

October 1, 2019

Revision of Section 504
Concrete Block Facing MSE Walls

Notice

This is a standard special provision that revises or modifies CDOT's *Standard Specifications for Road and Bridge Construction*. It has gone through a formal review and approval process and has been issued by CDOT's Project Development Branch with formal instructions for its use on CDOT construction projects. It is to be used as written without change. Do not use modified versions of this special provision on CDOT construction projects, and do not use this special provision on CDOT projects in a manner other than that specified in the instructions unless such use is first approved by CDOT's Standards and Specifications Unit. The instructions for use on CDOT construction projects appear below.

Other agencies which use the *Standard Specifications for Road and Bridge Construction* to administer construction projects may use this special provision as appropriate and at their own risk.

Instructions for use on CDOT construction projects:

1. Use in projects having Concrete Block Facing MSE Walls. Hybrid walls will be permitted, unless otherwise stated by the Designer in the General Notes for the MSE Work Sheets.
2. For Geosynthetic Reinforced Soil (GRS) Refer to Bridge Design GRS wall work sheets and Project Special Provisions: Revision of Section 504 - Concrete Block Facing Phased Built GRS wall.

Revision Of Section 504 Concrete Block Facing MSE Walls

Revise Section 504 of the Standard Specifications for this project to include the following:

Description

504.01 This work consists of constructing a Concrete Block Facing Mechanically Stabilized Earth (MSE) Retaining Wall System at the locations and to the lines and grades shown on the plans. Either metallic or geosynthetic reinforcement (woven fabrics or geogrids) as specified in this specification may be used as MSE reinforcement in the reinforced structure backfill zone. The retained structure backfill zone is the structure backfill retained by the reinforced structure backfill zone as shown on the plans.

Materials

504.02 Shop Drawings. The Contractor shall submit one electronic submittal of shop drawings and certified material test reports for review prior to construction of the wall. See subsection 504.07 for a complete list of submittal requirements. Shop drawings shall be submitted in accordance with subsection 105.02.

The shop drawings shall provide the details necessary to demonstrate compliance with the Contract, including:

- (a) *Wall Layouts.* Wall layouts shall conform to the lines and grades on the plans including start, corner, and end stations, leveling pad step breaks, total number of blocks and top and bottom of wall elevations. For walls with rail anchoring slabs, the top of block elevations or the cast in place leveling course shall be within 2 inches of the elevation shown on the plans measured from the bottom of the anchoring slab. The construction batter required to achieve the batter shown on the plans shall be shown on the shop drawings. If temporary walls are required for the construction of permanent walls, the permanent wall vendor shall provide the shop drawings and certified material test reports for temporary walls.
- (b) *Block Reinforcement Locations.* Unless otherwise shown on the plans, each layer of soil reinforcement shall be connected to the facial blocks. The block placement sequence, if other than bottom up and end to end of wall, shall be shown. The block to block reinforcement connections and the cut block limits at curved wall corners shall be shown.
- (c) *Wall Elevations.* Except for the top of the leveling pad, wall elevations given on the plans are based on an 8 inch nominal block height. The actual reinforcement elevations shall be marked on the shop drawings by taking into account the supplied block height, number of reinforced layers, thickness of soil reinforcing and shimming material, and, for curved corners, the interposing layers of reinforcement.

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- (d) *Soil Reinforcement Material.* The soil reinforcement type, Minimum Average Roll Value of the Ultimate tensile strength, T_{ULT} (MARV), for geosynthetic soil reinforcement or yield strength for metallic soil reinforcement, spacing, lengths, elevations, and the corresponding wall design height segments shall be shown on the shop drawings. The starting and ending stations for change in grade of reinforcement material shall be shown for walls with different grade of reinforcement material at the same elevation. Material grade shall be clearly identified on each roll of reinforcement to avoid errors in placement. Elevations of the reinforcement layers shall be as specified on the shop drawings.
- (e) *Soil Reinforcement Length (RL).* The soil reinforcement length shall be measured from the front face of wall for blocks less than 12" deep and from the back face of wall for blocks greater than 12" deep to the end of the soil reinforcement as measured to the neat end. Soil reinforcement lengths shall not be less than the lengths specified on the plans.
For wall segments with a Design Height (DH) greater than or equal to 8 feet, the soil reinforcement shall be the same length from top to bottom of the wall.

The Reinforcement Lengths shown on the shop drawings shall be the reinforcement length required for internal stability and pull out only. External Stability (bearing pressure, sliding and overturning) and global stability shall already be checked by the design Engineer of record.

(f) *Soil Reinforcement Spacing.*

1. The first (bottom) layer of soil reinforcement shall be one or two times the block height, not to exceed 16 inches, above the top of the leveling pad.
2. The last (top) layer of soil reinforcement shall be no further than three times the block height, not to exceed 24 inches, below the top of the uppermost concrete block.
3. The vertical spacing between layers of adjacent soil reinforcement shall be less than three times the block height, not to exceed 24 inches. For walls deriving their connection capacity by friction the maximum vertical spacing of the reinforcement shall be limited to two times the block depth (front face to back face), not to exceed 24 inches, to assure construction and long-term stability. For tributary strength computations, the top row of reinforcement shall be one-half the vertical spacing immediately below the top of the wall.

