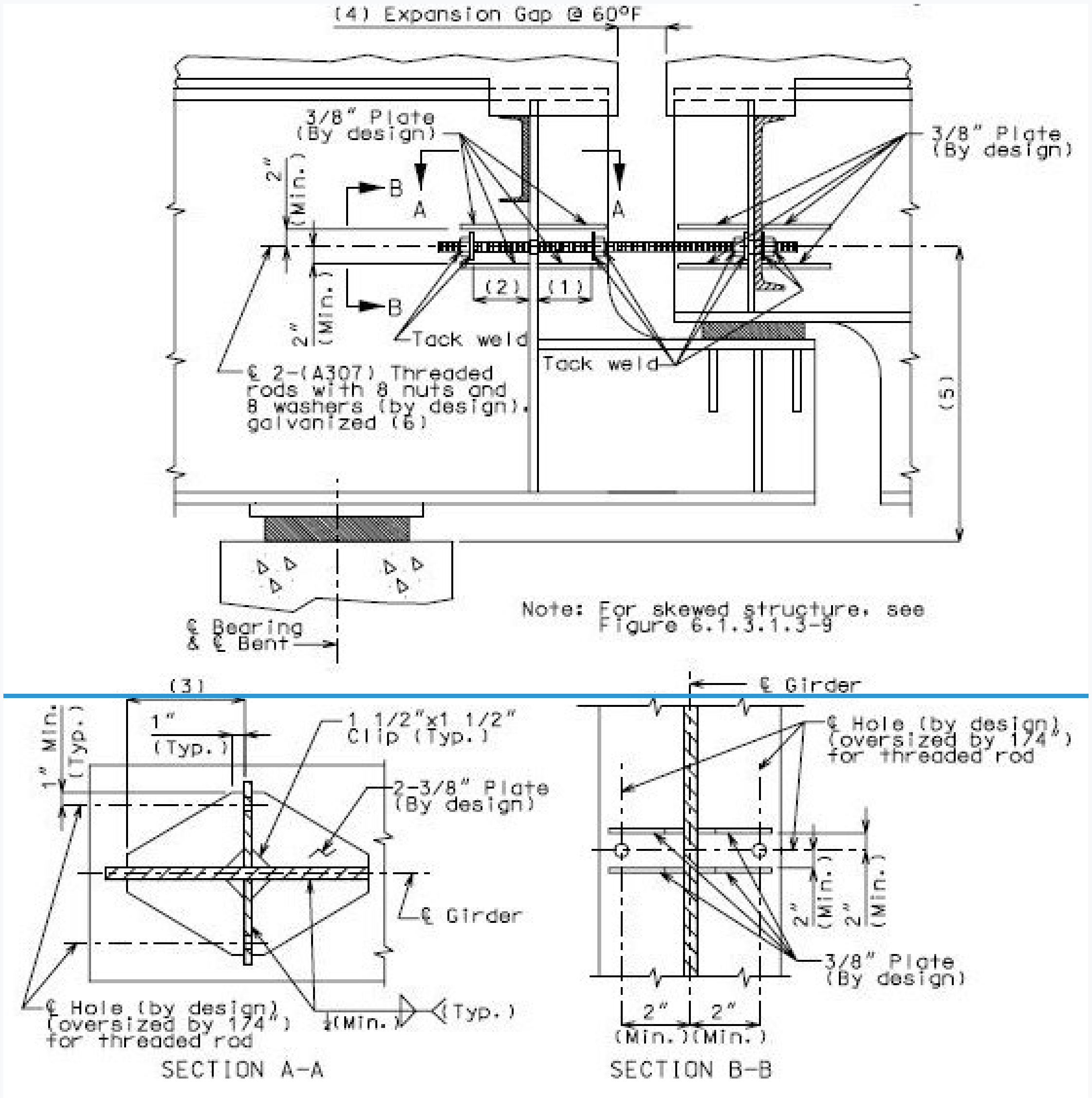
(3) Design length as required for the weld to develop the seismic force.

(4) On skewed structures, adjust this distance parallel to the centerline of roadway.

(5) Locate the restrainer as close as possible to the neutral axis of the superstructure. Use the gravity neutral axis of the composite section, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. Adjust the restrainer to clear channel and shop weld. Larger bracing is required for prestressed to steel beam restrainers.

(6) Omit restrainers on exterior faces of exterior girders.

Fig. 751.9.3.1.3.6 Longitudinal Restrainers (Intermediate Bents - Steel to Concrete Girders)



(1) (Expansion Gap @ 60° F) + 1/2".

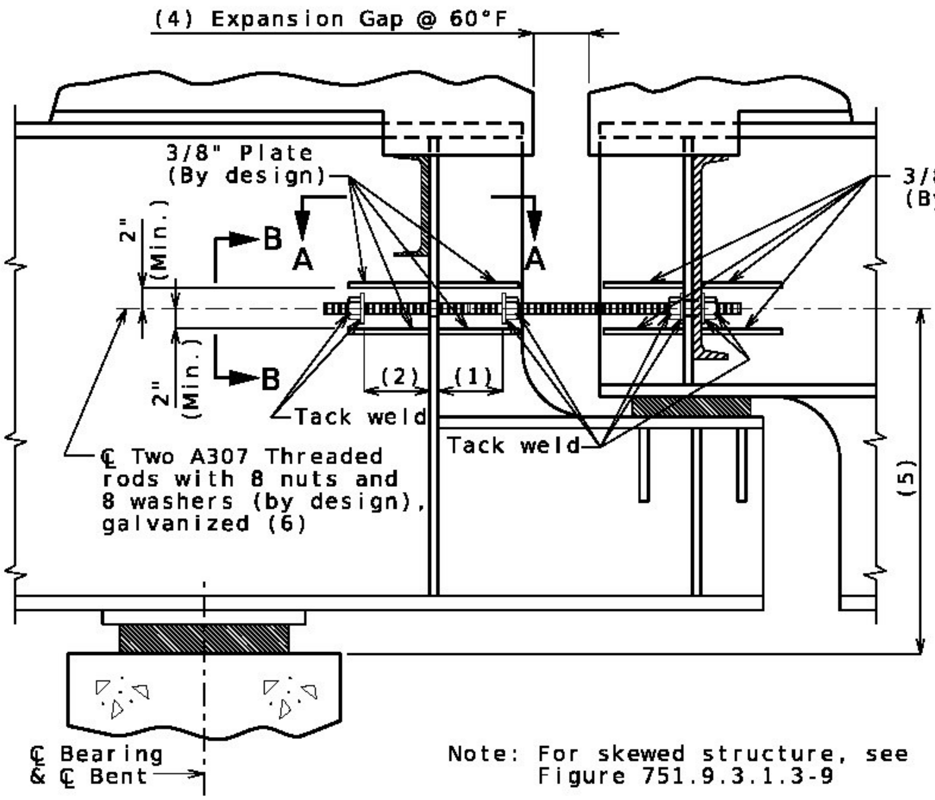
(2) Expansion Gap @ 60° F.

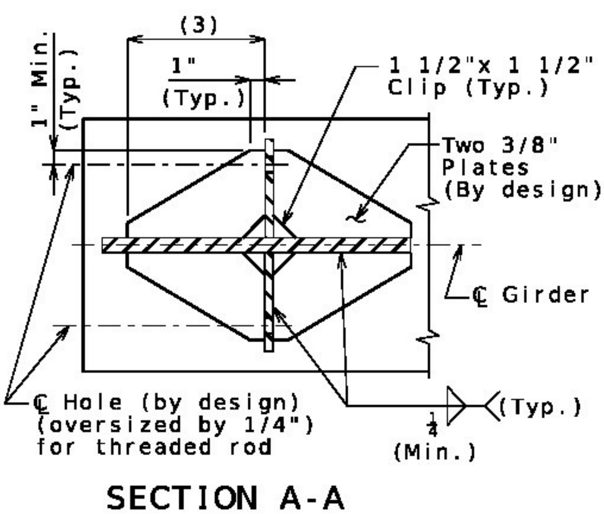
(3) Design length as required for the weld to develop the seismic force.

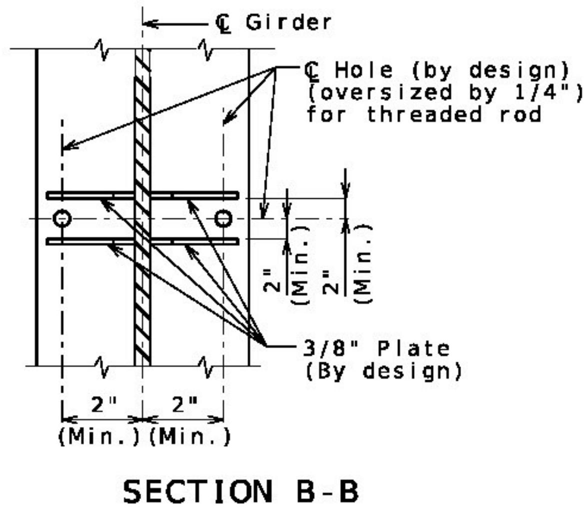
(4) On skewed structures, adjust this distance parallel to the C/L of roadway.

(5) Locate the restrainer as close as possible to the neutral axis of the superstructure and as close as possible to the bottom of the diaphragm. Use the gravity neutral axis of the girder, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. Adjust the restrainer to clear channel and shop weld.

(6) Omit restrainers on exterior faces of exterior girders.







(1) (Expansion Gap @ 60°F) + 1/2“

(2) Expansion Gap @ 60°F

(3) Design length as required for the weld to develop the seismic force.

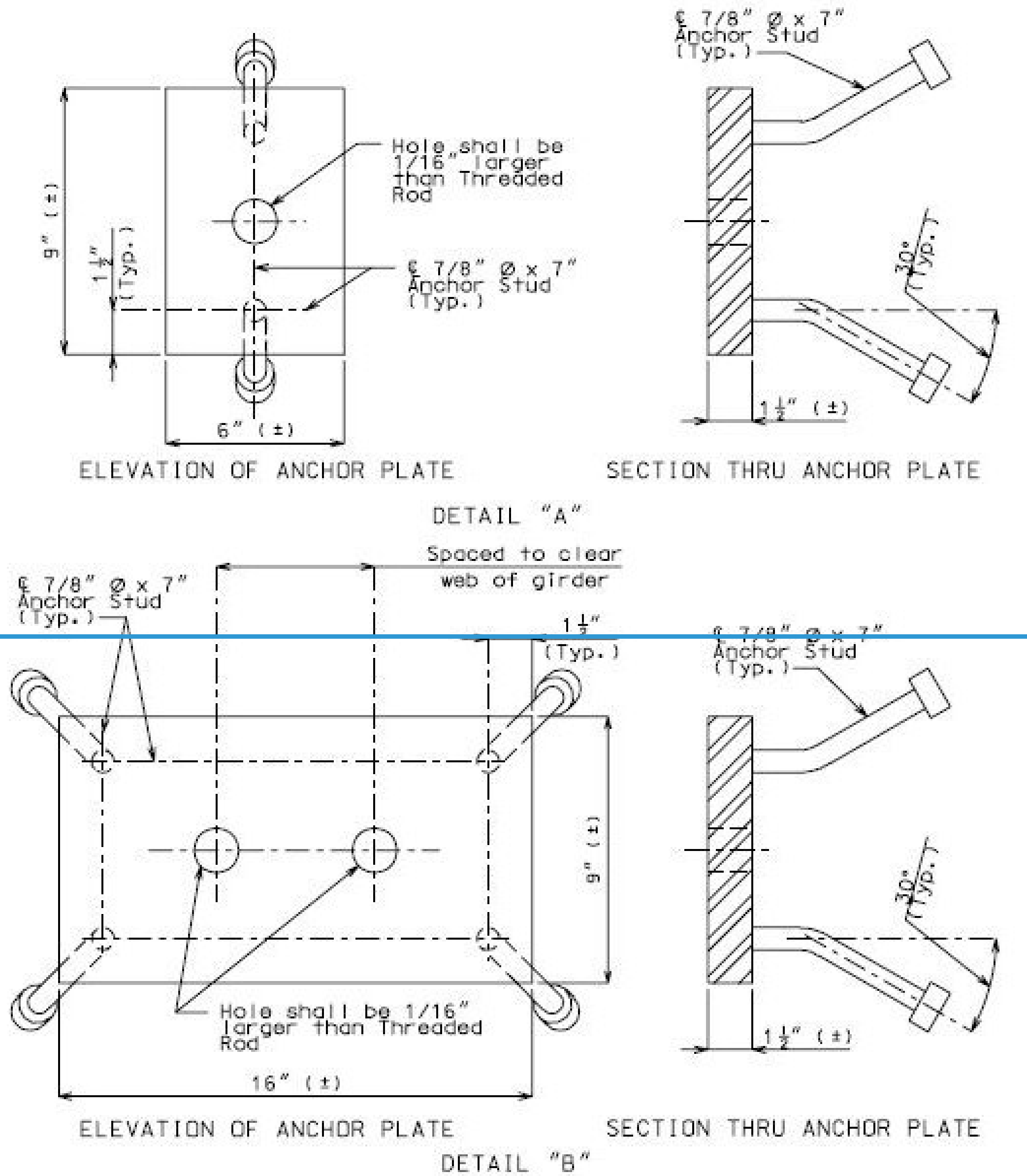
(4) On skewed structures, adjust this distance parallel to the centerline of roadway.

(5) Locate the restrainer as close as possible to the neutral axis of the superstructure and as close as possible to the bottom of the diaphragm. Use the gravity neutral axis of the girder, using the spacing between girders. If different beam depths are used, locate the restrainers at the neutral axis of the smaller beam. Adjust the restrainer to clear channel and shop weld.

(6) Omit restrainers on exterior faces of exterior girders.

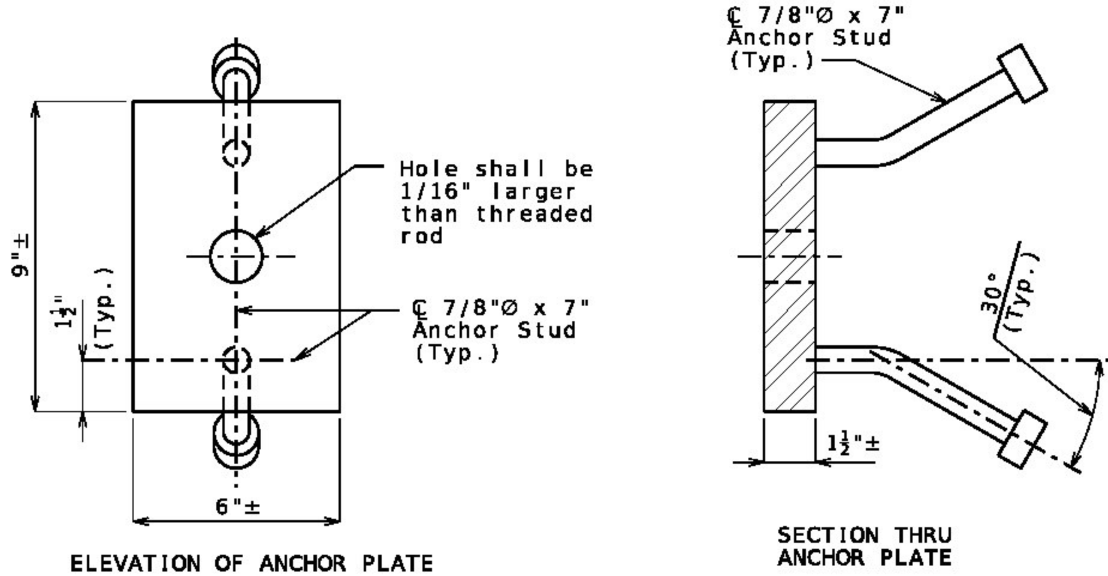
Fig. 751.9.3.1.3.7 Longitudinal Restrainers (Hinged Connection)

Note: Use Detail "A" for P/S I-Girder Structures at End and Int. Bents and also for all exterior girders on inside face.

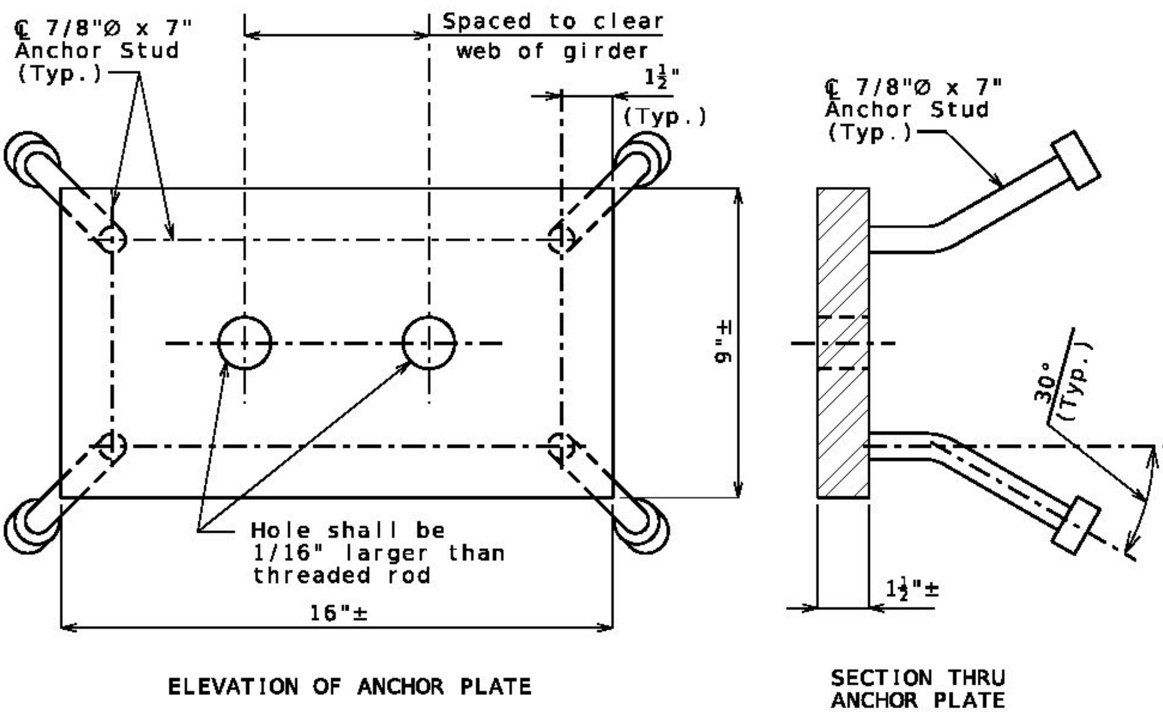


Note: Use Detail "B" for Steel Structures at End Bents or P/S I-Girders to Steel Structures at Int. Bents or whenever more than two restrainers occupy one anchor plate.

Pull-out 32K per stud. Working stress load 16K per stud. (See TRW Nelson Division Catalog.)



