

**Revision of Section 504
Concrete Panel Facing Phased Built GRS Wall**

Notice

This is a project special provision that revises or modifies the 2011 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 with project specific change and updating to meet the 2017 Specification allowed.

Revision Log

Name

RS, STW, GMT

Date

July 20, 2017 (New)

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Revisions to make spec online accessibility-compliant.
5.22.23 Additional accessibility work.

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

Description

504.06 This work consists of constructing a Concrete Panel Facing Geosynthetic Reinforced Soil (GRS) Retaining Wall System at the locations and to the lines and grades shown on the plans. The Phase II (two) concrete panel facing installation can only be commenced till the major portion of Phase I (one) GRS wall settlement completion. Only geosynthetic reinforcement as specified in this specification may be used as GRS 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

504.07 Shop Drawings. Unless specified in the plans shop drawings are only required for panel to wire basket connection of GRS walls with the default reinforcing spaced at 1'-0". If soil reinforcement spacing for phase I (one) wall requirement is not met (or as required to quantify and build the complete wall in one phase as dictated by special site geometry) the shop drawings will include the following.

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

- (a) *Wall Layouts.* Wall layouts shall conform to lines and grades on the plans including start, corner, and end stations, leveling pad step breaks, total number of panels and top and bottom of wall elevations. For walls with rail anchoring slabs, the top of panel elevations shall be within 8 inches of the elevation shown on the plans measured from the bottom of 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 wall, the permanent wall vendor shall provide the shop drawings and certified material test reports for temporary walls.
- (b) *Phase I Wire Basket Facing and Reinforcement Locations.* Unless otherwise shown on the plans, each layer of soil reinforcement is required to form a soil wrap inside of and along the entire height of the basket for wrap around(terminating ~4 FT. from the face of the wall). Secondary reinforcement if required will be detailed in the plans.

Phase II Panel to Wire Basket connection detail, and limits of special panels at curved wall corner shall be shown. The back of each panel shall be logically numbered with its location.

- (c) *Wall Elevations.* Except for the top of the leveling pad, wall elevations given on the

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plans are based on the desirable wall height. The actual panel and reinforcement elevations shall be marked on the shop drawings by taking into account the supplied panel as well as special panel heights for matching the front and top finished grade.

- (d) *Soil Reinforcement Material.* The soil reinforcement type, Minimum Average Roll Value of the Ultimate tensile strength T_{ULT} (MARV) for geosynthetic soil reinforcement, spacing, lengths, elevations, and the corresponding wall design height 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. Spacing (1'-0" Typ.) of the reinforcement layers shall be as specified in the plans.
- (e) *The soil reinforcement length (RL).* The soil reinforcement length for phase I wire basket wall shall be measured from front face of wire basket to the end of soil reinforcement as measured to the neat end. Soil reinforcement lengths shall not be less than the lengths specified on the plans.

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) *Panel Size and Soil Reinforcement Spacing.*

1. Except for full height panels, the maximum panel size is 50 square feet, and the minimum panel height shall be 30 inches.
2. For full height panels, the maximum panel width shall be 10 feet and the maximum panel height shall be 40 feet. Differential deflection between adjacent panels shall be limited to 1/500. The vendor shall supply design calculations regarding panel concrete crack size control during shipment and construction and estimated joint width and differential deflection limits. The use of full height panels with widths greater than 10 feet or heights greater than 40 feet shall be as approved by the Engineer.
3. The maximum vertical spacing between layers of adjacent soil reinforcement shall not exceed 12 inches. Except the half height panel used at the top and bottom of wall, including all partial and extended height panels at the top of wall there shall be at least two connectors per panel/basket interface.
4. Shiplap joints shall be required at horizontal and vertical joints for segmental panel walls and all vertical joints for full height panel walls. The gap between two adjacent panels shall be 1/2 to 1 inch. Shiplap joints are not required at the vertical joints of

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segmental and full height panel. A minimum of 12 inches depth of continuous Class 2 Geotextile is installed behind the joints as shown in the plans prior to Class D concrete infill between the Phase I wire basket and the Phase II panel. Geotextile (Class 2) will not be measured and paid for separately but shall be included in the work. Neoprene cushions shall be provided at all horizontal joints as shown in the plans.

(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 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 not allowed.
3. Geosynthetic Soil Reinforcement. Geosynthetic soil reinforcement shall be a woven geotextile. For polyester (PET), polypropylene (PP), and high-density polyethylene (HDPE) 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 ultimate tensile strength, T_{ULT} (MARV), i.e.

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

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

RF(ID): Installation damage reduction factor

RF(D): Durability reduction factor

RF(CR): Creep reduction factor

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

(1) Geogrid or Geofabric sheet reinforcement (HDPE, PET, PP):

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

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(2) Woven Geotextile will meet minimum bi-axial MARV of ultimate tensile 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 precast concrete coping for walls without railing. For walls that are in front of a bridge abutment that is founded on a MSE 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 GRS wall.

For geosynthetic reinforcement, if the default geofabric with 1'-0" spacing is not used 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 for the Engineer's approval. 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.

(k) *Table of Quantities.* **Not Required if default Geofabric with 1'-0" spacing is used.** A table comparing the Structural Backfill (Class 1), Mechanically Reinforced Soil (MRS), Geomembrane, and Panel 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), Geogrid Reinforced Soil, Geomembrane, and Panel 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.

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- (l) *Placement Schedule.* **Not Required** if default Geofabric with 1'-0" spacing is used. Geomembrane placement schedule and clearances to soil reinforcements shall be shown.
- (m) *Vertical Slip Joints.* Locations of vertical slip joints for differential settlement relief shall be as specified in subsection 504.16.

504.08 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). With the installation of isolation geomembrane, 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.