(g) *Long Term Design Strength (LTDS) of Reinforcement.*

1. The design charts on the plans define the strengths required for the zone of mechanical reinforcement of soil. Based on the total summed LTDS, the

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reinforcement proposed by the shop drawings for a specific wall height shall meet or exceed the total LTDS shown on the plans. This proposed reinforcement shall allow for a maximum of plus or minus 15 percent variation in each individual layer.

2. Metallic (Inextensible) Soil Reinforcement. The net section at the soil reinforcement to block connection shall be used for the sacrificial thickness calculation. The following minimum sacrificial thickness for reinforcement shall be applied to the 75 year LTDS calculations:

Galvanization Loss	15 µm/year for first 2 years 4 µm/year for subsequent years
Carbon steel loss	12 µm/year after zinc depletion

Steel Soil Reinforcement

$$LTDS = \frac{\phi A_c F_y}{b}$$

Where:

Φ=0.75 (Strip reinforcement)
=0.65 ((Grid reinforcement)

A_c= Area of reinforcement corrected for corrosion loss (in²)

F_y= minimum yield strength of steel (ksi)

b= unit width of reinforcement (ft)

3. Geosynthetic (Extensible) Soil Reinforcement. Geosynthetic soil reinforcement shall be either a geogrid or woven geotextile. For polyester (PET), polypropylene (PP), and polyethylene (PE) reinforcement, the LTDS of material shall be determined using the following K percentages to ensure the required design life. Unless otherwise specified, LTDS shall not exceed the following K percent of its published ultimate tensile strength, T_{ULT} (MARV), i.e.

$$LTDS = K * T_{ULT} (MARV)$$

$$Where K = \frac{\phi}{RF(ID) \times RF(D) \times RF(CR)}$$

RF(ID): Installation damage reduction factor

RF(D): Durability reduction factor

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RF(CR): Creep reduction factor

Meet AASHTO LRFD and/or FHWA GRS design method for 75 years design life.

- (1) Geogrid or Geotextile sheet reinforcement (PE, PET, PP):

Products	K (Geogrid)	K (Geotextile)
PE & PP	27%	18%
PET	35%	30%

(2) Woven Geotextile will meet minimum bi-axial MARV ultimate tensile strength of 4800 LB./FT. and a minimum tensile strength of 2400 LB./FT @ 5% strain based on ASTM D4595.

(3) All products not listed above: Follow AASHTO equations 11.10.6.4.3b-1 & 11.10.6.4.3b-2 using independently certified test results.

(h) *Design Heights and Supplied Reinforcing Material.* Unless otherwise defined on the plans, the wall design height shall be measured vertically from the top of the leveling pad to the top of the concrete rail anchoring slab for walls with railing, or to the top of the cast-in-place concrete coping for walls without railing. For walls that are in front of a bridge abutment that is founded on a deep foundation, the design height used to determine the soil reinforcement length shall be measured vertically from the top of the leveling pad to the top of the roadway carried by the bridge and the wall. Bridge approach slabs shall not be considered in the design of the MSE wall.

For both geosynthetic and metallic reinforcement, the required reinforcement LTDS and the supplied LTDS (determined in accordance with the K factors or depletion of material as defined above) with corresponding brand and grade of material shall be marked clearly on the elevation view or in a tabulation summary. The LTDS of the supplied reinforcement grade must meet or exceed the required LTDS corresponding to the reinforcement spacing provided.

- (i) *Tiered Walls.* For the reinforcement layouts of tiered walls, the overall geometry, the reinforcement length and the sum of the LTDS provided from all layers in all tiers shall be in close conformity with the retaining wall system shown on the plans in order to ensure that local, global, and internal stability requirements have been met.
- (j) *Obstructions.* Details for the placement of soil reinforcement around obstructions (i.e., steel piles, concrete piers, concrete boxes, pipes, etc.) shall be shown on the shop drawings. Design calculations shall be provided showing that the internal stability of the wall meets the required safety factors in the area of the obstruction.

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- (k) *Table of Quantities.* A table comparing the Structural Backfill (Class 1), Mechanical Reinforcement of Soil, Geomembrane, and Block Facing quantities shown on the plans to the quantities shown in the shop drawings and percent difference (positive percent indicates an increase in shop drawing quantities from the plans) shall be shown on the shop drawings. Structure Backfill (Class 1), Mechanical Reinforcement of Soil, Geomembrane, and Block Facing quantities shall be calculated in accordance with the Contract. The Contractor shall notify the Engineer of the difference in plan and shop drawing quantities before wall construction begins.
- (l) *Placement Schedule.* Geomembrane placement schedule and clearances to soil reinforcements shall be shown.
- (m) *Vertical Slip Joints.* Locations of stack bond blocks with vertical slip joints for differential settlement relief shall be as specified in subsection 504.14.

504.03 Backfill. Unless otherwise specified on the plans, wall backfill material in the reinforced structure backfill zone and the *associated* trapezoidal retained structure backfill zone shall conform to the requirements for Structure Backfill (Class 1) of Section 206. For reinforcement tensile stress and associated pullout, a friction angle of 34 degrees shall be assumed for Structure Backfill (Class 1). Structure Backfill (Class 1) shall be considered to be non-aggressive soil for corrosion and durability computations. All reinforcing elements shall be designed to ensure a minimum design life of 75 years for permanent structures.

504.04 Leveling Pad. Concrete for the leveling pad shall be Concrete (Class D) conforming to the requirements of Section 601. Unless specified on the plans, the maximum vertical step shall be no greater than either 24 inches or three blocks, whichever is less. The leveling pad shall be reinforced according to the plan. When the toe of the wall is founded on a slope steeper than 1.5 (H) to 1 (V), the leveling pad shall be constructed with reinforced concrete with same reinforcing schedule as at its steps. Leveling pad concrete shall be cured for at least 12 hours before placement of the concrete blocks.