DETAIL A



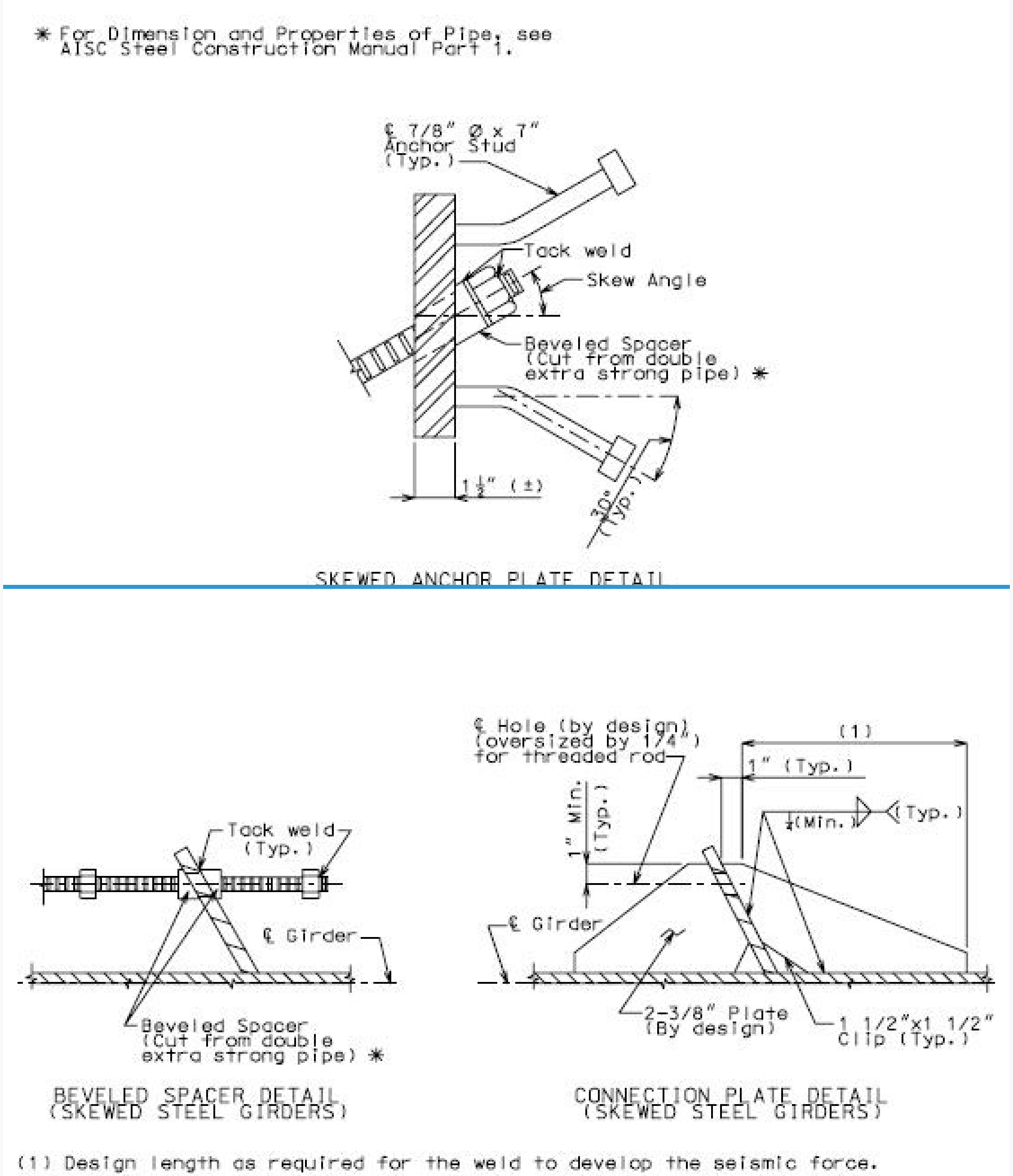
DETAIL B

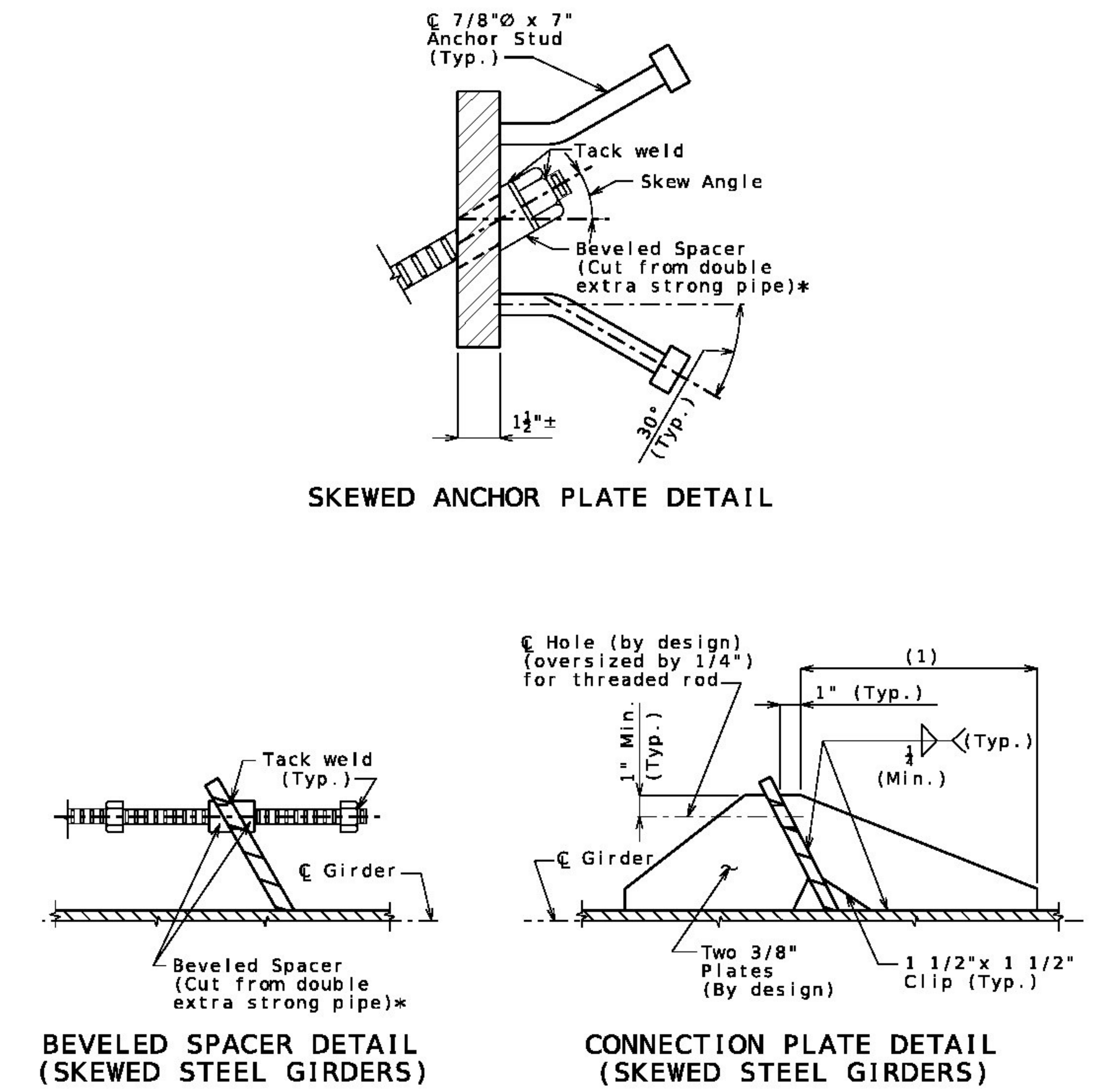
Note: Use Detail A for prestressed I-Girder structures at end and intermediate bents and also for all exterior girders on inside face.

Use Detail B for steel structures at end bents or P/S I-Girders to steel structures at intermediate bents or whenever more than two restrainers occupy one anchor plate.

Pull-out 32k per stud. Working stress load 16k per stud. (See TRW Nelson Division catalog.)

Fig. 751.9.3.1.3.8 Details "A" and "B" for Anchor Plates





* For dimension properties of pipe, see AISC Steel Construction Manual, Part 1.

(1) Design length as required for the weld to develop the seismic force.

Fig. 751.9.3.1.3.9 Details for Longitudinal Restrainers on Skewed Structures

751.9.3.1.4 Concrete Shear Blocks

For LRFD, see EPG 751.22.3.13 Concrete Shear Blocks for Concrete Shear Blocks design

~~Concrete shear blocks are used when 4 anchor bolts per bearing are insufficient, or for preventing loss of support on beams and stub bent footings. Design shear keys as specified in AASHTO 8.16.6.4. Design forces are as specified in AASHTO Div. I-A, Sections 3.6, 3.7, 5.2, 6.2 or 7.2. The following dimensions and sizes are for rough guidelines only and may be altered to fit specific situations:~~

~~Concrete shear block dimensions:~~

~~L = Length shall extend all the way across the beam (for ease of forming), oriented parallel to centerline of roadway.~~

~~W = Width is as required for concrete area. Allow about 1/2 in. (typical) clearance between the edge of the sole plate and the edge of the block to allow engaging of anchor bolts. H = Height of shear block shall extend to about an inch (+/-) above the top of the sole plate.~~

~~Steel reinforcement:~~

~~Bar size = #4 min. to # 6 max. hairpins placed parallel to the centerline of the beam, with #4 horizontal straight bars at the top of the hairpin to ensure proper alignment.~~

~~Spacing = Spacing of hairpin shear bars as required to provide the required steel area, with 6" minimum to 12" maximum. The maximum edge distance in the direction of the spacing = half of reinforcement spacing.~~

~~= demand shear per block, kips/block~~

~~where:~~

~~F_T = transverse component of total horizontal seismic force demand at the bent, normal to the centerline of the roadway, kips. Both seismic load cases, Case 1 = L+0.3T and Case 2 = 0.3L+T, must be satisfied.~~

~~R = 1.0 for Seismic Performance Category A~~

~~0.8 for Seismic Performance Categories B, C and D~~

~~φ = 0.85 for shear~~

~~N_B = the number of blocks resisting the seismic force. The designer should consider using a value of NB that is less than the total number of blocks, because all blocks may not resist equal amounts of force.~~

~~$V_{cap} = A_{vf} * f_y * \mu$ = nominal shear capacity of concrete shear block, kips/block~~

~~$V_{cap} \leq 0.2 * f'_c * A_{cv}$, kips~~

~~$V_{cap} \leq 0.8 * A_{cv}$, kips~~

~~A_{vf} = cross-sectional area of reinforcing bars at the shear plane, sq. inches~~

~~f_y = yield strength of reinforcing bars, ksi~~

~~μ = 1.0 for retrofits (bushhammering > 1/4", in Sec.703.3.11)~~

~~μ = 1.4 for new structures (monolithic construction)~~

~~f'_c = final compressive strength of concrete at 28-day cure, ksi~~

~~A_{cv} = area of concrete block at the shear plane, sq. inches~~

~~**Example:** An example of a shear block details can be found in EPG 751.22.3.13.~~

751.9.3.1.6 Seismic Isolation Bearings

Isolation Bearings

Seismic isolation bearings shall conform to AASHTO Guide Specifications for Seismic Isolation Design, 3rd Ed., July 2010 ~~1999~~. Isolation bearings should only be used when specified on the design layout or when required for special retrofit projects. See the Structural Project Manager for approval and for the design specifications for the specific proprietary system to be used.

For LRFD, Seismic isolation bearings shall conform to AASHTO Guide Specifications for Seismic Isolation Design, 4th Ed., 2023.

751.11.3.4 Bearing Edge Distance

Steel or Prestressed Girders

Beam Ledges

Heavy loads placed near the edge of a concrete surface can produce spalling. Two precautions should be taken to avoid the problem. Additional reinforcement should be placed under the load and around the corner. The bearing area of the load should not project beyond the straight portion of the stirrups, nor beyond the interior face of a transverse anchor bar (if one is provided). The recommended distance to a step, or the end of the bent cap in the transverse direction is 9 inches.

Provide minimum support length in accordance with Bridge Seismic Design Flowchart.

Bearing Clearance

When beams are placed to end at an intermediate bent, the clearance is governed by the bent up strands, diaphragm reinforcement, skew, and any vertical or horizontal curvature in the profile grade. A 9 inch minimum between bearing pads for prestressed girders is a general rule. For simply supported steel or constant depth girders the recommended minimum clearance is 2 inches between bearing pads. See Dimension "C". Also consider transverse girder offsets when using prestressed girders on horizontally curved alignments.

751.24 ~~LFD~~ Retaining Walls

Printable Version of September 2011 LFD Retaining Walls Info

EPG 751.24 LFD Retaining Walls presents the very latest information, but this pdf file may be helpful for those wanting to easily print the LFD seismic information as it was in September 2011.

751.24.1 General

For understanding the equivalency of seismic design category (SDC) and seismic zone for LRFD, see EPG 751.9.1.1 and Bridge Seismic Design Flowchart.

Retaining wall shall be designed to withstand lateral earth and water pressures, including any live and dead load surcharge, the self weight of the wall, temperature and shrinkage effect, live load and collision forces, and earthquake loads in accordance with the general principles of AASHTO Section 5 LRFD Section 11 and the general principles specified in this article.

Additional Information
LRFD 11
AASHTO 5.1

Seismic analysis provisions shall not be ignored for walls that support another structure (i.e. support abutment fill or building) in SDC B or C (seismic zone 2 or 3). No-seismic-analysis provisions may be considered for walls that do not support another structure (i.e. most of District walls) in SDC B or C (seismic zone 2 or 3) in accordance with LRFD 11.5.4.2 and Geotech report. Seismic analysis provisions shall not be ignored for walls in SDC D (seismic zone 4).

751.24.1.1 Wall Type Selection

Selection of wall type shall be based on an assessment of the magnitude and direction of loading, depth to suitable foundation support, potential for earthquake loading, presence of deleterious environmental factors, wall site cross-sectional geometry, proximity of physical constraints, tolerable and differential settlement, facing appearance and ease and cost of construction.

Additional Information
LRFD 11
AASHTO 5.2.1

The following wall types are the most commonly used in MoDOT projects

- Mechanically Stabilized Earth Retaining Walls
- Cast-In-Place Concrete Cantilever Retaining Walls
    - Cantilever Walls on Spread Footings
    - Cantilever Wall on Pile Footings
    - L-Shaped Walls on Spread Footings

Mechanically Stabilized Earth (MSE) Retaining Walls

MSE retaining walls use precast block or panel like facing elements combined with either metallic or geosynthetic tensile reinforcements in the soil mass. MSE walls are preferred over cast-in-place walls because they are usually more economical. Other advantages include a wide variety of design styles, ease and speed of installation, and their ability to accommodate total and differential settlements. Wall design heights upwards of 80 ft. are technically feasible (FHFW-SA-96-071). MSE walls may be used to retain fill for end bents of bridge structures.

Additional Information

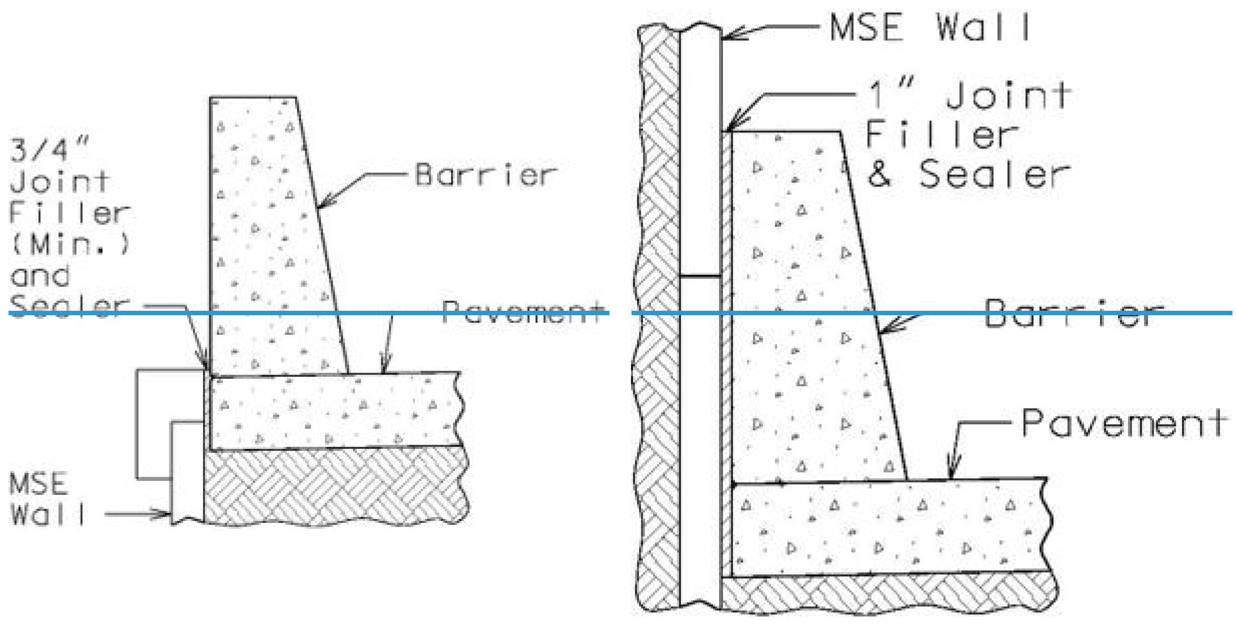
LRFD 11.10, FHWA-NHI-10-024 and 025

~~AASHTO 5.2.1.4 & 5.8~~

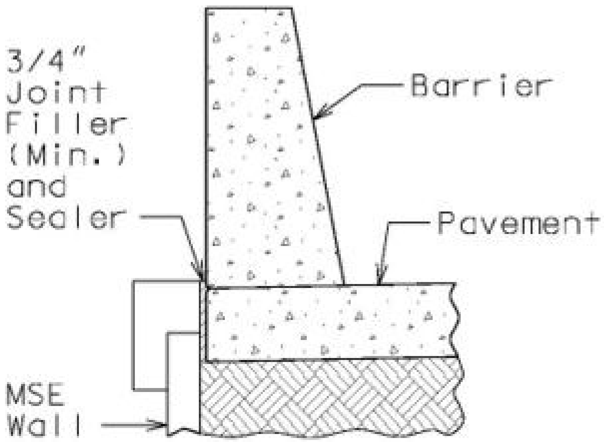
Situations exist where the use of MSE walls is either limited or not recommended. Some obstacles such as drop inlets, sign truss pedestals or footings, and fence posts may be placed within the soil reinforcement area, however, these obstacles increase the difficulty and expense of providing sufficient soil reinforcement for stability. Box culverts and highway drainage pipes may run through MSE walls, but it is preferable not to run the pipes close to or parallel to the walls. Utilities other than highway drainage should not be constructed within the soil reinforcement area. Be cautious when using MSE walls in a flood plain. A flood could cause scouring around the reinforcement and seepage of the backfill material. Soil reinforcements should not be used where exposure to ground water contaminated by acid mine drainage or other industrial pollutants as indicated by a low pH and high chlorides and sulfates exist. Galvanized metallic reinforcements shall not be used where stray electrical ground currents could occur as would be present near an electrical substation.

Sufficient right of way is required to install the soil reinforcement which extends into the backfill area at least 8 ft., 70 % of the wall height or as per design requirements set forth in EPG 751.6.2.17 Excavation, whichever is greater. For more information regarding soil reinforcement length, ~~and~~ excavation limits and Minimum Embedment Depth of MSEW, see EPG 751.6.2.17 Excavation.

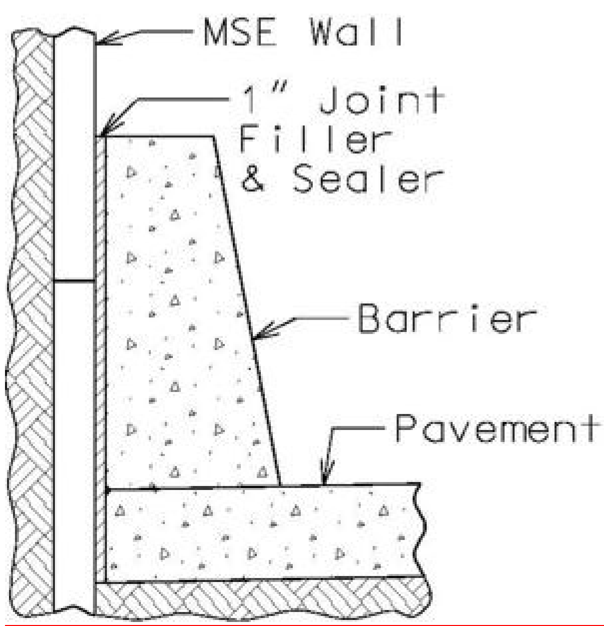
~~When a barrier is placed adjacent to an MSE wall space shall be provided to prevent the transfer of lateral forces to the MSE wall~~. Finally, barrier curbs constructed over or in line with the front face of the wall shall have adequate room provided laterally between the back of the wall facing and the curb or slab so that load is not directly transmitted to the top of MSE wall or facing units .



Barrier at Top of MSE Wall **Barrier in Front of MSE Wall**



Barrier at Top of MSE Wall



Barrier in Front of MSE Wall

Concrete Cantilever Wall on Spread Footing

Concrete cantilever walls derive their capacity through combinations of dead weight and structural resistance. These walls are constructed of reinforced concrete.

Concrete cantilever walls are used when MSE walls are not a viable option. Cantilever walls can reduce the rock cut required and can also provide solutions when there are right of way restrictions. Concrete walls also provide better structural capacity when barrier curbs on top of the walls are required.

Counterforts are used on rare occasions. Sign-board type retaining walls are a special case of counterfort retaining walls. They are used where the soil conditions are such that the footings must be placed well below the finished ground line. For these situations the wall is discontinued 12 in. below the ground line or below the frost line. Counterforts may also be a cost-savings option when the wall height approaches 20 ft. (*Foundation Analysis and Design* by Joseph E. Bowles, 4th ed., 1988). However, other factors such as poor soil conditions, slope of the retained soil, wall length and uniformity in wall height should also be considered before using counterforts.

Concrete Cantilever Wall on Pile Footing

Concrete cantilever walls on pile footings are used when the soil conditions do not permit the use of spread footings. These walls are also used when an end bent requires wings longer than 22 feet for seismic category A or 17 ft. for seismic category B, C or D. In these cases a stub wing is left attached to the end bent and the rest of the wing is detached to become a retaining wall as shown in 751.35.3.5 Wing & Detached Wing Walls.

NOTE: Move article 751.24.1.2 to 751.40.8.15 and replace with information below

751.24.1.2 Loads

Conventional retaining walls: Loads shall be determined in accordance with LRFD 3 and 11.6.

MSE retaining walls: Loads shall be determined in accordance with LRFD 3 and 11.10.

Note: For guidance, follow the 751.40.8.15 Cast-In-Place Concrete Retaining Walls and modify guidance of ASD as necessary to meet LRFD requirements until this section is modified for LRFD.

Dead Loads

Dead loads shall be determined from the unit weights in EPG 751.2.1.1 Dead Load.

751.24.2 Mechanically Stabilized Earth (MSE) Walls

751.24.2.1 Design

Designs of Mechanically Stabilized Earth (MSE) walls ~~are~~ shall be completed by consultants or contractors in accordance with Section 11.10 of LRFD specifications, FHWA-NHI-10-024 and FHWA-NHI-10-025 for LRFD. Bridge Pre-qualified Products List (BPPL) provided on~~5 of the AASHTO Specifications.~~ MoDOT web page and in Sharepoint ~~Internet site~~ contains a listing of facing unit manufacturers, soil reinforcement suppliers, and wall system suppliers which have been approved for use. See Sec 720 and Sec 1010 for additional information. The Geotechnical Section is responsible for checking global stability of permanent MSE wall systems, which should be reported ~~o~~in the Foundation Investigation Geotechnical Report. For MSE wall preliminary information, see EPG 751.1.4.3 MSE Walls. For design requirements of MSE wall systems and temporary shoring (including temporary MSE walls), see EPG 720 Mechanically Stabilized Earth Wall Systems. For staged bridge construction, see EPG 751.1.2.11 Staged Construction. For MSE wall preliminary information, see EPG 751.1.4.3 MSE Walls.

For seismic design requirements, see Bridge Seismic Design Flowchart. References for consultants and contractors include Section 11.10 of LRFD, FHWA-NHI-10-024 and FHWA-NHI-10-025.

Design Life

• 75 year minimum for permanent walls (if retained foundation require 100 year than consider 100 year minimum design life for wall).

Global stability:

Global stability will be performed by Geotechnical Section or their agent.

MSE wall contractor/designer responsibility:

MSE wall contractor/designer shall perform following analysis in their design for all applicable limit states.

- o External Stability
  - o Limiting Eccentricity
  - o Sliding
  - o Factored Bearing Pressure/Stress ≤ Factored Bearing Resistance

- o Internal Stability
  - o Tensile Resistance of Reinforcement
  - o Pullout Resistance of Reinforcement
  - o Structural Resistance of Face Elements
  - o Structural Resistance of Face Element Connections

- o Compound Stability

Capacity/Demand ratio (CDR) for bearing capacity shall be ≥ 1.0

$$Bearing\ Capacity\ (CDR) = \frac{Factored\ \ Bearing\ \ Resistance}{Maximum\ Factored\ Bearing\ Stress} \geq 1.0$$

Strength Limit States:

Factored bearing resistance = Nominal bearing resistance from Geotech report X Minimum Resistance factor (0.65, Geotech report) LRFD Table 11.5.7-1

Extreme Event I Limit State:

Factored bearing resistance = Nominal bearing resistance from Geotech report X Resistance factor

Resistance factor = 0.9 LRFD 11.8.6.1

Factored bearing stress shall be computed using a uniform base pressure distribution over an effective width of footing determined in accordance with the provisions of LRFD 10.6.3.1 and 10.6.3.2, 11.10.5.4 and Figure 11.6.3.2-1 for foundation supported on soil or rock.

B’ = L – 2e

Where,

L = Soil reinforcement length (For modular block use B in lieu of L as per LRFD 11.10.2-1)

B’ = effective width of footing

e = eccentricity

Note: When the value of eccentricity *e* is negative then B´ = L.

Capacity/Demand ratio (CDR) for overturning shall be ≥ 1.0

$$Overtuning\ (CDR) = \frac{Total\ Factored\ Resisting\ Moment}{Total\ Factored\ Driving\ Moment} \geq 1.0$$

Capacity/Demand ratio (CDR) for eccentricity shall be ≥ 1.0

$$Eccentricity\ (CDR) = \frac{e_{Limit}}{e_{design}} \geq 1.0$$

Capacity/Demand ratio (CDR) for sliding shall be ≥ 1.0 LRFD 11.10.5.3 & 10.6.3.4

$$Sliding\ (CDR) = \frac{Total\ Factored\ Sliding\ Resistance}{Total\ Factored\ Active\ Force} \geq 1.0$$

Capacity/Demand ratio (CDR) for internal stability shall be ≥ 1.0

Eccentricity, (e) Limit for Strength Limit State: LRFD 11.6.3.3 & C11.10.5.4

- For foundations supported on soil, the location of the resultant of the reaction forces shall be within the middle two-thirds of the base width, L or (e ≤ 0.33L).
- For foundations supported on rock, the location of the resultant of the reaction forces shall be within the middle nine-tenths of the base width, B or (e ≤ 0.45B).

Eccentricity, (e) Limit for Extreme Event I (Seismic): LRFD 11.6.5.1

- For foundations supported on soil or rock, the location of the resultant of the reaction forces shall be within the middle two-thirds of the base width, L or (e ≤ 0.33L) for $\gamma_{EQ} = 0.0$ and middle eight-tenths of the base width, L or (e ≤ 0.40L) for $\gamma_{EQ} = 1.0$. For γ_{EQ} between 0.0 and 1.0, interpolate e value linearly between 0.33L and 0.40L. For γ_{EQ} refer to LRFD 3.4.

Note: Seismic design shall be performed for $\gamma_{EQ} = 0.5$

Eccentricity, (e) Limit for Extreme Event II:

- For foundations supported on soil or rock, the location of the resultant of the reaction forces shall be within the middle eight-tenths of the base width, L or (e ≤ 0.40L).

General Guidelines

- Drycast modular block wall (DMBW-MSE) systems ~~Small block walls~~ are limited to a 10 ft. height in one lift.
- Wetcast modular block wall (WMBW-MSE) systems are limited to a 15 ft. height in one lift.
- For Drycast modular block wall (DMBW-MSE) systems and Wetcast modular block wall (WMBW-MSE) systems~~small block walls~~, top cap units shall be used and shall be permanently attached by means of a resin anchor system.
- For precast modular panel wall (PMPW-MSE) systems~~large block walls~~, capstone may be substituted for coping and either shall be permanently attached to wall by panel dowels.

- For precast modular panel wall (PMPW-MSE) systemslarge block walls, form liners are required to produce all panels. Using form liner to produce panel facing is more cost effective than producing flat panels. Standard form liners are specified on the MSE Wall Standard Drawings. Be specific regarding names, types and colors of staining, and names and types of form liner.

- MSE walls shall not be used where exposure to acid water may occur such as in areas of coal mining.

- MSE walls shall not be used where scour is a problem.

- MSE walls with metallic soil reinforcement shall not be used where stray electrical ground currents may occur as would be present near electrical substations.

- No utilities shall be allowed in the reinforced earth if future access to the utilities would require that the reinforcement layers be cut, or if there is a potential for material, which can cause degradation of the soil reinforcement, to leak out of the utilities into the wall backfill, with the exception of storm water drainage.

- The interior angle between two walls should be greater than 70°. However, if unavoidable, then place EPG 751.50 J1.31 41 note on the design plans.

- Drycast modular block wall (DMBW-MSE) systems and Wetcast modular block wall (WMBW-MSE) systems Small block walls may be battered up to 1.5 in. per foot. Modular blocks are also known as "segmental blocks".

- The friction angle used for the computation of horizontal forces within the reinforced soil shall be greater than or equal to 34°.

- For epoxy coated reinforcement requirements, see EPG 751.5.9.2.2 Epoxy Coated Reinforcement Requirements.

- All concrete except facing panels or units shall be CLASS B or B-1.

- The friction angle of the soil to be retained by the reinforced earth shall be listed on the plans as well as the friction angle for the foundation material the wall is to rest on.
- The following requirement shall be considered (from 2009_FHWA-NHI 10024 MSE wall 132042.pdf, page 200-201) when seismic design is required:

- For seismic performance Zones 3 or 4, facing connections in modular block faced walls (MBW) shall use shear resisting devices (shear keys, pin, etc.) between the MBW units and soil reinforcement, and shall not be fully dependent on frictional resistance between the soil reinforcement and facing blocks. For connections partially dependent on friction between the facing blocks and the soil reinforcement, the nominal long-term connection strength T_{ac}, should be reduced to 80 percent of its static value.

- Seismic performance design category and acceleration coefficients shall be listed on the plans for categories B, C and D. If a seismic analysis is required that shall also be noted on the plans. See EPG 751.50 Note A1.1.
-
- Plans note (EPG 751.50 J1.1) is required to clearly identify the responsibilities of the wall designer.

- Factors of Safety for MSE walls shall be 2.0 for overturning, 1.5 for sliding, 2.0 for ultimate bearing capacity and 1.5 for pullout resistance.

- ~~Factors of Safety for seismic design shall be 1.5 for overturning and 1.1 for sliding.~~

- Do not use Drycast modular block wall (DMBW-MSE) systems or Wetcast modular block wall (WMBW-MSE) systems ~~small block walls~~ in the following locations:

  - Within the splash zone from snow removal operations (assumed to be 15 feet from the edge of the shoulder).

  - Where the blocks will be continuously wetted, such as around sources of water.

  - Where blocks will be located behind barrier or other obstacles that will trap salt-laden snow from removal operations.

  - For structurally critical applications, such as containing necessary fill around structures.

  - In tiered wall systems.

- For locations where Drycast modular block wall (DMBW-MSE) systems and Wetcast modular block wall (WMBW-MSE) systems~~small block walls~~ are not desirable, consider coloring agents and/or architectural forms using precast modular panel wall (PMPW-MSE) systems~~large block walls~~ for aesthetic installations.

- For slab drain location near MSE Wall, see EPG 751.10.3.1 Drain Type, Alignment and Spacing and EPG 751.10.3.3 General Requirements for Location of Slab Drains.

- Roadway runoff should be directed away from running along face of MSE walls used as wing walls on bridge structures.

- Drainage:

  - Gutter type should be selected at the core team meeting.

  - When gutter is required without fencing, use Type A or Type B gutter (for detail, see Std. Plan 609.00).

  - When gutter is required with fencing, use Modified Type A or Modified Type B gutter (for detail, see Std. Plan 607.11).

  - When fencing is required without gutter, place in tube and grout behind the MSE wall (for detail, see MSE Wall Standard Drawings ~~Fig. 751.24.2.1.7~~, Fence Post Connection Behind MSE Wall (without gutter).

  - Lower backfill longitudinal drainage pipes behind all MSE walls shall be two-6” (Min.) diameter perforated PVC or PE pipe (See Sec 1013) unless larger sizes are required by design which shall be the responsibility of the District Design Division. Show drainage pipe size on plans. Outlet screens and cleanouts should be detailed for any drain pipe (shown on MoDOT MSE wall plans or roadway plans). Lateral non-perforated drain pipes (below leveling pad) are permitted by Standard Specifications and shall be sized by the District Design Division if necessary. Lateral outlet drain pipe sloped at 2% minimum.

  - Identify on MSE wall plans or roadway plans drainage pipe point of entry, point of outlet (daylighting), 2% min. drainage slopes in between points to ensure positive flow and additional longitudinal drainage pipes if required to accommodate ground slope changes and lateral drainage pipes if required by design.

- Adjustment in the vertical alignment of the longitudinal drainage pipes from that depicted on the MSE wall standard drawings may be necessary to ensure positive flow out of the drainage system.

- Identify on MSE wall plans or roadway plans the outlet ends of pipes which shall be located to prevent clogging or backflow into the drainage system. Outlet screens and cleanouts should be detailed for any drain pipe.

- For more information on drainage, see Drainage at MSE Walls.

Drainage at MSE Walls

- **Drainage Before MSE Wall**
  Drainage is not allowed to be discharged within 10 ft. from front of MSE wall in order to protect wall embedment, prevent erosion and foundation undermining, and maintain soil strength and stability.

- **Drainage Behind MSE Wall**
  Internal (Subsurface) Drainage
  Groundwater and infiltrating surface waters are drained from behind the MSE wall through joints between the face panels or blocks (i.e. wall joints) and two-6 in. (min.) diameter pipes located at the base of the wall and at the basal interface between the reinforced backfill and the retained backfill.

  Excessive subsurface draining can lead to increased risk of backfill erosion/washout through the wall joints and erosion at the bottom of walls and at wall terminal ends. Excessive water build-up caused by inadequate drainage at the bottom of the wall can lead to decreased soil strength and wall instability. Bridge underdrainage (vertical drains at end bents and at approach slabs) can exacerbate the problem.

  Subsurface drainage pipes should be designed and sized appropriately to carry anticipated groundwater, incidental surface run-off that is not collected otherwise including possible effects of drainage created by an unexpected rupture of any roadway drainage conveyance or storage as an example.

  External (Surface) Drainage
  External drainage considerations deal with collecting water that could flow externally over and/or around the wall surface taxing the internal drainage and/or creating external erosion issues. It can also infiltrate the reinforced and retained backfill areas behind the MSE wall.

  Diverting water flow away from the reinforced soil structure is important. Roadway drainage should be collected in accordance with roadway drainage guidelines and bridge deck drainage should be collected similarly.

  - **Guidance**

  ALL MSE WALLS

  5. Bridge deck, approach slab and roadway drainage shall not be allowed to be discharged to MSE wall backfill area or within 10 feet from front of MSE wall.

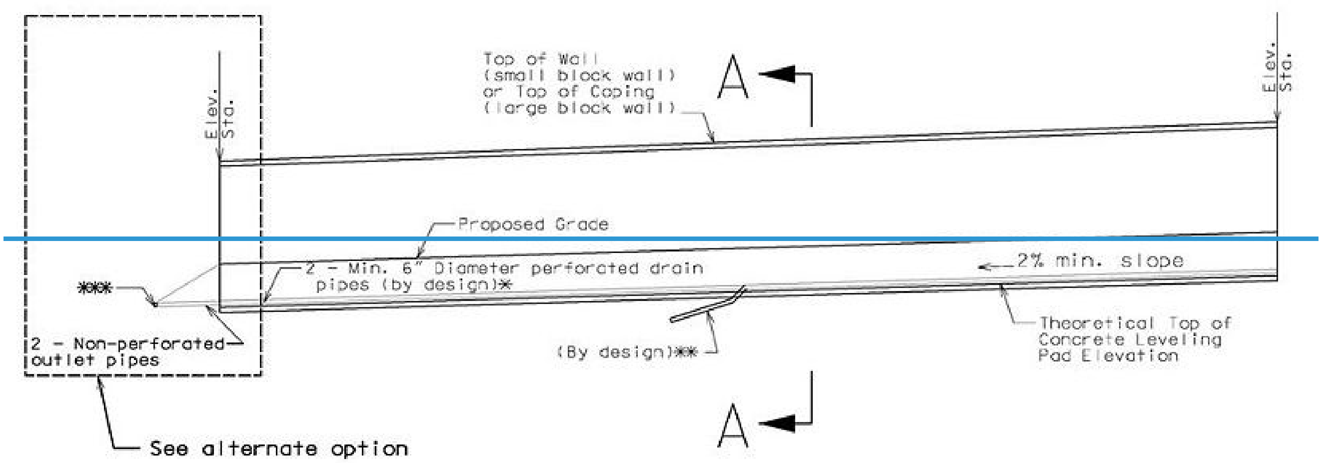
- (Recommended) Use of a major bridge approach slab and approach pavement is ideal because bridge deck, approach slab and roadway drainage are directed using curbs and collected in drain basins for discharge that protect MSE wall backfill. For bridges not on a major roadway, consideration should be given to requiring a concrete bridge approach slab and pavement incorporating these same design elements (asphalt is permeable).