504.05 Geomembrane and Joints. A Geomembrane shall be installed on all walls at the top of the reinforced structure backfill zone and retained structure backfill zone to intercept surface runoff and prevent salt penetration into the backfill of the wall as shown on the plans. The Geomembrane shall meet the requirements of subsection 712.07 for geomembrane and shall have a minimum thickness of 30 mils LLDPE. It shall be spliced with a dual track field seamed joint in accordance with ASTM D4437 and ASTM D5820. For small local coverage areas, less than 30 square feet, the membrane may be spliced using a 6 inch minimum overlap and an adhesive or a single seam portable thermal welding tool, as suggested by the membrane manufacturer and approved by the Engineer. Unless otherwise shown on the plans, the membrane shall have a minimum coverage length measured perpendicular to the wall face of at least the Pay Length for Geomembrane (PLG) as shown in the plan. The membrane shall be installed with a slope between 20:1 (minimum) and 10:1 (maximum), as shown on the plans, from the block facing to a drainage system located at the cut or pre-filled slope as shown on the plans.

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Contractor shall provide site specific working drawing that indicates sheet splices, pattern, slope and daylight location. Prior to membrane installation working drawing shall be submitted by the Contactor and approved by the Engineer.

The drainage system shall consist of a 12 inch wide Geo-Composite strip drain inserted into a slot in the Geomembrane, at 10 foot maximum spacing, that collects the water from the membrane and conveys it to a water collector system at the toe of the excavation slope as shown on the plans. The water collector system shall consist of a 4 inch diameter perforated collector pipe surrounded by Filter Material Class B and wrapped with Class 1 Geotextile. A 4 inch diameter non-perforated drainpipe, at 100 foot maximum spacing, shall be used to discharge the water in the water collector system out the face of the wall.

Alternatives for the drainage system shown on the plans may be used by the Contractor. A detailed layout of this equivalent site specific water collection system including membrane joints shall be provided as working drawing by the Contractor and approved by the Engineer.

For tiered walls, a Geomembrane shall be installed between the top of the bottom wall and the toe of the top wall as shown on the plans.

504.06 Prefabricated Concrete Facing Blocks. Concrete blocks including partial blocks shall conform to the requirements shown on the plans and these specifications including the color, texture, and pattern. The Contractor shall provide certification that the results of tests performed in accordance with this subsection meet the requirements of the appropriate specification.

- (a) Cementitious material shall meet the requirements of Section 701.
- (b) Aggregates used in concrete blocks shall conform to ASTM C33 for normal weight concrete aggregate.
- (c) The 28 day compression strength for concrete blocks shall be equal to or greater than 4500 psi. The quality of blocks shall be maintained such that the variations of the compression strengths are within 10 percent. The minimum oven dry unit weight shall be 125 pcf with a maximum water absorption rate by weight of 6 percent. Testing shall be performed in accordance with ASTM C140.
- (d) All units shall be sound and free from cracks or other defects that would interfere with proper placement of the unit or impair the strength or permanence of the construction. Cracks, chips, or color blemishes will be cause for rejection.

Any architectural or graffiti resistant treatments shall meet the requirements shown on the plans. If architectural coating is used and graffiti resistant treatments or water repellent sealer is required, the Contractor shall provide the Engineer with four sample blocks for each different color and texture prior to beginning wall construction. Water-resistant or repellent coatings shall conform to ASTM C1262.

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The permissible variations in the exterior dimensions of the concrete blocks shall not differ more than plus or minus $\frac{1}{8}$ inch, except the height of the block shall be within plus or minus $\frac{1}{16}$ inch from the specified dimensions for an individual block. The minimum thickness of any walls or webs within the block shall be on average 2.5 inches at the face and 1.5 inches and 2 inches at stem and back. The vertical edges, if applicable, shall be chamfered for splitting and precise dimensioning.

- (e) The Engineer shall be allowed access to the manufacturer's facilities to inspect and sample units from lots prior to delivery with a minimum 2 working days advance notice. The Engineer will reject any concrete blocks, which do not meet the requirements of this specification. The Contractor shall notify the Engineer in writing at least 3 working days before shipment of blocks begins.

504.07 Certifications, Calculations and Testing Reports. The Contractor shall provide the following reports, certifications, calculations and checklists as needed to accompany the shop drawing submittal. All engineering calculations, as stated in subsections 504.02(g), 504.02(j), 504.02(k), 504.07(e) and 504.07(f) shall be certified and stamped by a Professional Engineer licensed in the State of Colorado.

- (a) *Certification of T_{ULT} (MARV) or Ultimate Tensile Strength.* For geo-synthetic reinforced systems only, the Contractor shall submit a certification letter from the manufacturer which provides the T_{ULT} (MARV) and certifies that the T_{ULT} (MARV) of the supplied materials have been determined in accordance with ASTM D4595 or ASTM D6637 as appropriate. For metallic wall reinforcement, a mill test report containing the ultimate tensile strength for the soil reinforcement shall be included in the certification.
- (b) *Report Of the Block-Reinforcement Connection Test.* The test report shall be prepared and certified by an independent laboratory. The block to reinforcement connection test method shall conform to the requirements of ASTM D6638 with a service state connection strength displacement criterion of $\frac{3}{4}$ inch or National Concrete Masonry Association (NCMA) Methods SRWU-1.
- (c) *Report For Block-Block Connection Test.* An independent laboratory shall prepare the test report. The block-to-block connection test method shall conform to the requirements of NCMA Methods SRWU-2. The service state connection strength displacement criterion shall be $\frac{3}{4}$ inch.
- (d) *Report For Soil to Reinforcement Interface Pullout Test.* The test report shall be prepared and certified by an independent laboratory. The soil to reinforcement interface pullout test method shall conform to the requirements of ASTM D6706. Tests shall include the full range of overburden pressures as defined by the wall design heights.