- (Less Recommended) Use of conduit and gutters:

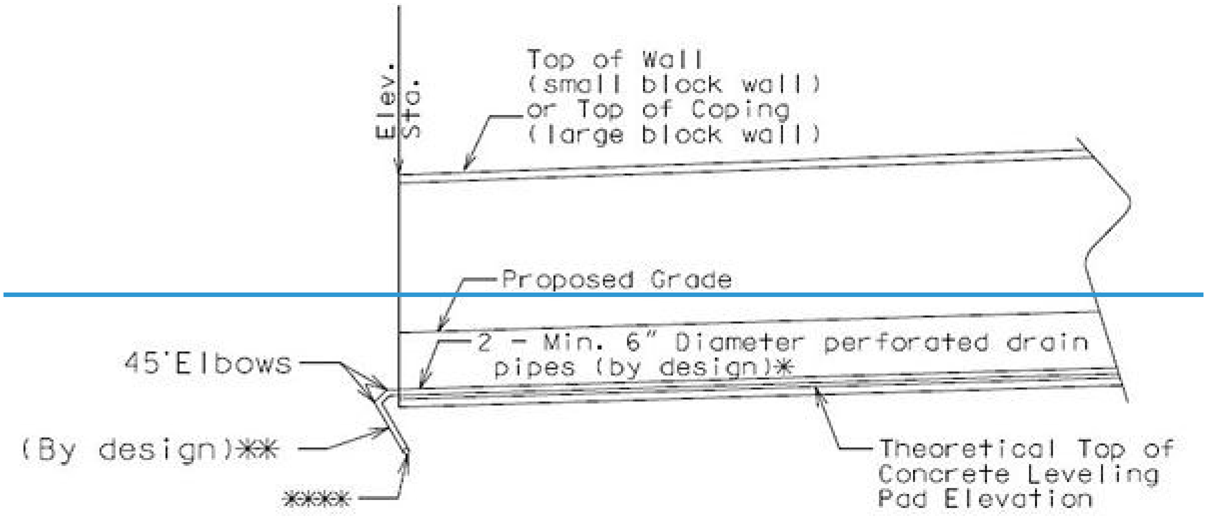
- Conduit: Drain away from bridge and bury conduit daylighting to natural ground or roadway drainage ditch at an eventual point beyond the limits of the wall. Use expansion fittings to allow for bridge movement and ~~(can~~ consider placing conduit to front of MSE wall and discharging more than 10 feet from front of wall or using lower drain pipes to intercept slab drainage conduit running through backfill.

- Conduit and Gutters: Drain away from bridge using conduit and 90° elbow (or 45° bend) for smoothly directing drainage flow into gutters and that may be attached to inside of gutters to continue along downward sloping gutters along back of MSE wall to discharge to sewer or to natural drainage system, or to eventual point beyond the limits of the wall. Allow for independent bridge and wall movements by using expansion fittings where needed. See EPG 751.10.3.1 Type, Alignment and Spacing and EPG 751.10.3.3 General Requirements for Location of Slab Drains.

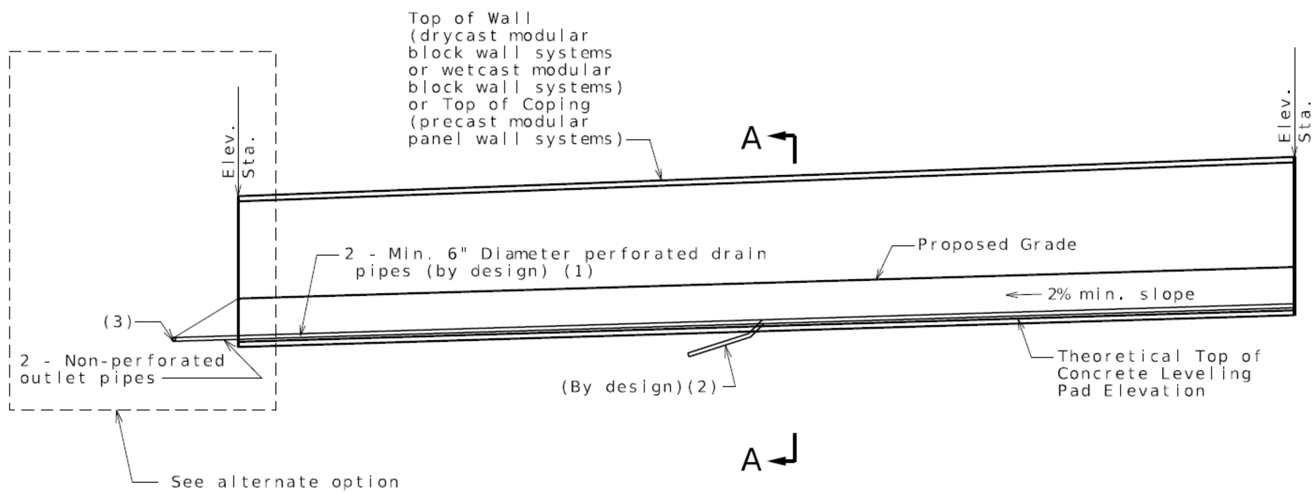
Example: Showing drain pipe details on the MSE wall plans.



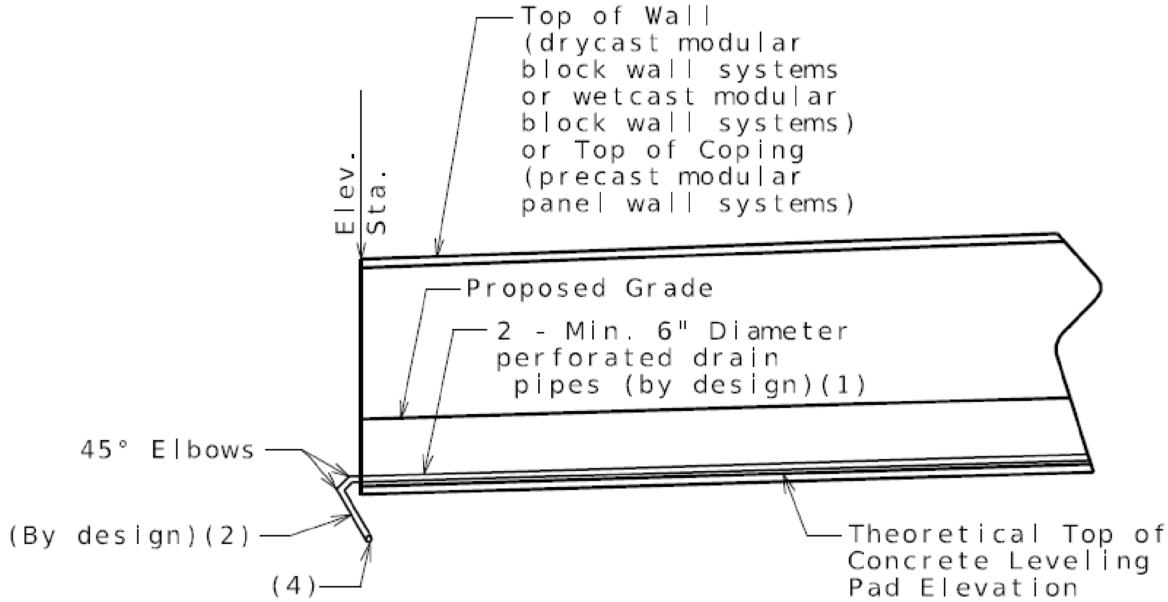
ELEVATION SHOWING DRAIN PIPE



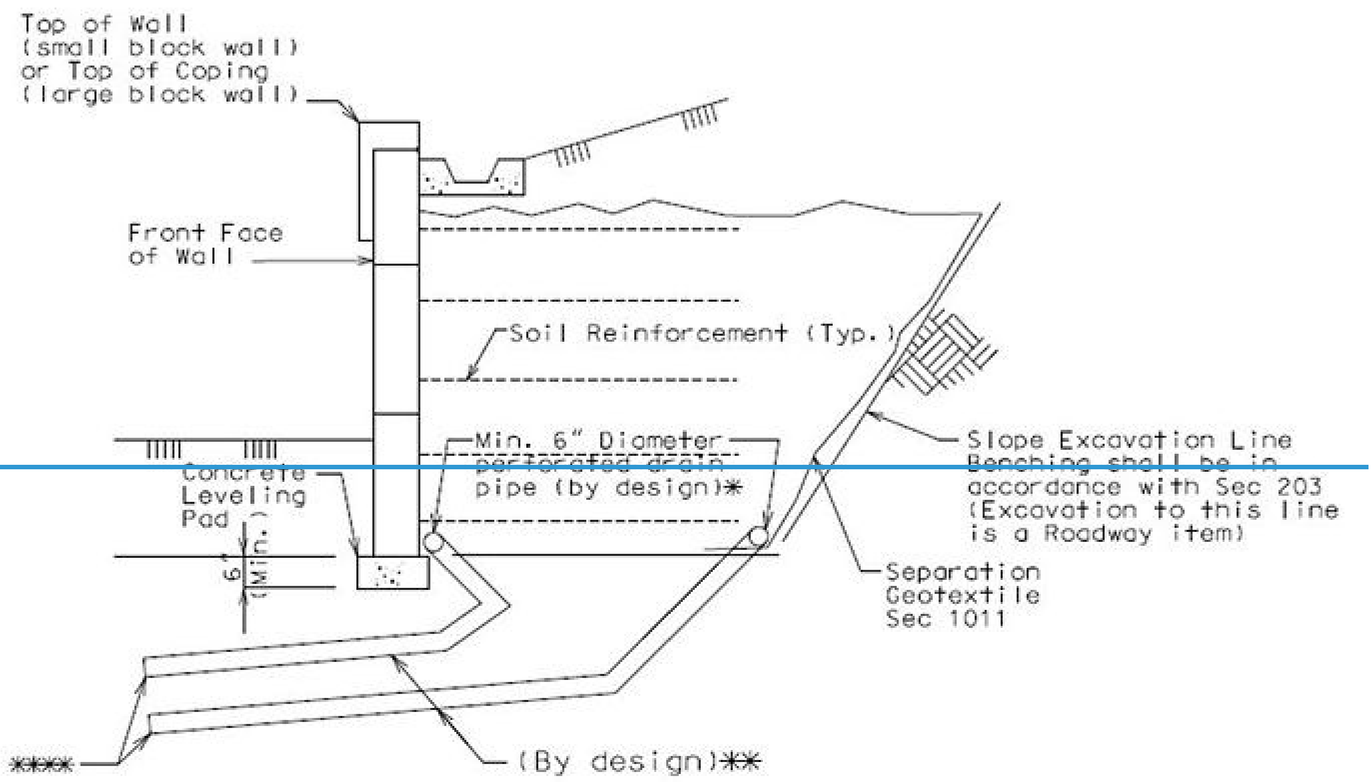
Alternate option



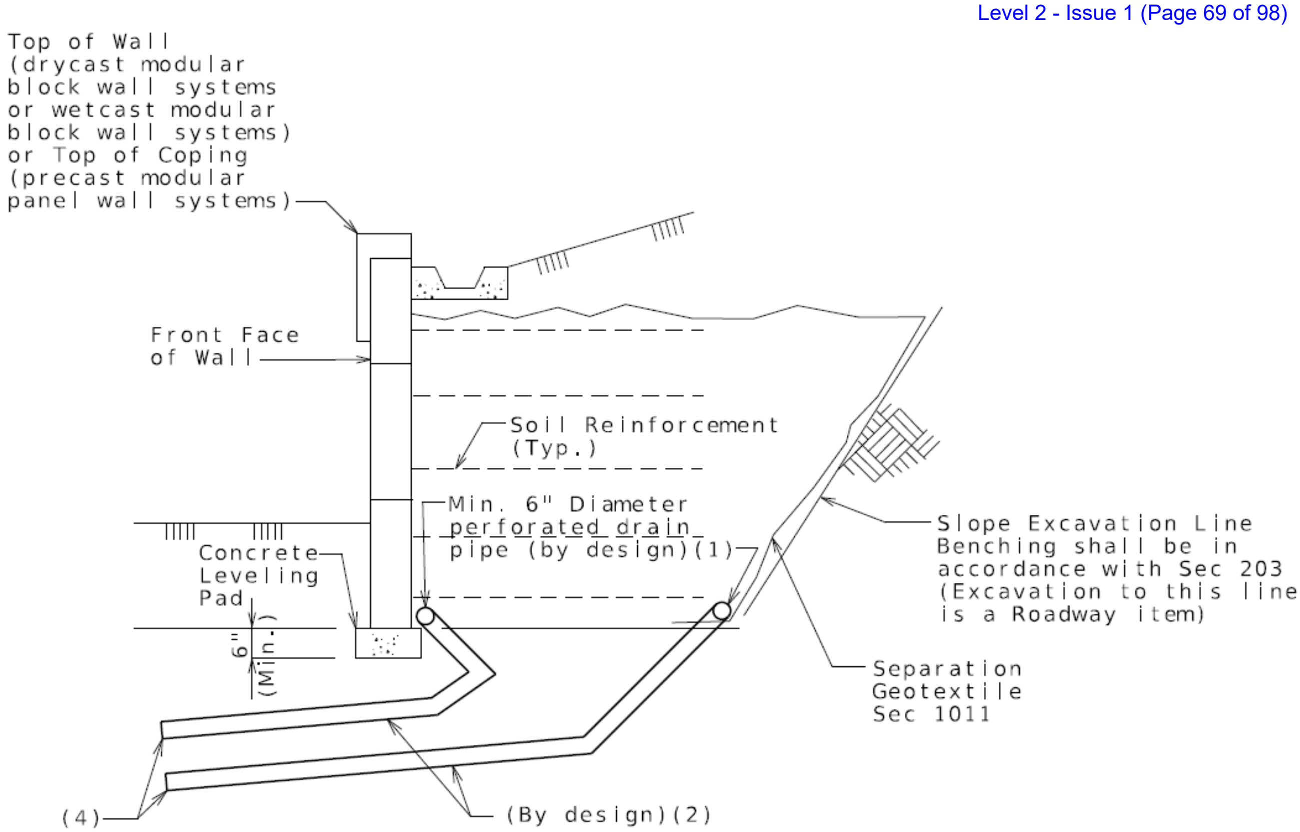
ELEVATION SHOWING DRAIN PIPE



ALTERNATE OPTION



SECTION A-A



SECTION A - A

Notes:
*(1) To be designed by District Design Division.
**(2) To be designed by District Design Division if needed. Provide non-perforated lateral drain pipe under leveling pad at 2% minimum slope. (Show on plans).
***(3) Discharge to drainage system or daylight screened outlet at least 10 feet away from end of wall (typ.). (Skew in the direction of flow as appropriate).
****(4) Discharge to drainage system or daylight screened outlet at least 10 feet away from front face of wall (typ.). (Skew in the direction of flow as appropriate).

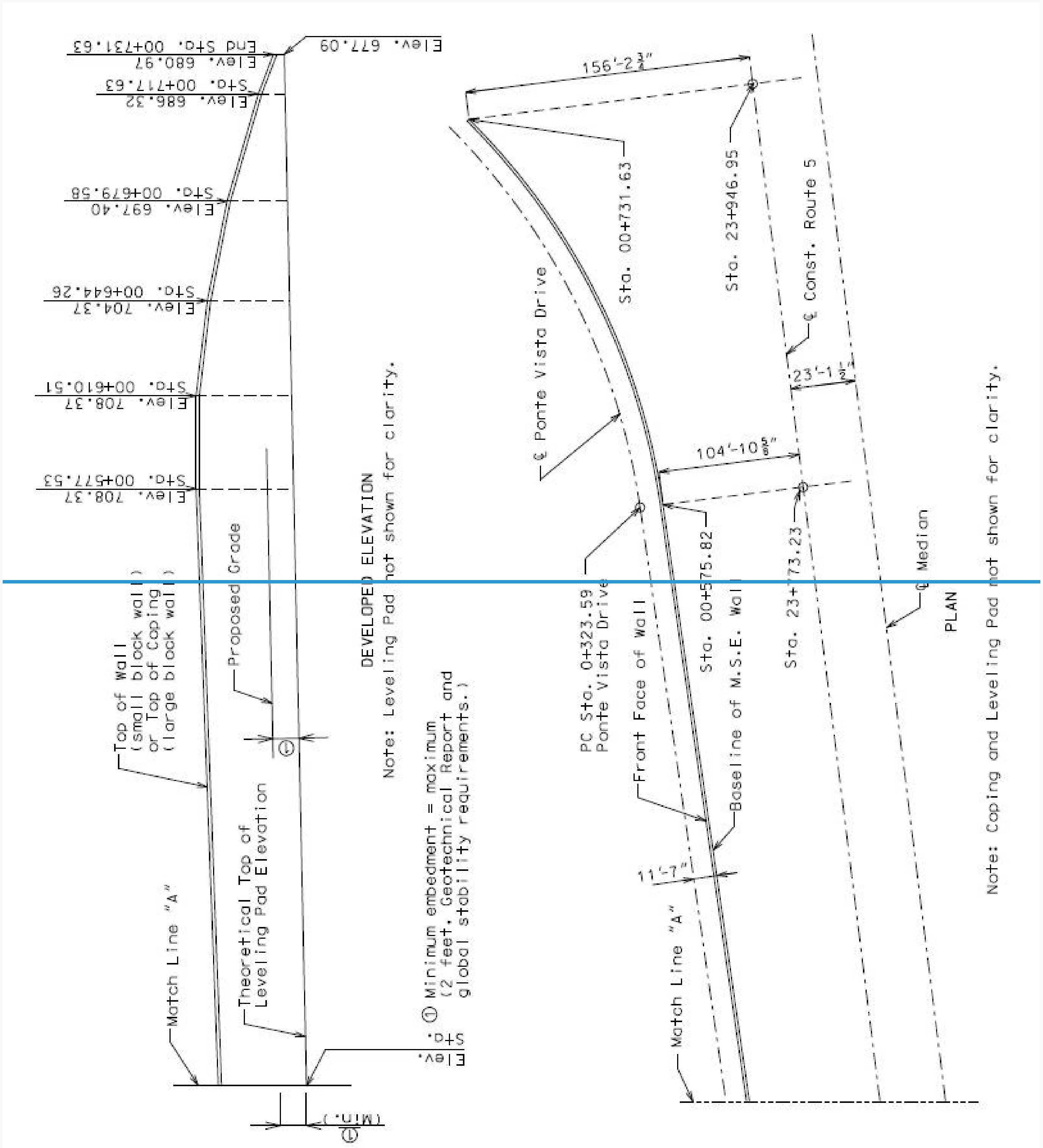
751.24.2.2 Excavation

For estimating excavation and minimum soil reinforcement length, see EPG 751.6.2.17 Excavation.

For division responsibilities for preparing MSE wall plans, computing excavation class, quantities and locations, see EPG 747.2.6.2 Mechanically Stabilized Earth (MSE) Wall Systems.

751.24.2.3 Details

Bridge Standard Drawings
MSE Wall



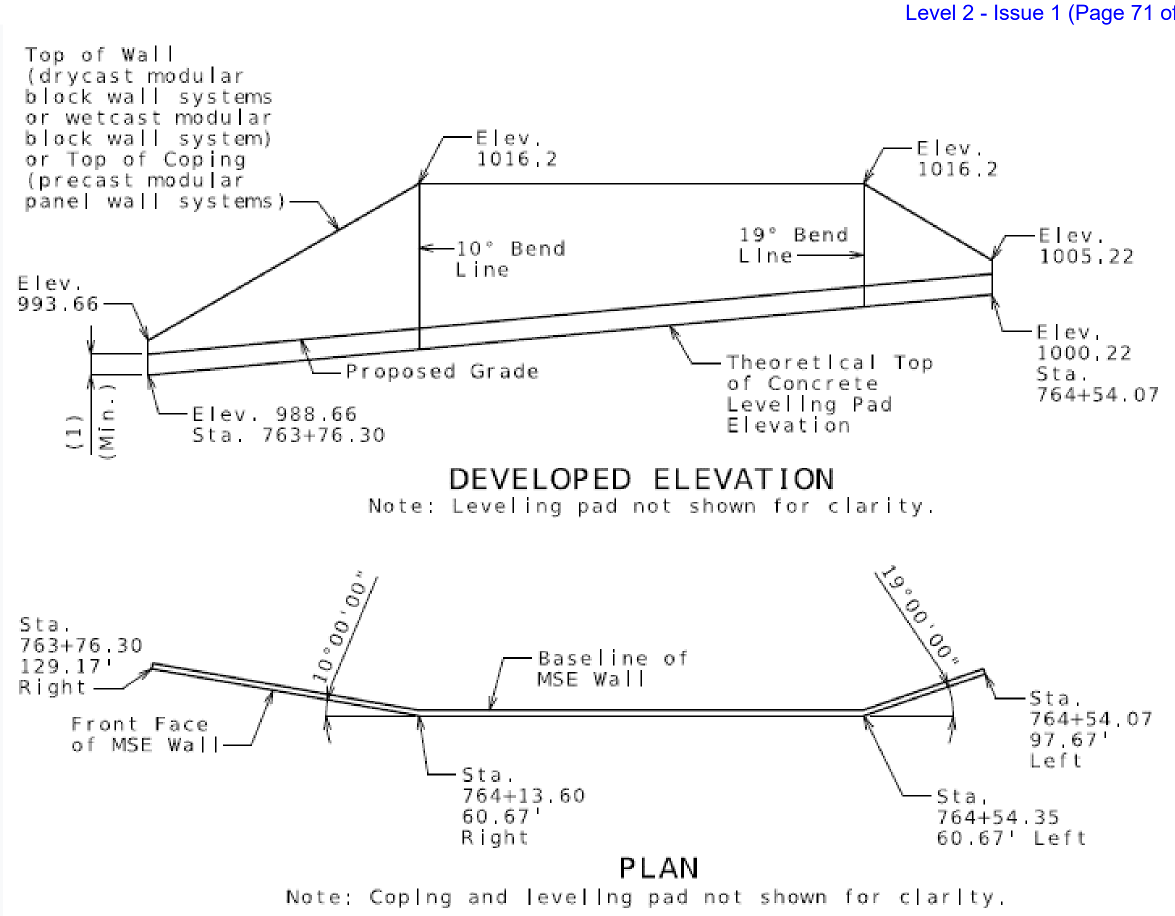


Fig. 751.24.2.~~2~~3.1 MSE Wall Developed Elevation and Plan

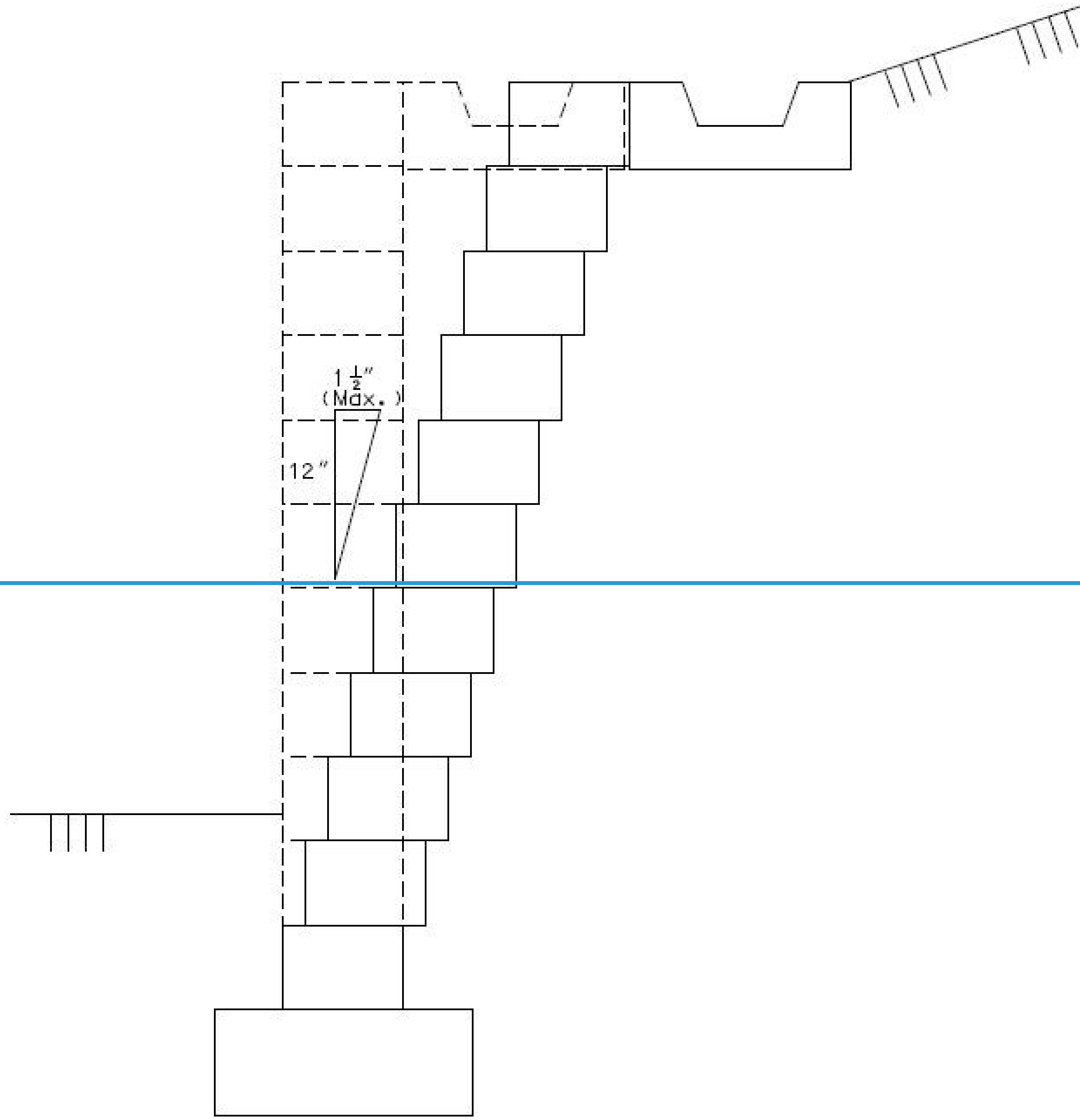
(1) Minimum embedment = maximum (2 feet; or embedment based on Geotechnical Report and global stability requirements; or FHWA-NH1-10-0124, Table 2-2); or as per Geotechnical Report if rock is known to exist from Geotechnical Report.

Battered Drycast Modular Block Wall Systems and Wetcast Modular Block Wall Systems~~Small Block Walls~~

Battered mechanically stabilized earth wall systems may be used unless the design layout specifically calls for a vertical wall (precast modular panel wall systems~~large block walls~~ shall not be battered and drycast modular block wall systems or wetcast modular block wall systems ~~small block walls~~ may be built vertical). If a battered MSE wall system is allowed, then ~~the following~~ EPG 751.50 J1.19 note shall be placed on the design plans~~:~~.

~~"The top and bottom of wall elevations are given for a vertical wall. If a battered system is used, the height of the wall shall be adjusted as necessary to fit the ground slope. If fence is built on an extended gutter, then the height of the wall shall be adjusted further."~~

For battered walls, note on the plans whether the horizontal offset from the baseline is fixed at the top or bottom of the wall. Horizontal offset and corresponding vertical elevation shall be noted on plans.


1 1/2"
(Max.)
12"

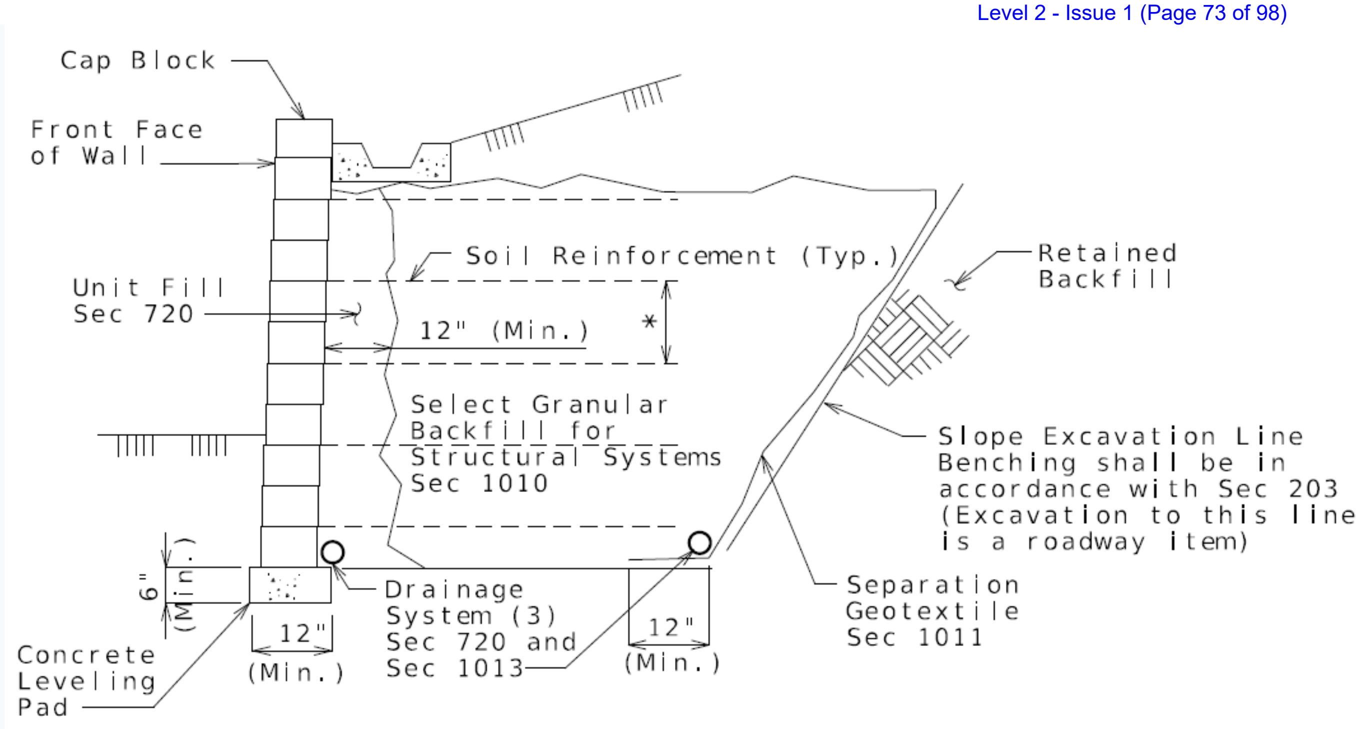


Fig. 751.24.2.~~2~~3.2 Typical Section Through Generic Drycast Modular Block Wall (DMBW-MSE) System or Wetcast Modular Block Wall (WMBW-MSE) System ~~Small Block Wall~~

*** The maximum vertical spacing of reinforcement should be limited to two times the block depth or 32 in., whichever is less. For large modular block (block height > 16 in.), maximum vertical spacing of reinforcement equal to the block height.**

Fencing (See Bridge Standard Drawing for details)

Fencing may be installed on the Modified Type A or Modified Type B Gutter or behind the MSE Wall.

For Modified Type A and Modified Type B Gutter and Fence Post Connection details, see Standard Plan 607.11.

751.24.3 Cast-In-Place Concrete Retaining Walls

NOTE: Move articles 751.3.1 thru 751.3.8 to 751.40.8.15.3.1 thru 751.40.8.15.3.8 and replace with the following 751.24.3.1 and 751.24.3.2

751.24.3.1 Unit Stresses

Concrete for retaining walls shall be Class B Concrete (f'c = 3000 psi) unless the footing is used as a riding surface in which case Class B-1 Concrete (f'c = 4000 psi) shall be used.

Reinforcing Steel

Reinforcing Steel shall be Grade 60 (fy = 60,000 psi).

Pile Footing

For steel piling material requirements, see the unit stresses in EPG 751.50 Standard Detailing Notes.

Spread Footing

For foundation material capacity, see Foundation Investigation Geotechnical Report.

751.24.3.2 Design

Note: For design concepts and guidance, follow the design process (EPG 751.40.8.15) and modify design/details of ASD as necessary to meet LRFD requirements until EPG 751.24 is updated for LRFD.

Capacity/Demand ratio (CDR) for bearing capacity shall be ≥ 1.0

$$Bearing\ Capacity\ (CDR) = \frac{Factored\ \ Bearing\ \ Resistance}{Maximum\ Factored\ Bearing\ Stress} \geq 1.0$$

Strength Limit States:
Factored bearing resistance = Nominal bearing resistance from Geotech report X Minimum Resistance factor (0.55, Geotech report) LRFD Table 11.5.7

Extreme Event I and II Limit State:
Factored bearing resistance = Nominal bearing resistance from Geotech report X Resistance factor
Resistance factor = 0.8 LRFD 11.5.8

When wall is supported by soil:
Factored bearing stress per LRFD eq. 11.6.3.2-1

When wall is supported by a rock foundation:
Factored bearing stress per LRFD eq. 11.6.3.2-2 and 11.6.3.2-3

Note: When the value of eccentricity *e* is negative then use e = 0.

Capacity/Demand ratio (CDR) for overturning shall be ≥ 1.0

$$Overtuning\ (CDR) = \frac{Total\ Factored\ \ Resisting\ Moment}{Total\ Factored\ Driving\ Moment} \geq 1.0$$

Capacity/Demand ratio (CDR) for eccentricity shall be ≥ 1.0

$$Eccentricity\ (CDR) = \frac{e_{Limit}}{e_{design}} \geq 1.0$$

Capacity/Demand ratio (CDR) for sliding shall be ≥ 1.0

$$Sliding\ (CDR) = \frac{Total\ Factored\ Sliding\ \ Resistance}{Total\ Factored\ Active\ Force} \geq 1.0$$

Sliding shall be checked in accordance with LRFD 11.6.3.6 and 10.6.3.4

Eccentricity, (e) Limit for Strength Limit State: LRFD 11.6.3.3

- For foundations supported on soil, the location of the resultant of the reaction forces shall be within the middle two-thirds of the base width, B or ($e \leq 0.33B$).

- For foundations supported on rock, the location of the resultant of the reaction forces shall be within the middle nine-tenths of the base width, B or ($e \leq 0.45B$).

Eccentricity, (e) Limit for Extreme Event I (Seismic): LRFD 11.6.5.1

For foundations supported on soil or rock, the location of the resultant of the reaction forces shall be within the middle two-thirds of the base width, B or ($e \leq 0.33B$) for $\gamma_{EQ} = 0.0$ and middle eight-tenths of the base width, B or ($e \leq 0.40B$) for $\gamma_{EQ} = 1.0$. For γ_{EQ} between 0.0 and 1.0, interpolate e value linearly between 0.33B and 0.40B. For γ_{EQ} refer to LRFD 3.4.

Note: Seismic design shall be performed for $\gamma_{EQ} = 0..5$

Eccentricity, (e) Limit for Extreme Event II:

- For foundations supported on soil or/and rock, the location of the resultant of the reaction forces shall be within the-middle eight-tenths of the base width, B or ($e \leq 0.40B$).

751.31 Open Concrete Intermediate Bents

Update minimum support length links in this article to 751.9 Bridge Seismic Design

751.32 Concrete Pile Cap Intermediate Bents

Update minimum support length links in this article to 751.9 Bridge Seismic Design

751.34.2.2 Loads

Dead Loads

Loads from stringers, girders, etc. shall be applied as concentrated loads applied at the centerline of bearing. Loads from concrete slab spans shall be applied as uniformly distributed loads.

Live Loads

Loads from stringers, girders, etc. shall be applied as concentrated loads applied at the centerline of bearing. Dynamic load allowance (impact) should be included for the design of the beam. No dynamic load allowance should be included for foundation design.

For wings with detached wing walls, no portion of the bridge live load shall be distributed to the detached wall. The detached wing wall shall be designed as a retaining wall. The weight of the barrier or railing on top of the wall shall be included in the dead load.

Collision

Collision shall be designed if abutments are located within a distance of 30.0 feet to the edge of roadway, or within a distance of 50.0 feet to the centerline of a railway track and conditions do not qualify for exemptions given in EPG 751.2.2.6. If designed for, the collision force shall be a static force of 400 kips assumed to act in any direction in a horizontal plane, at a distance of 4.0 feet above ground.

Temperature

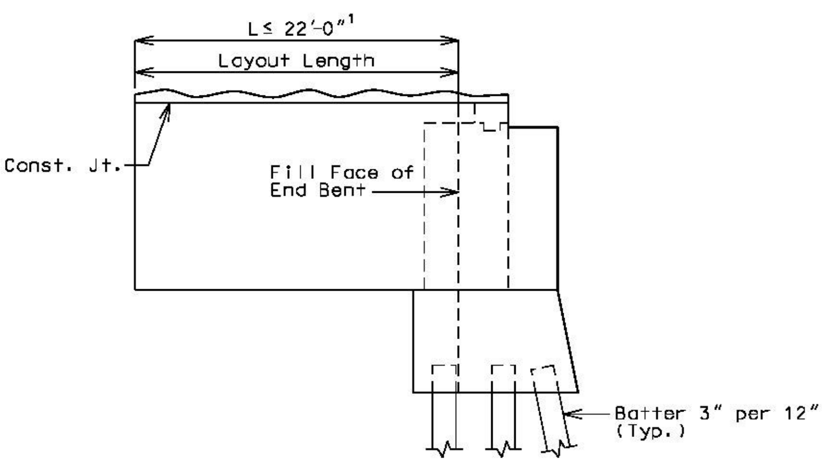
The force due to expansion or contraction applied at bearing pads are not used for stability or pile bearing computations. However, the movement due to temperature should be considered in the bearing pad design and expansion device design.