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- (e) *Certification of Facial Block to Reinforcement Long-Term Connection Strength.* A certification shall be provided with detailed calculations according to the latest AASHTO Standard Specification including Interim and independent laboratory test results performed in accordance with FHWA NHI-00-043, Appendix A3 to demonstrate that the facial block to reinforcement connection meets or exceeds the current AASHTO 75 year design life requirements.
- (f) *Certification of Reinforcement Pullout.* A certification shall be provided with detailed calculations to demonstrate that reinforcement pullouts meet or exceed the current AASHTO requirements. The metal reinforcement breakage and pullout calculations shall include a combination of 75 years of material depletion for carbon steel and galvanization loss.
- (g) *Report and Certification for Concrete Block 28 Day Compression Strength and Water Absorption Rate.* For the 28 day compressive strength test, either a full block or a saw cut coupon compressive test is acceptable to verify the 28-day concrete strength provided the sample allows the test to conform to ASTM C90. The sampling shall be done at manufacturer's casting yard and testing results shall be pre-approved before shipment. The Engineer will approve the sample selections for the coupon tests. Coupons shall be cut from the two sides or the back of block (not the front split face) with maximum two original concrete surfaces. The average compressive strength of three tests from three randomly selected blocks, with load applied in the bearing direction shall be equal to or greater than 4500 psi with the minimum of 4000 psi for individual tests in accordance with ASTM C90 and ASTM C140. For the water absorption rate test, a minimum of two coupons shall be prepared and marked for each block, one coupon for successfully conducting the supplier's tests and one spared for future Engineer's test. The spared coupons from the three tests shall be labeled and delivered to the Engineer with the certification. The minimum oven dry density of concrete coupons shall be 125 pcf with a maximum water absorption rate by weight of 6 percent as determined by ASTM C140. Coupons shall be cut from relatively the same location of each block and prepared with uniform workmanship. Each individual sample must test within 12 percent of the average of the three.
- (h) *Efflorescence and Freeze and Thaw Test.* The block shall be visually efflorescence free. Efflorescence control agent shall be used in concrete mix design. An independent laboratory shall provide reports and certifications using one of the following tests in accordance with ASTM C1262 using tap water or 3 percent saline solution and ASTM C1372 as appropriate:
- (1) Test results for freeze and thaw durability shall be graphed and supplied with test data points at a maximum of every 50 cycles up to 300 cycles to confirm that blocks with concrete additives alone can survive 150 cycles with weight loss for each of 4 of the five samples not exceeding 0.75 percent and for 300 cycles not exceeding 1.5 percent of the initial weight in a tap water solution.

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- (2) Test results for freeze and thaw durability shall be graphed and supplied with test data points at a maximum of every 30 cycles up to 120 cycles to confirm that blocks with concrete additives alone can survive 60 cycles with weight loss for each of 4 of the five samples not exceeding 0.75 percent and for 120 cycles not exceeding 1.5 percent of the initial weight in a 3 percent saline solution.

A project specific freeze and thaw durability test shall be required for walls meeting one of the following requirements:

- (1) Projects with a total facing area greater than 6000 square feet, as calculated in subsection 504.20, item (1), or
- (2) Projects with any wall in front of or adjacent to bridge abutments and piers.

Wall construction may begin when acceptable freeze and thaw durability test results of units made with the same material, concrete mix design, manufacturing process, and curing method, conducted not more than 12 months prior to delivery until the test results of the actual blocks used in the wall can be obtained and submitted. The test results shall be submitted within one week of being recorded. The frequency of the freeze and thaw durability test shall be a minimum of one test every 6000 square foot of facing, as calculated in subsection 504.20, item (1).

For walls not requiring a project specific freeze and thaw durability test, the Contractor shall submit a certification letter from the facing manufacturer. The certification letter shall include acceptable freeze and thaw durability test results conducted not more than 12 months prior to delivery, that meet the requirements of subsection 07 (h) -(1) or (2) above. The Certification shall be for units made with the same material, concrete mix design, manufacturing process, and curing method. The Engineer shall be allowed access to the manufacturer's facilities and records to verify that the mix design used in the certified freeze and thaw durability test results is the same as the mix design used for the actual blocks used in the project.

- (i) *Submittal Checklist.* The Contractor shall submit the dry cast facing or blocked faced MSE Wall Submittal Checklist, Form 1401, with the Certifications, Calculations and Testing Report submittal package included with the shop drawing submittal.

514.08 Conditions to Waive Shop Drawing and the Block-Reinforcement Connection Testing Reports. Unless otherwise noted on the plans the Contractor's Professional Engineer seal requirement for the Facial Block to Reinforcement Long-Term Connection Strength certified test report required by subsection 504.07(e) may be waived if the following conditions are met:

- (1) For Geosynthetic Reinforced Soil (GRS) wall, every block shall be connected by friction with either a main or a secondary reinforcement starting at 2 inches maximum from the front face of block.

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- (2) The spacing for main reinforcement is two blocks maximum or 16 inches, whichever is less.
- (3) The secondary reinforcement shall be applied in between the main reinforcement. The same grade of material as used for main reinforcement shall be used for the secondary reinforcement: however only a minimum of 48 inches total length measured from the face of block is required.
- (4) Aggregate filled cells shall be filled with $\frac{1}{4}$ inch aggregate. In lieu of aggregate filled cells, the cells in the top four blocks of the wall shall be doweled with steel or fiberglass bars and grouted with cement. Punched or poked holes through fabric reinforcement are allowed to accommodate grout and dowel bars.

504.09 Hybrid or Large Block MSE Wall Systems.

A hybrid system is one which combines elements of both externally and internally stabilized systems.

An externally stabilized system uses a physical structure to hold the retained soil. The stabilizing forces of this system are mobilized either through the weight of a shape stable structure or through the restraints provided by the embedment of wall into the soil, if needed, plus the tieback forces of anchorages.

An internally stabilized system involves reinforced soils to retain fills and sustain loads. Reinforcement may be added to either the selected fills as earth walls or to the retained earth directly to form a more coherent stable slope. These reinforcements can either be layered reinforcements installed during the bottom-to-top construction of selected fills or be driven piles or drilled caissons built into the retained soil. All this reinforcement must be oriented properly and extend beyond the potential failure mass.

Hybrid MSE wall systems may be used unless otherwise noted on the plans. Hybrid MSE wall systems are subject to the same design requirements for MSE walls and this specification. The shop drawings for Hybrid MSE wall system shall include a combination of design calculations and appropriate test results to demonstrate that it meets or exceeds the block facing system. Each unit in the hybrid MSE wall system shall have a facing area of 3.5 square feet and be stabilized by a counterfort. Hybrid MSE wall facing units shall be factory made with Class B Concrete with the following additional requirements:

- (1) Minimum Cementitious Material Content: 610 lb./cu. yd.
- (2) No more than 50 percent fine aggregate (AASHTO M6) by volume of total aggregate.
- (3) Ambient temperature shall be a minimum of 40° F and rising when casting.
- (4) Hybrid MSE wall facing shall be cured in accordance with AASHTO M170.

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The following Certifications, Calculations and Testing Reports in subsection 504.07(c), (e), (g), and (h) are not required for Hybrid MSE wall systems. The facing to soil reinforcement connection test, subsection 504.07(b), may be waived only if the soil reinforcing spacing is less than or equal to 8 inches or the facing is secured and stabilized by hybrid components with primary reinforcement spacing less than 24 inches. The Contractor shall provide the following additional reports, certifications and calculations to accompany the shop drawing submittal for Hybrid MSE wall systems:

The Contractor shall submit the dry cast facing MSE Wall Submittal Checklist, Form 1401, or the wet cast facing MSE Wall Submittal Checklist, Form 1402, with the Certifications, Calculations and Testing Report submittal package included with the shop drawing submittal.

Construction Requirements

504.10 Approval and Qualifications of MSE Wall Installer. The job site wall foreman shall have experience in construction of at least five transportation related MSE walls within the last three years. Transportation related MSE walls are walls that carry or are adjacent to vehicular traffic and are constructed with MSE reinforcement in the reinforced structure backfill zone. The foreman must have prior experience or adequate training on the products that the Contractor elects to use on the project. The resume and credentials of the foreman shall be submitted to the Engineer for approval prior to the pre-construction meeting. The foreman shall be on the site for 100 percent of the time during which the wall is being constructed.

504.11 Wall Test Segment. The wall test segment shall be the first segment of the wall constructed. The wall test segment shall be constructed in the presence of the Technical Representative and the Engineer and shall include construction of each of the 5 elements listed in subsection 504.12. The minimum length of the wall test segment shall be 40 feet or the full length of the wall if less than 40 feet. A wall test segment shall be constructed for the first wall constructed from each wall product used on the project.

504.12 Technical Representative of Wall Product Supplier. The Contractor shall arrange for a technical representative (Tech Rep) of the manufacturer of the wall products to be present during the construction of each wall test segment. If the wall products are supplied from different manufactures, a Tech Rep from each wall product shall be present. The Tech Rep shall be present for construction of the wall test segment and each of the following elements:

- (1) Placement of a minimum of the first two layers of primary soil reinforcement and backfill,
- (2) If obstructions (i.e., steel piles, concrete piers/abutments, concrete boxes, pipes, etc.) exist, placement of primary soil reinforcement and backfill at one of the obstructions,

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- (3) Placement of a minimum of the first six courses of blocks or a minimum of a four foot wall height,
- (4) If a vertical slip joint is required, construction of the vertical slip joint in a minimum of a six course portion of block or a minimum of a four foot wall height, and
- (5) If corners are required, construction of a corner representative of the corners in the wall in the project in a minimum of a six course portion of block or a minimum of a four foot wall height..

Before construction of the wall test segment the Tech Rep shall provide the Contractor and the Engineer the following:

- (1) Technical instructions as required in the construction of the earth retaining wall system.
- (2) Product specific specifications in the placement of the soil reinforcement and backfill in accordance with the wall system.
- (3) Guidelines in placing the facing units and attaching them to the soil reinforcement in accordance with the system requirements.
- (4) Provide technical assistance to the facing unit fabricator.