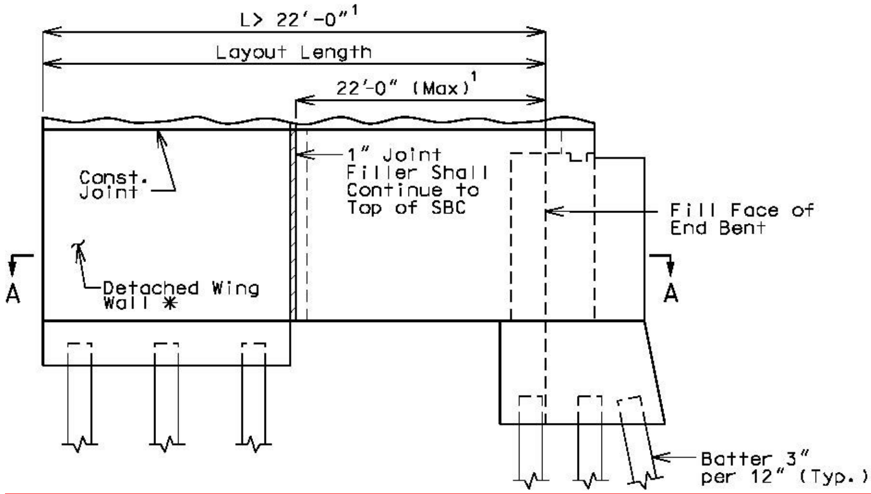
Distribution of Loads

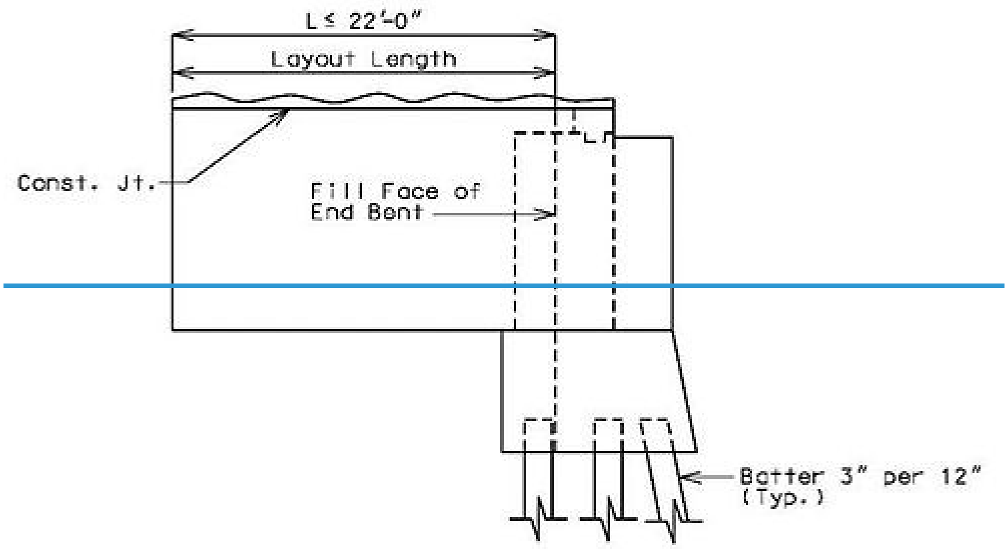
Wing ~~with~~ and Detached Wing Walls

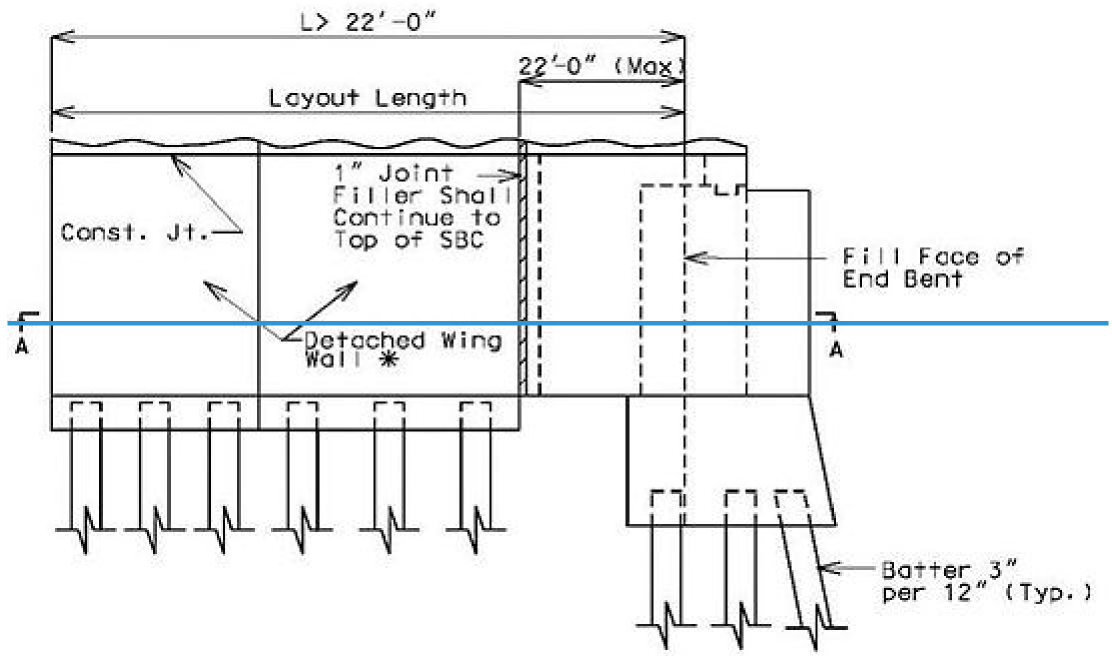
For seismic design category A: When Wing Length, L, is greater than 22'-0", use maximum of 22'-0" non-integral abutment~~rectangular~~ wing wall combined with a detached wing wall.

Standard wing reinforcement is developed assuming a pinned connection at the bottom (tip) of wing. This assumption is applicable for cases where the passive pressure from the fill slope can be counted on to partially resist the active forces from the backfill. In a seismic event the forces on the wings are developed by the wings moving into the soil backfill and the fill slope resistance is less reliable. For seismic forces wings shall be designed assuming there is no lateral restraint at the bottom of the wing. The reduced restraint conditions require a more practical limit for the wing length.



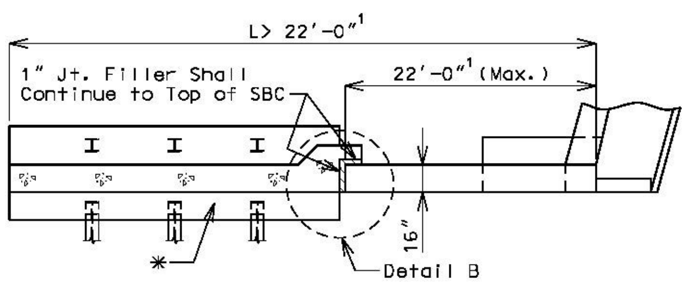

L> 22'-0"¹
Layout Length
22'-0" (Max)¹
Const. Joint
1" Joint Filler Shall Continue to Top of SBC
Fill Face of End Bent
Detached Wing Wall *
A
A
Batter 3" per 12" (Typ.)

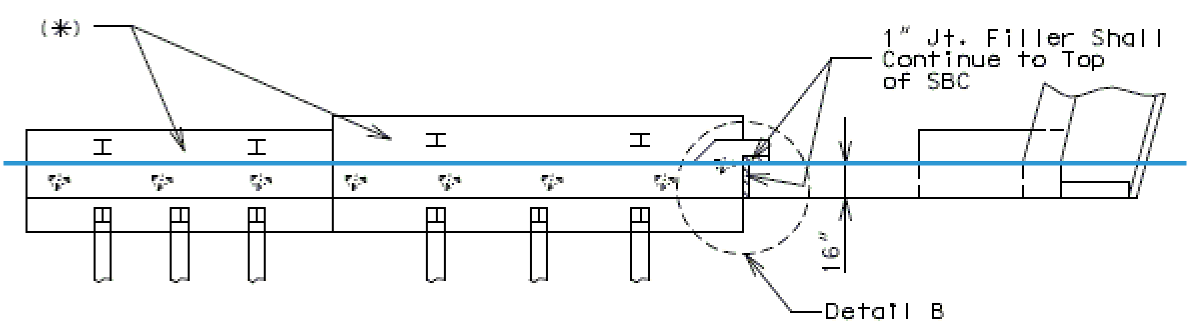

L ≤ 22'-0"
Layout Length
Const. Jt.
Fill Face of End Bent
Batter 3" per 12" (Typ.)



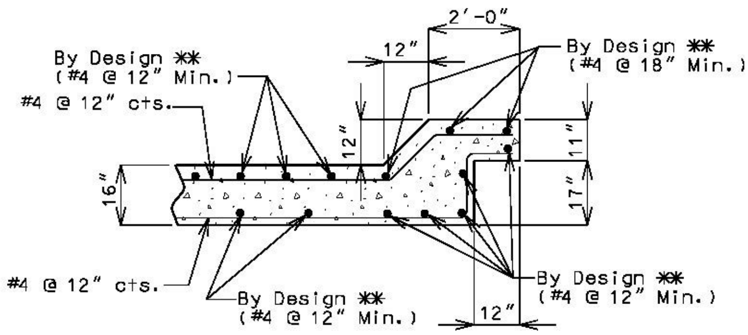
* ~~Detached wing wall shown is for illustration purpose only. Design detached wing wall as a retaining wall.~~

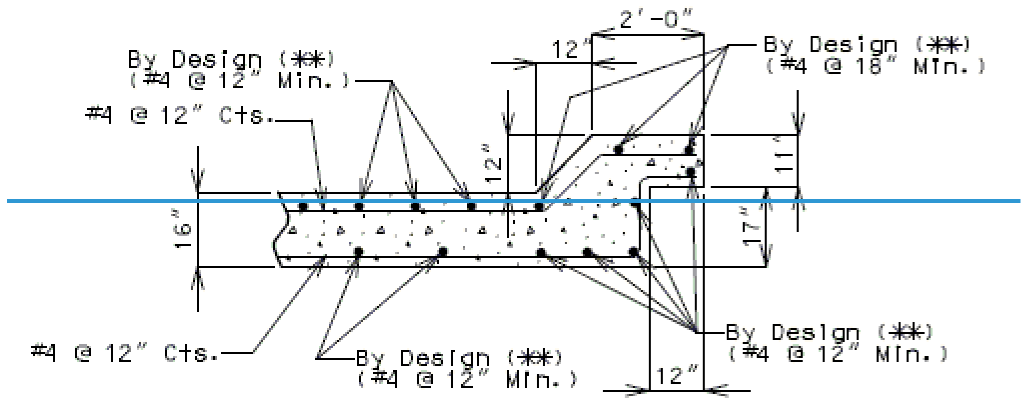
~~Report Pile Cut-off Elev. and Minimum Galvanized Penetration (Elev.) (See Foundation Data).~~





Section A-A





Detail B

(*)* Detached wing wall shown is for illustration purpose only. Design detached wing wall as a retaining wall.

(**)** Use retaining wall design.

[1] For seismic design category B, C and D only: The wing length shall not be greater than 17 feet. When a detached wing wall is required the non-integral abutment wing length shall not exceed 17 feet.

Report Pile Cut-off Elev. and Minimum Galvanized Penetration (Elev.) (See EPG 751.50 Standard Detailing Note E2, (Foundation Data Table).

751.34.2.3 Design Assumptions

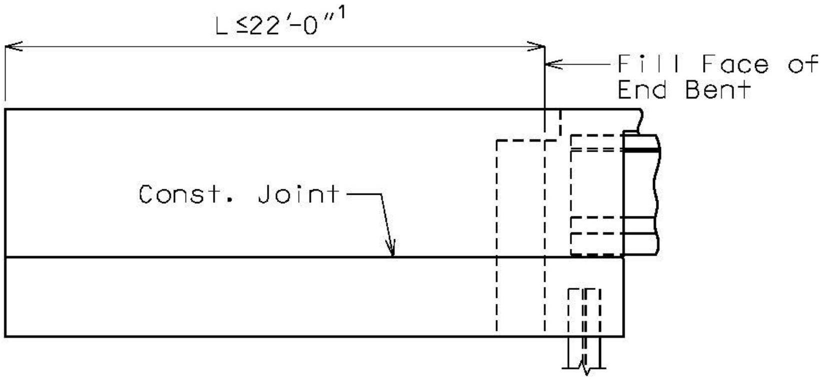
751.34.3.2 Wide Flange Beams, Plate Girders and Prestressed Girders

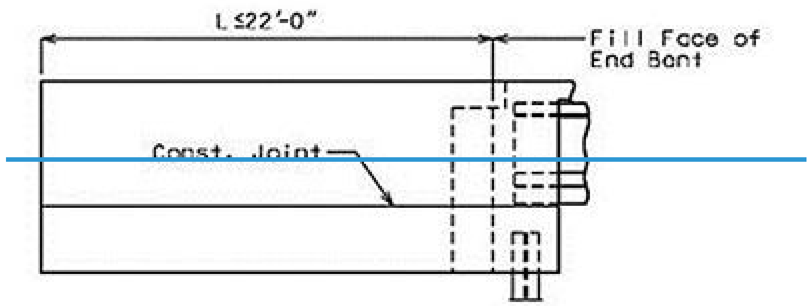
Update minimum support length links in this article to 751.9 Bridge Seismic Design

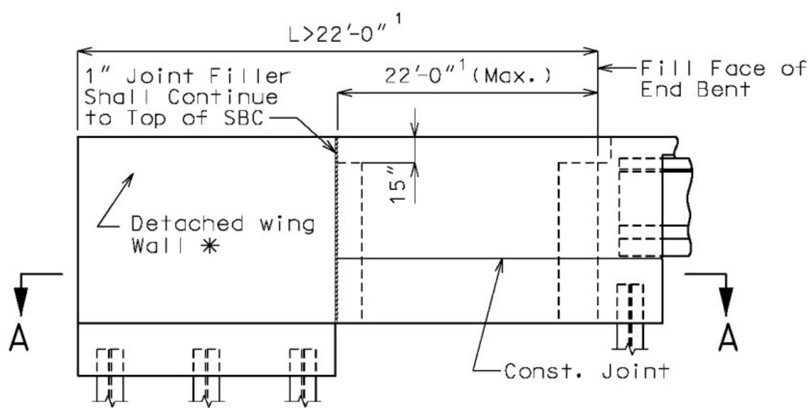
751.35.3.5 Wing & Detached Wing Walls

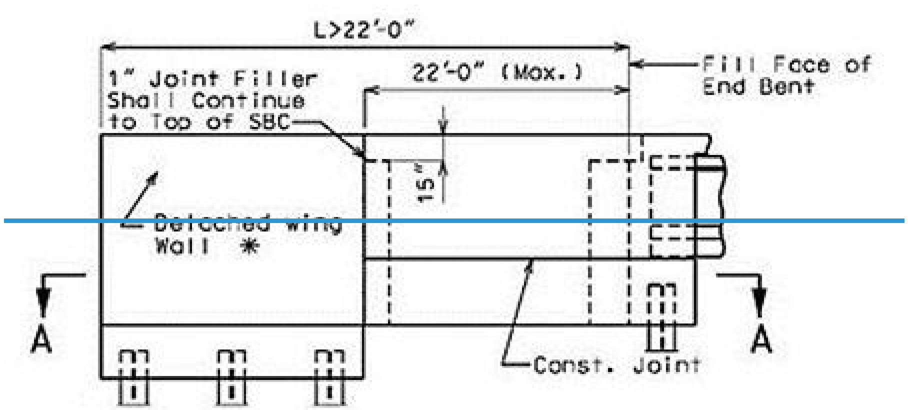
For seismic design category A: When wing length, L, is greater than 22'-0", use maximum 22'-0" integral abutment wing wall combined with detached wing wall.

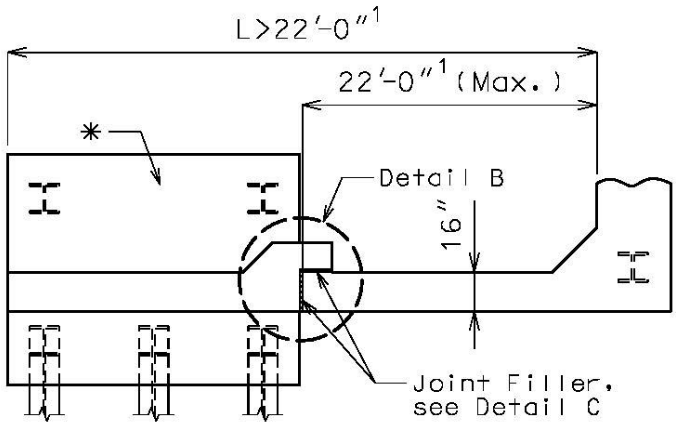
Standard wing reinforcement is developed assuming a pinned connection at the bottom (tip) of wing. This assumption is applicable for cases where the passive pressure from the fill slope can be counted on to partially resist the active forces from the backfill. In a seismic event the forces on the wings are developed by the wings moving into the soil backfill and the fill slope resistance is less reliable. For seismic forces wings shall be designed assuming there is no lateral restraint at the bottom of the wing. The reduced restraint conditions require a more practical limit for the wing length.

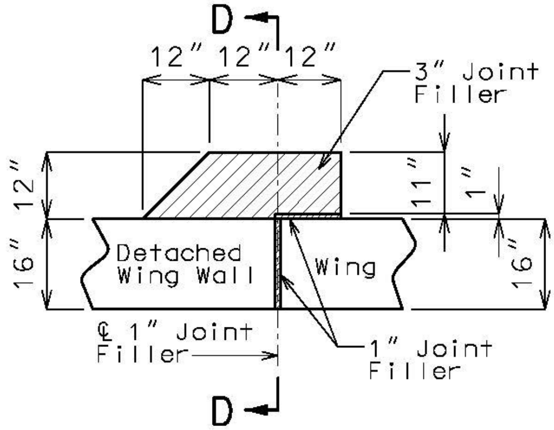


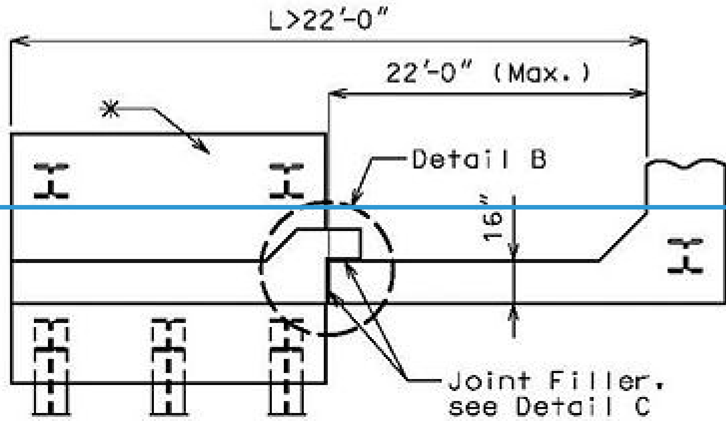




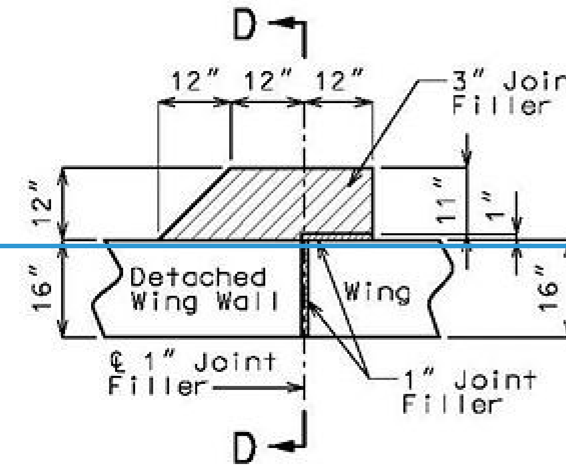




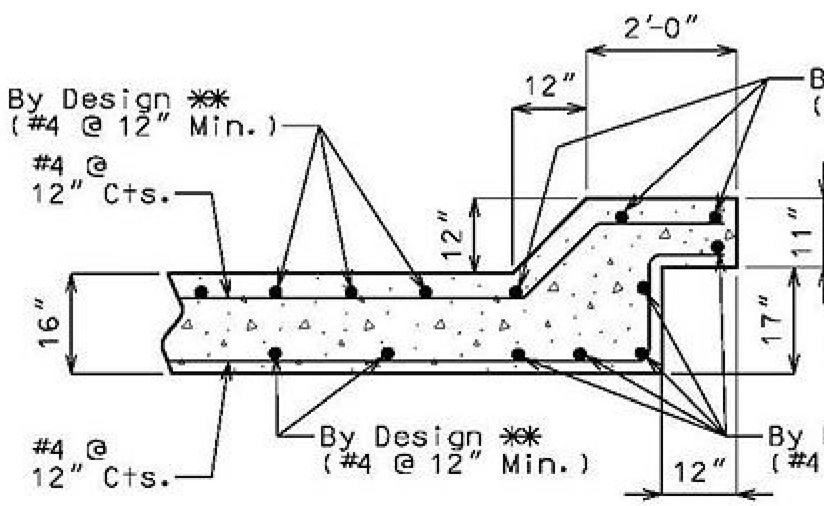




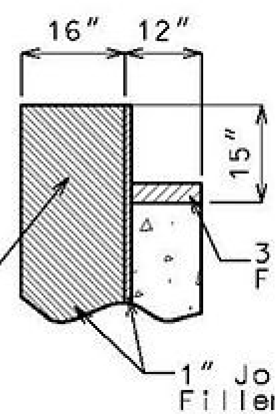
Section A-A



Detail "C"



Detail B



Section D-D

Note:

* Detached wing wall shown is for illustration purpose only. Design detached wing wall as a ~~LFD~~ retaining wall (EPG 751.24).

** ~~See EPG 751.24 LFD Retaining Walls~~Use retaining wall design.

[1] For seismic design category B, C and D only: The wing length shall not be greater than 17 feet. When a detached wing wall is required the integral abutment wing length shall not exceed 17 feet.

Report Pile Cut-off Elevation and Minimum Galvanized Penetration (Elev.) (See EPG 751.50 Standard Detailing Note E2, (Foundation Data Table).

751.35.4 Reinforcement

751.40.8.9.3.5 Pile Footing Design and Details

SEISMIC PERFORMANCE CATEGORIES B, C & D

1. For Seismic Performance categories B, C & D, the connection between the bottom of Column and the footing is a fixed connection.
2. Footing design is based on (Seismic Design of Beam-Column Joint).

(*) The design of all bridges in seismic performance B, C & D are to be designed by earthquake criteria in accordance with EPG 751.9 ~~LFD~~ Bridge Seismic Design.

751.40.8.12.2.1 General

(*) Channel shear connectors are to be used in Seismic Performance Categories B, C & D. For details not shown, see EPG 751.9 ~~LFD~~ Bridge Seismic Design.

(**) 2'-6" Min. for Seismic Performance Category A.
2'-9" Min. for Seismic Performance Categories, B, C & D.

Note: Use square ends on Prestress Double-Tee Structures.

751.40.8.13.1.4 Design Assumptions – Loadings

2) Analysis Procedure

b. *Find the axial stiffness of a pile,* K_a:

For friction pile, K_a may be determined based on a secant stiffness approach as described in EPG 751.9 ~~LFD~~ Bridge Seismic Design or by the in-house computer program “SPREAD” where K_a is calculated as:

751.2440.8.15.3 Cast-In-Place Concrete Retaining Walls

-751. 40.8.1524.1.2 Loads

751.40.8.15.2 Not used

751. 40.8.1524.3.1 Unit Stresses

751. 40.8.1524.3.2 Design

751. 40.8.1524.3.3 Example 1: Spread Footing Cantilever Wall

751. 40.8.1524.3.4 Example 2: L-Shaped Cantilever Wall

751. 40.8.1524.3.5 Example 3: Pile Footing Cantilever Wall

751. 40.8.1524.3.6 Dimensions

751. 40.8.1524.3.7 Reinforcement

751. 40.8.1524.3.8 Details

751.50 Standard Detailing Notes

A. General Notes

A1. Design Specifications, Loadings & Unit Stresses and Standard Plans

The format for these notes as they would appear on the plans is as follows with the indention shown being optional. For additional applicable notes for MSE walls, see J. MSE Wall Notes.

General Notes:

Design Specifications:

A1.1

Design Loading:

A1.2

Design Unit Stresses:

A1.3

Standard Plans:

A1.4

(A1.1) Design Specifications:

Use for all LRFD standard culverts and standard culverts-bridge designs in which the design and/or details are completely covered by the Missouri Standard Plans for Highway Construction and/or EPG 751.8 in accordance with the following design specifications.

2010 AASHTO LRFD Bridge Design Specifications and 2010 Interim Revisions

Use for all LRFD bridge final designs initiated on or after June 1, 2020.

2020 AASHTO LRFD Bridge Design Specifications (9th Ed.)

Use for all LRFD bridge final designs initiated before June 1, 2020.

2017 AASHTO LRFD Bridge Design Specifications (8th Ed.)

Refer to these seismic notes for LRFD preliminary bridge design initiated after June 1, 2024.

2023 11 AASHTO Guide Specifications for LRFD Seismic Bridge Design (3r2nd Ed.) and 2014 Interim Revisions (Seismic Seismic Details)

Seismic Design Category = _ A (Nonseismic Seismic Details)

Seismic Design Category = B C D (Complete Seismic Analysis Seismic Details plus Abutment Seismic Design)

Design earthquake response spectral acceleration coefficient at 1.0 second period, S_{D1} <0.15 = _

Acceleration Coefficient (effective peak ground acceleration coefficient), A_s = (2) _

2002 AASHTO LFD (17th Ed.) Standard Specifications (Seismic Seismic Details)

Seismic Performance Category = _

Acceleration Coefficient = _

Bridge Deck Rating = _ (1)

Use for all LRFD bridge final designs initiated before June 1, 2020. Refer to these seismic notes for LRFD preliminary bridge design initiated before June 1, 2024.

2017 AASHTO LRFD Bridge Design Specifications (8th Ed.)

2011 AASHTO Guide Specifications for LRFD Seismic Bridge Design (2nd Ed.) and 2014 Interim Revisions (Seismic Seismic Details)

Seismic Design Category = _

Design earthquake response spectral acceleration coefficient at 1.0 second period, S_{D1} = _

Acceleration Coefficient (effective peak ground acceleration coefficient), A_s = _

2002 AASHTO LFD (17th Ed.) Standard Specifications (Seismic Seismic Details)

Seismic Performance Category = _

Acceleration Coefficient = _

Bridge Deck Rating = _ (1)

Use for all LFD bridge final designs.

2002 AASHTO LFD (17th Ed.) Standard Specifications

2002 AASHTO LFD (17th Ed.) Standard Specifications (Seismic Seismic Details)

Seismic Performance Category = _

Acceleration Coefficient = _

Bridge Deck Rating = _ (1)

Use for all LRFD retaining wall (Conventional retaining wall, MSE wall or other) final designs. For additional applicable notes for MSE walls, see J. MSE Wall Notes.

2020 AASHTO LRFD Bridge Design Specifications (9th Ed.)

2023 AASHTO Guide Specifications for LRFD Seismic Bridge Design (3rd Ed.)
Seismic Design Category = A (Seismic Zone 1)
Seismic Design Category = B (Seismic Zone 2) (Seismic Analysis No Seismic Analysis (3))
Seismic Design Category = C (Seismic Zone 3) (Seismic Analysis No Seismic Analysis (3))
Seismic Design Category = D (Seismic Zone 4) (Seismic Analysis)
Design earthquake response spectral acceleration coefficient at 1.0 second period, S_{D1} < 0.15 = ______
Acceleration Coefficient (effective peak ground acceleration coefficient), A_s = (2)

(1) Use when repairing concrete deck. The rating (3 to 9) is from the bridge inspection report.

(2) Use value for A_s per Geotech report/Design layout or N/A if not reported in Geotech report/Design layout. If A_S > 0.75 then use A_S = 0.75.

(3) Use "No seismic analysis" if retaining wall is not supporting another structure foundation (i.e. not supporting abutment fill or building) and only if Geotech report allow this option.

(A1.2) Design Loading:

Use for all LRFD bridge, retaining wall and culvert final designs.

Vehicular = HL-93 minus lane load (1)
No Future Wearing Surface = 35 lb/sf
Defense Transporter Erector Loading
Earth = 120 lb/cf (4 6)
Equivalent Fluid Pressure = (2)
Ø =
(3) Superstructure: Simply-Supported, Non-Composite for dead load.
Continuous Composite for live load.

Use for all LFD bridge final designs.

HS20-44 HS20 Modified (4) (5)

35 lb/sf No Future Wearing Surface

Military 24,000 lb Tandem Axle (5)

Defense Transporter Erector Loading (5)

Earth 120 lb/cf , Equivalent Fluid Pressure (2)

Ø =

Fatigue Stress - Case I Case II Case III

(3) Superstructure: Simply-Supported, Non-Composite for dead load.
Continuous Composite for live load.

For rehabilitation of decks originally designed using above loads, specify using current wording when the original wording varies from that now used ("Military" used to be specified as "Modified").

(1) Include for all culverts and culverts-bridges unless lane load is used.

(2) For bridges and retaining walls use "45 lb/cf (Min.)" unless the Ø angle requires using a larger value. For box culverts use "30 lb/cf (Min.), 60 lb/cf (Max.)".

(3) Use with all prestressed concrete structures. Omit underline portions for single spans.

(4) For rehabilitation of decks originally designed using loads other than those shown, specify loading as shown on original plans.

(5) For rehabilitation of decks specify the original design year in parentheses, e.g. (1965).

(6) Unless different value is provided in the Geotechnical report.

(A1.3) Use for LRFD. (For ASD, LFD, and allowable stresses, see Development Section.)

Design Unit Stresses:

Class B Concrete (Substructure)	f'c = 3,000 psi
Class B Concrete (Retaining Wall)	f'c = 3,000 psi
Class B-2 Concrete (Drilled Shafts & Rock Sockets)	f'c = 4,000 psi
Class B-1 Concrete (Superstructure)	f'c = 4,000 psi
Class B-2 Concrete (Superstructure, except Prestressed Girders Beams and Safety Barrier and Median Barrier Curb)	f'c = 4,000 psi
Class B-1 Concrete (Substructure)	f'c = 4,000 psi
Class B-1 Concrete (Box Culvert)	f'c = 4,000 psi
Class B-1 Concrete (Safety Barrier and Median Barrier Curb)	f'c = 4,000 psi
Class B-2 Concrete (Superstructure, except Safety Barrier and Median Barrier Curb)	f'c = 4,000 psi (1)
Reinforcing Steel (Grade 40)	f_y = 40,000 psi
Reinforcing Steel (ASTM A615 Grade 60)	f_y = 60,000 psi
Reinforcing Steel (ASTM A706 Grade 60)	f_y = 60,000 psi (2)
Structural Carbon Steel(ASTM A709 Grade 36)	f_y = 36,000 psi
Structural Steel (ASTM A709 Grade 50)	f_y = 50,000 psi
Structural Steel (ASTM A709 Grade 50W)	f_y = 50,000 psi
Structural Steel (ASTM A709 Grade HPS50W)	f_y = 50,000 psi
Structural Steel (ASTM A709 Grade HPS70W)	f_y = 70,000 psi
Structural Steel HP Pile (ASTM A709 Grade 50S)	f_y = 50,000 psi
Welded or Seamless steel shell (pipe) for CIP pile (ASTM A252 Grade 3)	f_y = 45,000 psi

For precast prestressed panel stresses, see Sheet No. _.

For prestressed girder stresses, see Sheets No. _ & _ .

For prestressed solid slab voided slab box beam stresses, see Sheets No. _ & _ .

(1) Slabs, diaphragms or beams poured integrally with the slab.
(2) Use for LRFD bridges in seismic design category B, C and D.

Note: Any new construction using structural steels A514 or A517 requires permission of the State Bridge Engineer. Any construction involving these structural steels requires notification to the State Bridge Engineer.

J. MSE Wall Notes (Notes for Bridge Standard Drawings)

J1. General

(J1.1)

~~Factor of safety shall be 2.0 for overturning and 1.5 for sliding.~~

For strength limit state and extreme event limit state, the wall designer to confirm that the minimum Capacity to Demand Ratio (CDR) for bearing, sliding, overturning, eccentricity, and internal stability is greater than equal to 1.0. MSE wall designer shall include this note on shop drawings.

For Extreme Event I limit state, the wall designer shall design wall for $\gamma EQ = 0.5$

(J1.2)

Use either or both factored bearing resistance notes for foundation ground with appropriate value(s) as determined by the Geotechnical Section and reported in the Foundation Investigation Geotechnical Report times resistance factor and use the following maximum applied factored bearing stress instructional note. Extreme event portions of the instructional note shall be included when seismic design is required for category B, C, or D or when collision loads are considered.

For unimproved foundation ground, factored bearing resistance is _____ ksf for strength limit state and factored bearing resistance is _____ ksf for extreme event limit state.

For improved foundation ground, factored bearing resistance is _____ ksf for strength limit state and factored bearing resistance is _____ ksf for extreme event limit state.

The maximum applied factored bearing stress for the strength and extreme event limit state(s) at the foundation level shall be shown on the shop drawings and shall be less than the factored bearing resistance.

(J1.3) Use the underlined portion when limits of improved foundation ground is required by Geotechnical Section.

Factored bearing resistance and limits of improved foundation ground shall be used as shown on the plans. No adjustments are allowed.

(J1.4) Use for MSE walls that support another structure foundation (i.e. support abutment fill, building or Bridge MSE wall) in SDC B or C (seismic zone 2 or 3). Use for all MSE walls in SDC D.

Seismic analysis provisions shall not be ignored for MSE wall design.

(J1.5) Use for MSE walls that do not support another structure foundation (i.e. Not supporting abutment fill or building (District MSE wall) in SDC B or C (seismic zone 2 or 3)) and only if Geotechnical report allow otherwise use note J1.4. Use note J1.4 for all MSE walls in SDC D.

No-Seismic-Analysis provisions may be considered for MSE wall design in accordance with LRFD 11.5.4.2.

(J1.26) Use for MSE walls when traffic barrier is provided in front of MSE wall.

The cost of joint filler and joint seal, complete in place, will be considered completely covered by the contract unit price for Concrete Traffic Barrier (Type A B D). See Roadway Plans.

~~(J1.3) For seismic design the factor of safety shall be 1.5 for overturning and 1.1 for sliding.~~

(J1.47)

$ø_b$ = __° and Unit weight, γ_b = ___pcf for retained backfill material to be retained by the mechanically stabilized earth wall system.

(J1.58) Use either or both foundation parameter notes for foundation ground as determined by the Geotechnical Section and reported on the Foundation Investigation Geotechnical Report.

$ø_f$ = __° for unimproved foundation ground where wall is to bear.
$ø_f$ = __° for improved foundation ground where wall is to bear.

(J1.69)

Contractor shall include design $ø_r$ (actual $ø_r \geq 34°$) and the total unit weight, γ_r,for the select granular backfill (reinforced backfill and wedge area backfill) for structural systems on shop drawings. Contractor shall identify source of select granular backfill material, submit proctor in accordance with AASHTO T 99 (ASTM D698) and gradation with the shop drawings. When backfill material is too coarse to develop a proctor curve the contractor shall determine the maximum dry density (relative density) in accordance with ASTM D4253 and ASTM D4254 and assume percent passing the 200 sieve for optimum water content.

Total unit weight, γ_r = (95% compaction) x (maximum dry density) x (1 + optimum water content)

(J1.710)

Design Φ_r = 34° for the select granular backfill (reinforced backfill) only for structural systems.

(J1.811)

All concrete for leveling pad and coping shall be Class B or B-1 with f'_c = 4000 psi.

(J1.912)
The minimum compressive strength of concrete for precast modular panel precast modular ~~concrete~~ (drycast and wetcast) block shall be 4,000 psi in accordance with Sec 1052.

(J1.1013) For epoxy coated reinforcement requirements, see EPG 751.5.9.2.2 Epoxy Coated Reinforcement Requirements. Use this note if epoxy coated reinforcements required for MSE wall.

Precast modular pPanel, concrete block drycast modular block, wetcast modular block, and coping (or capstone) reinforcement shall be epoxy coated.

(J1.1114)

Soil reinforcement shall be spaced to avoid roadway drop inlet behind wall.

(J1.12a15)

A filter cloth meeting the requirements for a Separation Geotextile material shall be placed between the select granular backfill for structural systems and the backfill being retained by the mechanically stabilized earth wall system.

(J1.12b16) Use for all precast modular panel wall systemslarge block walls.

Minimum 18" wide geotextile strips shall be centered at vertical and horizontal joints of panel. Geotextile material shall be adhered to back face of panel using an adhesive compound supplied by the manufacturer. All edges of each fabric strip shall provide a positive seal. A minimum 1812" overlap shall be provided between spliced filter fabric.

(J1.1317) Use for all precast modular panel wall systemslarge block walls.

Coping shall be required on this structure. Bond breaker (roofing felt or other approved alternate) between wall panel and coping is required if precast coping is used. Coping joints shall use ¾-inch chamfers and shall be sealed with ¾-inch joint filler. Coping reinforcement shall terminate 1 ½-inch minimum from face of coping joint.

(J1.13a18)

Wall contractor shall show the following items on the design drawings and/or on the fabricator shop drawings.

1. Leveling pad horizontal.
2. Leveling pad length and step elevations shall be based on wall manufacture's recommendation. Top of leveling pad elevations shall not be higher than theoretical top of leveling pad elevations shown on these plans.

Use for drycast modular block wall system or wetcast modular block wall system unless either wall system is to be built vertical.

(J1.1419)

The top and bottom elevations are given for a vertical wall. The height of the wall shall be adjusted as necessary to fit the ground slope and the concrete leveling pad shall be adjusted as necessary to account for the wall batter. If a fence is built on an extended gutter, then the height of the wall shall be adjusted further.

The baseline of the wall shown is for a vertical wall. This baseline shall correspond to Elevation ____.

(J1.1520)

The contractor shall be solely responsible to coordinate construction of the wall with bridge and roadway construction and ensure that the bridge and roadway construction, resulting or existing obstructions, shall not impact the construction or performance of the wall. Soil reinforcement shall be designed and placed to avoid damage by pile driving, guardrail post installation, utility and sign foundations. (See Roadway and Bridge plans.)

PREQUALIFIED MSE WALL SYSTEMS

(J1.~~16~~21) [MS Cell]

MSE Wall Systems Data Table					
Proprietary Wall Systems		Combination Wall Systems			
Manufacturer	System	Facing Unit Manufacturer	Facing Unit	Geogrid Manufacturer	Geogrid

MSE Wall Systems Data Table is to be completed by MoDOT construction personnel to record the manufacturer of the proprietary wall system or the manufacturers of the combination wall system that was used for constructing the MSE wall.

(J1.~~17~~22) Use for all precast modular panel wall systems~~large block walls~~. Use for drycast modular block wall system or wetcast modular block wall system ~~small block walls~~ if either system ~~small block walls are~~ is to be built vertical.

The MSE wall system shall be built vertical.

(J1.~~18~~23) Use ~~where only a small or large block wall shall be used. Do not use note where either a small or large block may be used~~ when the type of MSE wall system is not optional.

The MSE wall system shall be a drycast modular block or wetcast modular block ~~small~~ precast modular panel ~~large block~~ wall system.

(J1.~~19~~24)

Topmost layer of reinforcement shall be fully covered with select granular backfill for structural systems, as approved by the wall manufacturer, before placement of the Separation Geotextile.

(J1.~~19a~~25)

Minimum ________ diameter perforated PVC or PE pipe.

(J1.~~20~~26)

Manufacturer shall show drain details on design plans to be submitted as shown on MoDOT MSE wall plans and/or roadway plans.

(J1.3227)

Contractor shall modify the drain details as shown if it will improve flow as may be the case for a stepped leveling pad, and for an uneven ground line (approval of the engineer required).