At the completion of the wall test segment the Tech Rep shall provide the following:

- (1) Documentation that the wall test segment was constructed in accordance with the product specific specifications. This documentation shall include a location description (starting and ending stations and elevations) of the wall test segment.
- (2) Documentation that the job site wall foreman is familiar with the wall products used to construct the walls on the project.

After completion of the wall test segment the Tech Rep shall be available whenever there is any special field condition such as change of geological condition, when there are equipment or personnel changes, or when requested by the Engineer.

504.13 Facial Block Quality Control, Placing Plan and Daily Placement Logs. Before the start of each wall construction, the Contractor shall provide a block-placing plan and shall supply daily placement logs to the Engineer weekly and at the completion of the wall. The daily placement log shall consist of an elevation view of the wall showing the dates, number of blocks placed, and the lot numbers of the blocks placed. The block quality control shall contain multiple submittals if required by subsection 504.07(g). Blocks shall be labeled with the manufacturer's lot number for each pallet and corresponding certification with one set of random samples tested for each 6000 blocks. At least one certification with supporting test results is required for each wall. Test results shall be reviewed and pre-approved by

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the Engineer before shipment. The Engineer may conduct separate tests with the spared coupons from the original samples. Block testing shall be increased to one set of sampling for every 3000 blocks if the Engineer identifies substandard blocks or when block color or concrete mix changes. With the Engineer's approval, block sampling may be reduced to one set of sampling for every 12,000 blocks after the first acceptable sampling results. The blocks used for Engineer's verification purposes shall be a maximum of 0.5 percent of the total number of blocks. The Engineer will conduct block sampling as early as possible and acquire blocks regularly. However, when tests are not performed within 90 days of the sampling date, the blocks will be returned untested. The Contractor shall coordinate and mark the block and backfill placing sequence on the daily placement logs. The log serves as means for the Engineer to identify where each lot of blocks was placed.

504.14 Wall with Curved Alignments, Tight Curved Corners, and Sections Adjacent to Bridge Abutment. The Contractor shall provide a placement plan that shows curved layouts, special block or saw cut block dimensions, sequence of block placement, and construction off-sets as recommended by the manufacture. For tight curved corners, 8 foot radius or less, and dissimilar foundations such as bridge abutment, to avoid blocks with random cracks, the Contractor shall install stack bond blocks with vertical slip joints as shown on the shop drawings; however reinforcement spacing shall be reduced to one block height, or other properly designed methods of block stabilization shall be used as approved by the Engineer. Short secondary reinforcements used to tied-back cut blocks in between main reinforcements are acceptable. A vertical slip joint for stress relief may be built either with pre-cut or partial pre-cut individual blocks or by saw cutting block face of breaking running bond vertically right after installation.

504.15 Excavation and Backfill. The base of the leveling pad shall receive the same compaction as cut areas required by subsection 203.07. The Contractor shall report to the Engineer in writing density test results for any unsatisfactory bearing material not meeting the minimum 90 percent compaction for walls less than 16 feet high and 95 percent of T-180 for walls higher than 16 feet. If the excavation for the placement of the leveling pad exposes an unsatisfactory bearing material, the Engineer may require removal and replacement of that material. The removed material shall be replaced with Structure Backfill (Class 1) compacted in conformance with subsection 206.03. The Engineer with the assistance of the geotechnical engineer of record will provide the limits including the depth of removal. As directed by the Engineer, and if required, Structure Backfill (Class 1) shall be reinforced with soil reinforcements in conjunction with wick drains and outlet pipes.

The Contractor shall grade the foundation for the bottom of the wall for a width equal to or exceeding the limits of the Reinforcement Length (RL) plus 18 inches as shown on the plans. This graded area shall be compacted with an appropriate vibratory roller weighing a minimum of 8 tons for at least five passes or as directed by the Engineer. For cut wall with continuous seepage, phasing of foundation construction or a different drainage and foundation improvement plan may be necessary.

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The reinforced structure backfill zone and the retained structure backfill zone portion immediately behind the wall as defined on the plans shall be Structure Backfill (Class 1). Recycled asphalt, recycled concrete, and flow-fill material shall not be substituted for Structure Backfill (Class 1). Each compacted layer of backfill within a distance equal to the reinforcement spacing away from the back of the block shall not exceed 4 inches. The triangular or trapezoidal portion behind the concrete blocks and above the spill of backfill, as shown on the plans, shall be filled with $\frac{3}{8}$ + inch crushed rock, filter aggregates with filter fabric, or wall system specific fill as approved by the Engineer. Density tests behind and parallel to the wall in the triangular or trapezoidal portion above the backfill spill zone are not required. Each compacted layer of backfill shall not exceed 8 inches and shall be roughly leveled with the top of block elevation of the lift. The fill and compaction operation shall start 3 feet from the wall back face and progress toward the end of the reinforcement. All Structure Backfill (Class 1) including fill material under the wall and on-site material as allowed under subsection 504.03 shall be compacted to a density of at least 95 percent of the maximum density as determined according to AASHTO T 180. For on-site foundation material containing more than 30 percent retained on the $\frac{3}{4}$ inch sieve, a method of compaction consisting of a conventional heavy vibratory roller starting with minimum 5 passes shall be used to establish the number of passes required to exceed the 95% T180 density requirement.