(J1.20a28)

Select granular backfill shall extend a minimum of 12" beyond the end of all soil reinforcement. Where the angle, Θ, between the retained backfill excavation/fill line and the horizontal is less than 90°, the wedge area backfill between Θ and 90° shall be filled with select granular backfill for structural systems meeting the requirements of Section 1010.

- For (45°+ Φ_b/3) < Θ ≤ 90°, properties for retained backfill shall be used for active force computations.

- For Θ ≤ (45°+ Φ_b/3), contractor shall have the option to use properties for select granular backfill, Φ_r, or better aggregate material, Φ_w for active force computations in the wedge area backfill. For active force computations, the angle of internal friction for wedge area backfill material, Φ_r or Φ_w, shall be limited to 34° unless determined otherwise in accordance with Section 1010. If Φ_r or Φ_w > 34° is desired for wedge area backfill then test report shall be submitted with manufacturer's design plans. Φ_r or Φ_w shall not be greater than 40°. Final configuration of this option shall be sent to Geotechnical Section for a new overall global stability analysis. Design Φ_w $\Phi_r°$ shall be shown on manufacturer's plans if used.

The slope excavation line shall be benched and separation geotextile shall be placed between the retained backfill and either select granular backfill or better aggregate material, and between the select granular backfill and better aggregate material.

Show range of acceptable theta (Θ) angle on shop drawings which must be consistent with design computations and proposed construction of wall. Show active force computation properties ($\Phi° = \Phi_r°$ and $\gamma = \gamma_r$ or $\Phi° = \Phi_b°$ and $\gamma = \gamma_b$) on shop drawings and in design computations. Coordination between wall designer (manufacturer) and contractor is required before shop drawing submittal.

Material Properties Used In Design						
Reinforced Fill/Select Granular Backfill			Active Force Computations			Foundation
$\Phi_r°$	γ_r (pcf)		Φ°	γ (pcf)		$ø_f°$

MSE Wall designer shall include table on shop drawings and provide values used in the design computations. Effects of cohesion shall be ignored unless approved by the engineer.

Use Notes J1.29 thru J1.33 for all precast modular panel wall systems large block walls

(J1.21a29)

Inverted U-shape reinforced capstone may be used in lieu of coping. Panel dowels for level-up concrete shall be required, and provided by manufacturer. The dowels shall be field trimmed to clear the capstone by a minimum of 1 1/2 inches and a maximum of 2 1/2 inches.

(J1.3330) Use for MSE walls in seismic design category B, C, and D (seismic zone 2, 3, and 4).

Upper two layers of soil reinforcement shall be extended 3 feet beyond the lower layers when wall height is greater than or equal to 10 feet.

(J1.21b31)

Aluminized soil reinforcement shall have edges coated with coating material per manufacturer.

(J1.2332) Use for MSE Walls when there may be contact between dissimilar metals.

All steel soil reinforcements shall be separated from other metallic elements by at least 3 inches.

(J1.21c)
Use default values for the pullout friction factor, F*, in accordance with AASHTO figure 5.8.5.2A and default value for scale effect correction factor, α, in accordance with AASHTO table 5.8.5.2A. For approved steel strips not shown in AASHTO figure 5.8.5.2A, use F* ≤ 2.0 at zero depth and F* ≤ Tan Φ_r at 20 feet depth and Φ_r design = 34°. F* and α values shall be shown on the shop drawings.

(J1.33)

Use default values for the pullout friction factor, F*, in accordance with LRFD figure 11.10.6.3.2-2 and default value for scale effect correction factor, α, in accordance with LRFD table 11.10.6.3.2-1. For approved steel strips not shown in LRFD figure 11.10.6.3.2-2, use F* ≤ 2.0 at zero depth and F* ≤ Tan Φ_r at 20 feet depth and Φ_r design = 34°. F* and α values shall be shown on the shop drawings.

(J1.2234) Use for all MSE wall plans.

The MSE wall system shall be built in accordance with Sec 720.

(J1.2435) Use for MSE Walls when there may be obstructions in reinforced soil mass.

The splay angle should be less than 15° and tensile capacity of splayed reinforcement shall be reduced by the cosine of the splay angle. Soil reinforcement shall clear the obstruction by at least 3 inches.

No reinforcement shall be left unconnected to the wall face or arbitrarily cut/bent in the field to avoid the obstruction.

Where interference between the vertical obstruction and the soil reinforcement is unavoidable, the design of the wall near the obstruction may be modified using one of the alternatives in FHWA-NHI-10-24, Section 5.4.2. Show detail layout on the drawings. For wall designs with horizontal obstructions in reinforced soil mass, see FHWA-NHI-10-024, Section 5.4.3.

(J1.25)

Use either or both allowable bearing pressure notes for foundation ground with appropriate allowable bearing pressure value(s)as determined by the Geotechnical Section and reported on the Foundation Investigation Geotechnical Report and use the following maximum applied bearing pressure note.

For unimproved foundation ground, the allowable bearing pressure is ______ ksf.
For improved foundation ground, the allowable bearing pressure is ______ ksf.
The maximum applied bearing pressure for the controlling design case at the foundation level shall be shown on the shop drawings and shall be less than the allowable bearing pressure for foundation ground provided herein. For seismic design the maximum applied bearing pressure shall be less than two times the allowable bearing pressure.

(J1.25a) Use the underlined portion when limits of improved foundation ground required by Geotechnical Section.

Allowable bearing pressure and limits of improved foundation ground shall not be adjusted from that as shown on the plans.

Use Notes J1.36 thru J1.40 fFor drycast modular block wall systems or wetcast modular block wall systems. Small Block Walls

(J1.2636) Permanent shims for drycast modular block wall systems or wetcast modular block wall systems Small block MSE wall:

Permanent sShims will be sparingly allowed to maintain horizontal and vertical control. The preferable shim shall be made of a plastic material that will not rust, stain, rot or leach onto the concrete and has a minimum compressive strength equal to block wall unit. Steel or wood shims will not be allowed. Shims shall not exceed 3/16 inch" in thickness and shall distribute load in order to not induce stress into block wall units. No shim shall be used between the concrete leveling pad and the base course of the block wall.

(J1.2737)

Holes shall be 5/8" - inch round and extended 4" inches into the third layer of blocks, recessed 2" inches deep by 1 ½" inches round.

(J1.2838)

Rods or reinforcing bars shall be secured by an approved resin anchor system in accordance with Sec 1039.

(J1.2939)

Recess hole shall be backfilled with non-shrink cement grout.

(J1.40) Use for MSE walls in seismic design category B, C, and D (seismic zone 2, 3, and 4).

Upper two layers of soil reinforcement shall be extended 3 feet beyond the lower layers when wall height is greater than 10 feet.

(J1.3141) Use when interior angle between two precast modular panel walls is less than or equal to 70°.

When interior angle between two walls is less than or equal to 70°, the affected portion of the MSE wall shall be designed as an internally tied bin structure with at-rest earth pressure coefficients. Acute angle corner structures shall not be stand-alone separate structures. For additional design steps see (FHWA NHI-10-024).

Use for all MSE wall plans.

(J1.3042)

Excavation quantities and pay items are given on the roaq22=====Q2ay plans. Excavation quantities are based on a soil reinforcement length of _________ ft. The soil reinforcement length may vaery based upon the wall design selected by the contractor. Plan excavation quantities will be paid regardless of any actual quantities removed based on the soil reinforcement length and design selected.

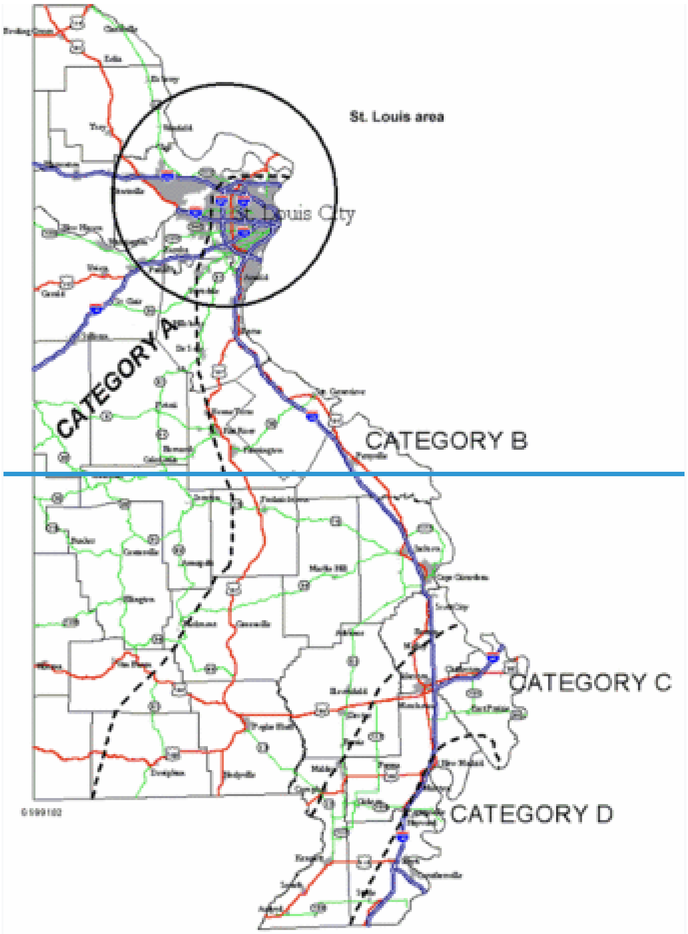
(J1.~~34~~43) For staged bridge construction with MSE walls at the abutments show following note on the plan details when temporary MSE wall is required. Also use note J1.41 when interior angle between two walls is less than or equal to 70°.

Contractor shall be responsible for the internal stability, external stability, compound stability, and overall global stability of the temporary MSE wall structure. The soil parameters assumed for the temporary MSE wall design shall be those shown on the plan details for the MSE Wall and shown in the foundation report. The contractor shall submit the proposed method of temporary MSE wall construction to the engineer prior to beginning work.

See special provisions

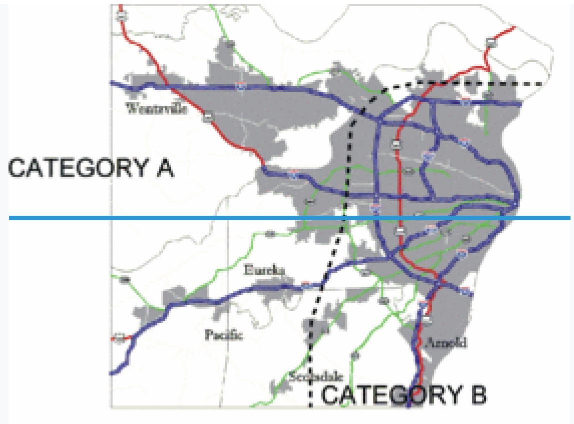
Category:756 Seismic Design

For bridge seismic design considerations, see EPG 751.9 Bridge Seismic Design.



LFD Seismic Performance Categories

The entire state of Missouri outside of Categories B, C and D is Category A.



LFD Seismic Performance Categories for St. Louis Area

LFD

All new bridges on the state system shall include some level of seismic design and/or detailing to resist earthquakes per the LFD Bridge Seismic Design Process Flowchart and an expected seismic event for a given return period. For example, for a multi span bridge in Seismic Performance Categories B, C or D, both design and detailing work is needed or detailing work only needed shall be determined as per "LFD Bridge Seismic Design Process Flowchart".

LFD Bridge Seismic Design Process Flowchart

When existing bridges are identified as needing repairs or maintenance, a decision on whether to include seismic retrofitting in the scope of the project shall be determined per the "LFD Bridge Seismic Design Process Flowchart", the extent of the rehabilitation work and the expected life of the bridge after the work. For example, if the bridge needs painting or deck patching, no retrofitting is recommended. However, redecking or widening the bridge indicates that MoDOT is planning to keep the bridge in the state system with an expected life of at least 30 more years. In these instances, the project core team should consider cost effective methods of retrofitting the existing bridge.

LRFD

LRFD Bridge Seismic Design Process Flowchart

All new bridges on the state system shall include some level of seismic design and/or detailing to resist earthquakes per the LRFD Seismic Bridge Design Process Flowchart and an expected seismic event for a given return period. For example, for a bridge in Seismic Design Categories A, B, C or D, seismic analysis or seismic detailing shall be determined as per "LRFD Seismic Bridge Design Process Flowchart".

1052.2.3 Precast Modular Panel Wall (PMPW-MSE) Large Block Wall and Sound Wall System Procedure

The producing district is responsible for acceptance of precast modular panel walls large block and sound wall panels and posts. Acceptance of precast panels and posts shall be on the producer's adherence to their producer quality management plan in accordance with Sec 1001 and product compliance. Currently the American Concrete Pipe Association (ACPA), and National Precast Concrete Association (NPCA) are approved industry recognized audit programs with MoDOT. Approval of a producer quality management plan is the responsibility of Central Office Construction and Materials. Prior to allowing production under a producer quality management plan, the district must confirm that the producer's certification is current and that it covers the material being produced. The district should audit the producer at least once a year and perform MoDOT Quality Assurance Testing on a quarterly basis while the produce is making products for MoDOT use. The district should perform additional auditing upon startup or when a problem arises. The district should perform MoDOT Quality Assurance Testing at the below recommended frequency:

1052.2.3.1 Aggregate

Aggregate shall be concrete quality rock from an approved quarry and in accordance with Sec 1005. Max aggregate size is set by the wall system manufacturer for constructability and minimum cover requirements. Gradation limits found in Sec 1005 do not apply. Producer QC and QA aggregate sampling and testing shall occur as per Sec 1052.

1052.2.4 Drycast Modular Block Wall (DMBW-MSE) and Wetcast Modular Block Wall (WMBW-MSE)Small Block Wall System Procedure

The producing district is responsible for acceptance of drycast modular blocks and wetcast modular blocks. Acceptance of drycast modular blocks and wetcast modular small blocks shall be on the producer's adherence to their producer quality management plan in accordance with Sec 1001 and product compliance. Approval of a producer quality management plan is the responsibility of Central Office Construction and Materials. Prior to allowing production under a producer quality management plan, the district must confirm that the producer's certification is current and that it covers the material being produced. The district should audit the producer on a regular basis and should perform additional auditing upon startup or when a problem arises. Audits may include a review of all applicable paperwork, a review of the producer's QC process, and an active inspection of current production. A record of each audit should be made in AWP using the 1052XXQCPA material code. The producer should notify the district in advance of their intended production schedule to allow MoDOT to schedule resources accordingly.

1052.2.4.1 Aggregate

Aggregate shall be concrete quality rock from an approved quarry and in accordance with Sec 1005. Max aggregate size is set by the wall system manufacturer for constructability and minimum cover requirements. Gradation limits found in Sec 1005 do not apply. Producer QC and QA aggregate sampling and testing shall occur as per Sec. 1052.

MoDOT should audit the producer's aggregate testing records as necessary. When a problem arises or when the producer testing records are in question, MoDOT's audit should include sampling and testing of the aggregates.

1052.2.4.3 Concrete Mixture

Some ~~small~~ modular blocks are produced using a dry cast concrete mixture while others are wet cast (traditional concrete). The concrete should follow the requirements found in Sec 501 when wet cast systems are used. When dry cast systems are used, the producers may override Sec 501 with the engineer's approval. Prior to production, the producer should submit a mix design for approval. Any exposed concrete should be air entrained for freeze thaw durability reasons. Sec 1052 requires ~~small~~ modular block manufacturers to perform free-thaw testing of their blocks periodically. This freeze thaw testing is important to ensure that salt exposure does not degrade the block. Blocks produced by dry cast systems are often prone to freeze thaw damage. When the installation location of a block system is outside the salt spray zone, the Engineer may consider waiving the freeze-thaw durability requirements. Non-standard admixtures not covered by the standard specifications may be used if approved the engineer.

MoDOT~~dot~~ should audit the producer's records to ensure the approved mix design was followed.

1052.2.4.4 Steel Reinforcement

While most drycast modular blocks and wetcast modular ~~small~~ blocks do not include any steel reinforcement, any Sec 1036 steel used or hardware used to complete the wall system should meet all of the applicable Buy America requirements. A record of compliance should be kept by the producer in accordance with the producer quality management plan and be available to the inspector upon requested.

MoDOT should audit the producer's steel reinforcement records as necessary. When a problem arises or when the records are in question, MoDOT's audit should include sampling and testing of the reinforcing steel. MoDOT's audit should also include visually checking PAL materials when possible for proper storage, handling, and labeling. MoDOT's audit may also include checking steel reinforcement placement when necessary.

1052.2.4.5 Finished pieces

The finished sections are to be examined by QC for conformance to dimensions, workmanship, and marking. Permissible variations in dimensions and rejection criteria for workmanship are specified in Sec 1052.

MoDOT's audit may include checking finished pieces for conformance to project plans.

1052.2.4.6 Compressive Strength Test

During the production of ~~small~~ modular blocks, the producer shall randomly sample the concrete in accordance with ASTM C140. Compressive strength samples shall be randomly selected for every production lot. A production lot will be defined as a group of ~~small~~ modular blocks that shall consist of a single day's production or a maximum of 5000 blocks.

Field cured compressive strength samples shall be used as the basis of acceptance. For dry cast systems QC will pick random ~~small~~ modular blocks for compressive strength testing. For wet cast systems QC shall make sufficient cylinders that are cured in the same manner as the ~~small~~ modular blocks and tested for design strength compliance. Therefore, the cylinders shall be treated in the same manner as the panels. The average compressive strength of these cylinders, when tested in accordance with AASHTO T 22, shall represent the compressive strength of the production lot. When a compressive strength result falls below design strength, the engineer of record must evaluate and approve acceptance of non-conformance.

MoDOT should audit the producer's QC/QA compressive strength testing records as necessary. When a problem arises or when the producer testing records are in question, MoDOT's audit should include sampling and testing of the concrete.

1052.2.4.7 Placement of Concrete

The transporting and placing of concrete shall be by methods that will prevent the segregation of the concrete material.

1052.2.4.8 Curing

Precast small modular blocks shall be cured by any one of the following methods, or combination of methods approved by the engineer that will give satisfactory results, or in accordance with panel manufacturer's recommendations. The modularsmall blocks shall be cured until design strength is met.

Steam Curing. Steam curing shall be in accordance with Sec 1029. Units may be placed in a curing chamber, free from outside drafts and cured in a moist atmosphere maintained by the injection of steam for such time and at such temperature as may be needed to enable the modularsmall block to meet the strength requirements. The curing chamber shall be so constructed as to allow full circulation of steam around the entire unit.

Water Curing. Precast drainage units may be water cured by covering with water-saturated material or by a system of perforated pipes, mechanical sprinklers, porous hose, or by any other approved method that will keep the unit moist during the specified curing period.

Curing Membrane. Curing membrane, in accordance with Sec 1055, may be applied to the back of panels only, if used the modularsmall blocks shall be left in the forms until the strength requirements are met. If modularsmall blocks are removed from the forms before design strength has been met another curing method shall be used. Curing membrane shall not be used on posts for soundwall systems, as it may cause discoloration.

1052.2.4.9 Tolerances

ModularSmall blocks should be produced within the tolerances specified by Sec 1052 or the wall system manufacturer. In case of conflict, the wall system manufacturer's tolerances prevail. Pieces outside these tolerances should result in a non-conformance report to ensure they do not pose structural, constructability, or aesthetic problems.

1052.2.4.10 Identification Marking

ModularSmall blocks have no marking requirements.