At least 6 inches of material shall be in place prior to operation of tracked vehicles over soil with reinforcement. Only power operated roller or plate compaction equipment weighing less than 1,000 pounds is allowed within 3 feet of the front face of the wall. The reinforcement shall not be connected to the wall until the compacted fill is at or slightly higher than the location of the connector.

Backfill containing frost or frozen lumps shall not be used. Backfill that has been placed and becomes frozen shall be removed and replaced at the Contractor's expense. If cold weather conditions prevent the placement of Structure Backfill (Class 1), the Contractor may use Filter Material Class B as backfill without compaction at the Contractor's expense and approved by the Engineer. The Contractor shall provide a test report, prepared and certified by an independent laboratory, that the internal friction angle of soil for the Filter Material Class B meets or exceeds that shown on the plans.

The Contractor shall place additional blocks including partial height blocks and properly compacted fill material to return the finished grade to the plan elevations if settlement, as determined by the Engineer, has occurred. A final inspection before the installation of rail anchoring slab will be made after construction settlement, if any, has occurred or 30 days after the completion of the wall. The Contractor shall provide immediate temporary storm water protection and wind erosion control at the end of each day during construction. If settlement occurs as the result of loss of backfill due to wind or water erosion, non-conforming backfill such as frozen fill or over-saturated fill, or if the backfill does not meet compaction requirements, the Contractor shall remove the backfill, wash the soil reinforcement, and bring the elevation to the finished grade at the Contractor's expense.

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Before final project acceptance, the Contractor shall repair any backfill losses due to wind and water erosion.

To avoid the foundation of the leveling pad being washed out by rain, the area in front of the wall and around the leveling pad shall be backfilled as soon as practicable.

504.16 Reinforcement. Steel reinforcement shall be slack free and geosynthetic reinforcement shall be slightly pre-tensioned. The minimum coverage ratio for geogrid reinforcement shall be 67 percent and the spaces between rolls shall be staggered between layers of soil reinforcement. The minimum coverage ratio for woven fabric reinforcement shall be 100 percent and an overlap between rolls is not required. Woven fabric sheet reinforcement shall be laid to within 1 inch of the front face of block. Soil reinforcement shall not be cut to avoid obstructions unless shown on the shop drawings.

504.17 Leveling Pad. The foundation of the leveling pads shall meet the requirements of subsection 504.15. The leveling pad shall be level within the tolerance of $1/16$ inch for any two block lengths, and within $1/4$ inch for any two points that are 10 feet apart.

Cushion or shimming material (Expansion Joint Material, Concrete Mortar Grout, Roofing Felt, or Geosynthetic Reinforcement) shall be used to support the blocks that are to be directly founded on the leveling pad. Before starting a new course of blocks, the Contractor shall take measures to ensure that the wall elevations will be matched at the next leveling pad step. Cushion or shimming material or grinding as necessary shall be used to obtain the necessary block elevations at the next leveling pad step.

504.18 Block Facing. For walls that support a roadway, the wall layout line at the leveling pad shall be set back and pre-measured with appropriate batter (5 to 8 percent) from the top of the blocks according to the offset with respect to the centerline of the road. For walls adjacent to a roadway, the wall layout line at the leveling pad shall be directly offset from the centerline of the road. An overall negative batter (wall face leaning outward) between the bottom and the top of the wall is not allowed. For vertical walls, unless otherwise noted on the plans, the final wall face shall be vertical or shall have a positive batter that is not greater than 5 percent for construction control purposes. For walls higher than 16 feet, the 5 percent batter requirement shall be relaxed to a maximum of 8 percent as required for special block products. The surface of the wall face shall be tested with a 10 foot straightedge laid along the surface in the horizontal and vertical directions. Except as necessary for horizontal alignment of the wall, a convex deviation (wall belly) of the wall face from the straightedge shall not be allowed, and any concave deviation (wall depression) from the straightedge shall be less than $3/4$ inch.

Unless otherwise noted, all blocks shall be dry-stacked and placed with each block spanning the joint in the row below (running bond). Shimming or grinding shall control the elevations of any two adjacent blocks within $1/24$ inch. The top of blocks shall be tested with a 3 foot or longer straight edge bubble level. All high points identified by the straight edge shall be ground flat. Tilting of the blocks, from front to back of the wall, shall be checked at each

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course, correction by shimming shall be done no later than three completed courses. For walls without a rail-anchoring slab, the top two courses, or a cast-in-place reinforced concrete cap course and the two courses directly below it, shall be pinned and internally grouted together with a minimum of two #4 rebars per block. The concrete block shall have cells to accommodate grouted pins and modifications shall be made for blocks that do not have such cells. Grout is limited to penetrate a maximum depth of three blocks measured from the top of fill for each operation. For grout more than three blocks in height, if specified on the plans, multiple grout operations are required. A layer of fabric shall retain the grout in the lowest grouted block layer. The aggregate for grout shall be modified according to cell size and geogrid aperture. Grout in any 20 foot long wall segment shall be placed and consolidated by a minimum of two simultaneously working concrete vibrators. Precast cap blocks shall not be used in lieu of a cast-in-place reinforced concrete cap. All concrete used for cast-in-place cap and grout shall have a minimum 28 day compression strength of 4500 psi.

For walls with rail anchoring slabs, the top of block elevations shall be within 2 inches of the bottom of the anchoring slab. Cast-in-place concrete or sawcut partial height blocks may be used to accomplish this without extra cost to the project.

Where the Geomembrane for drainage interferes with the continuation of reinforcement, the blocks beyond the termination shall be reinforced or shimmed with the same grade of soil reinforcing material to maintain the reinforcing at the constant block elevation.

As shown on the plans, facing blocks directly exposed to spray from deiced pavements and indirect windborne spray shall have three coats of water resistant or repellant concrete sealer applied to the front face of the wall before the wall is opened to traffic.

504.19 Fill under Leveling Pad. For walls requiring fill under the planned elevation of the leveling pad, the Contractor may lower the elevation of the leveling pad as approved by the Engineer, except that the finished elevation at the top of the wall shall not be altered. As requested by the Contractor, and with the Engineer's approval, the higher wall shall be redesigned with longer reinforcement length and revised reinforcement schedule.

Method Of Measurement

504.20 MSE retaining walls will not be measured for payment in the field but will be paid for by the calculated quantities shown on the plans for the five major components of the wall: structure excavation, structure backfill, block facing, mechanical reinforcement of soil, and geomembrane. The Contractor's construction of a system that requires increased or decreased quantities of any of the components to complete the wall to the dimensions shown will not result in a change in pay quantities. Exceptions will be made when field changes are ordered or when it is determined that there are discrepancies on the plans in an amount of at least plus or minus five percent of the plan quantity.

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- (1) The block facing quantity was calculated for the square foot of wall front face area from the top of the leveling pad (or average pad elevations) as shown on the plans to the top of the anchoring slab for walls with railing, or to the top of the cast in place coping for walls without railing.
 - (2) The structure excavation quantity was calculated for the total volume of earth to be removed before the installation of the reinforced zone as shown on the plans.
 - (3) The structure backfill quantity was calculated for the total volume behind the wall (the retained structure backfill zone) including the material in the reinforced zone as shown on the plans.
 - (4) The mechanical reinforcement of soil quantity was calculated for the total volume of the reinforced zone as shown on the plans.
 - (5) Geomembrane was PLG specified in the plan disregarding the slope of the membrane.
- The square foot and cubic yard quantities computed for payment are the wall plan quantities based on the height measured at 20 foot maximum intervals along the wall layout line.

Basis Of Payment

504.21 The accepted quantities will be paid for at the contract unit price per unit of measurement for the pay items listed below:

Payment will be made under:

Pay Item	Pay Unit
Block Facing	Square Foot

Structure excavation will be paid for under the Section 206 Pay Item Structure Excavation. Structure backfill will be paid for under the Section 206 Pay Item Structure Backfill (Class 1). Soil reinforcement will be paid for under the Section 206 Pay Item Mechanical Reinforcement of Soil. Geomembrane will be paid for under the Section 420 Pay Item Geomembrane.

Rail anchoring systems (slabs) at the tops of walls and leveling pads at the bottom of wall will be measured and paid for separately under the Section 601 Pay Item Concrete and the Section 602 Pay Item Reinforcing Steel.

Payment will be full compensation for all work and materials required to construct the concrete block facing MSE wall. Miscellaneous items such as, dual track welding of Geomembrane, drainage ditches, rundowns, filter material, filter fabric, grout, pins, shimming material, concrete block coating and providing a technical representative will not be measured and paid for separately but shall be included in the work.

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504.22 Block Facing Payment Reductions. In this subsection, “block” refers to either a concrete block or a hybrid unit.

- (1) A dislocated block is where the edge of an individual block is offset outward more than ¼ inch or placed with a vertical joint more than ¼ inch from the edge of adjacent blocks.
- (2) A cracked block is an individual block with any visible crack visible in natural light from a distance equal to the wall height.
- (3) A corner knock-off is a block with any missing facial corners or any side longer than ½ inch at the corner.
- (4) Substandard blocks are concrete blocks installed in any wall segments that do not meet the certified values of compression strength, water absorption rate, or freeze/thaw cycles; substandard blocks include blocks actually in the wall for which the Contractor does not provide reports and certifications as required in subsection 504.07.

In the completed wall, or completed portion of the wall, if the number of defective blocks (cracked blocks, corner knock-off blocks, dislocated blocks, efflorescence or cement blemished blocks and substandard blocks) and blocks failing the straightedge test exceeds 3 percent of the total number of blocks in any wall segment of 40 foot horizontal or arc length, a price reduction will be applied to that portion of the wall. The price reduction shall be 3 percent for each percent of defective blocks in this portion of the wall exceeding 3 percent. This percentage shall accumulate thereafter to a maximum reduction of 21 percent. For blocks subject to price reduction, if the defects are repairable or the overall quality of wall can be improved, with the consent from the Engineer, the Contractor may repair and reduce the percentage of price reduction. Finished wall facing profile either outside of acceptable zone or into negative batter and blocks not meet freeze and thaw requirement are not repairable, the non-repairable portion shall receive a 21 percent price reduction for each wall pay item. A walkthrough inspection will be made as requested by the Contractor before final payment.

% Of Defective Blocks (x) in 40 foot section	$x \leq 3$	$3 < x \leq 4$	$4 < x \leq 5$	$5 < x \leq 6$	$6 < x \leq 7$	$7 < x \leq 8$	$8 < x \leq 9$	$9 < x \leq 10$	$x > 10$
% Of Price Reduction for that section	0	3	6	9	12	15	18	21	Rejection

The overall payment reduction percentage shall be calculated by dividing the sum of all defective blocks by the total number of blocks in that portion of the wall. When this percentage exceeds 10 percent, the Engineer will reject the entire wall or portions thereof. The Contractor shall replace the rejected wall at his own expense.