504.09 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 36 inches. The leveling pad shall be reinforced only at the steps. When the toe of wall is founded on 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 panels. To avoid panel cracking from high contact points, a 1/4 inch thick expansion joint material with the same thickness as the panels may be installed between the first layer of panels and the leveling pad.

504.10 Geomembrane and Joint. 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 (a) for geomembrane and be LLDPE with a minimum thickness of 30 mils. It shall be spliced with a dual track field seamed joint in accordance with ASTM D4437 or 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 wall Design Height (DH) plus Soil Reinforcement Length (RL) plus 1.5 feet. The membrane shall be installed with a slope between 20:1 (minimum) and 10:1 (maximum), as shown in the plans, from the panel facing to a drainage system located at the cut or pre-filled slope as shown on the plans.

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 1:1 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

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diameter non-perforated drain pipe, at 100 foot maximum spacing, shall be used to discharge the water in the water collector system out the face of the wall.

For complex geometry (such as structural skew, superelevation, tiered wall and staged construction) a detailed layout of the membrane and drainage system shall be provided as working drawings in accordance with subsection 105.02 by the Contractor and as 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.

504.11 Pre-Cast Concrete Panel Facing Unit and Panel Joint Material. The pre-cast concrete panels shall conform to the requirements shown on the plans and these specifications including the color, texture, dimensions and pattern. These facing units shall be factory made with Class B Concrete with the following additional requirements:

- (1) Minimum Cementitious Content specified by contract. Approved mix design shall be used per the contract.
- (2) Ambient form temperature: shall be a minimum of 40° F and rising when casting panels.
- (3) Pre-cast panels shall be cured in accordance with NPCA, QCM Chapter 4, section 4.5.
- (4) Quality Control Manual shall contain: Safety, pre & post-pour inspection criteria and procedures; applicable ASTM standards for concrete testing procedures, personnel qualifications, certifications, equipment calibrations, and repair procedures for precast units. The QC Manual shall be submitted to the governing agency upon request. Proof of conformance to specific federal, state or local standards shall be maintained on file at the fabrication location.
- (5) Lifting Inserts / Lifting Hardware materials used in precast concrete products shall be verified for capacity, and shall have an adequate factor of safety, taking into account the various forces acting on the device(s), including form release suction, impact and various positioning of the product during handling. (OSHA 29 CFR 1926.704(d))
- (6) Pre-Pour / Post-Pour Operations inspections shall be performed and documented per the procedures outlined in the Quality Control Manual.
- (7) Hot and Cold Weather Precautions: During hot weather, the concrete temperature, at the time of placement, shall not exceed 90 degrees F. Hot weather is defined as; High ambient temperature, High concrete temperature, Solar radiation and wind. During cold weather, the concrete temperature, at the time of placement, shall not be less than 50 degrees F. Cold weather is defined as; Average daily temperature is less than 45 degrees F., The ambient temperature is not greater than 50 degrees F. for more than one-half of any 24 hour period.
- (8) Concrete Curing: Moisture retention and control of hydration curing temperatures shall be maintained. The maximum hydration curing temperature shall not exceed 150 degrees F.

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Reinforcing steel shall conform to the requirements of Section 602 of the specifications. The concrete in the pre-cast units shall be compacted using a vibrating table, grid vibrator, or screed vibrator. All panels shall be cast face down on flat level surface.

Panel dimensions and facing treatment shall conform to the architectural requirements shown on the plans. Width of panel from center to center of joint shall be an even whole increment of the pattern dimensions selected to match the architectural treatment. Thickness shall be a minimum of 6 inches plus the depth of rustication. Panel shall be cast to the dimension that accommodates the architectural treatment.

Panels may be longer than 5 feet provided their section strength can be shown to accommodate handling and erection without cracking. Soil reinforcement attachment devices shall be within 1 inch of shop drawing locations. All unit dimensions shall be within ¼ inch of plan. Concrete surface for the front face of the wall shall match the architectural treatment requirements and structural concrete color shown on the plans. Squareness determined by the difference between two diagonals, shall not exceed ½ inch Surface defects on the front face textured surface, shall not exceed ³/₁₆ inch when measured with a 5 foot straight edge, except when intentionally roughened.

The Engineer shall be allowed access to the manufacturer's facilities to inspect and sample units from lots prior to delivery with a minimum of 2 working days advance notice. The Engineer will reject any concrete panels, which do not meet the requirements of this specification. Panels shall not be shipped until the concrete strength, at the time of shipping, is greater than 0.9 times f'_c . The Contractor shall notify the Engineer in writing at least 3 working days before shipment of panels begins.

Cover on the back face of the wall for horizontal and vertical joints is required between panels and shall be a drainage geotextile conforming to Subsection 712.08, a minimum of 12 inches wide, nailed or glued in place prior to placing backfill.

At horizontal joints, a cellular type or molded expansion joint material shall be placed and shall be a size suggested by the supplier and approved by the Engineer.

504.12 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 504.07(f), 504.07(g), 504.07(j), 504.07(k), 504.12(e), 504.12 (f), 504.12(g), and 504.12(i) shall be certified and stamped by a Professional Engineer licensed in the State of Colorado.

(a) *Certification of T_{ULT} (MARV).* For geo-synthetic reinforced system only, the Contractor shall submit a certification letter from the manufacturer which provides the T_{ULT} (MARV) and certifies the T_{ULT} (MARV) of the supplied materials have been determined in accordance with ASTM D4595 or ASTM D6637 as appropriate.

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- (b) *Mill Report for Metallic Reinforcements and Connectors.* This includes, but is not limited to mill certifications on weldability, ultimate tensile and yield strength.
- (c) *Report of The Panel-Reinforcement Connection Test.* **NOT REQUIRED UNLESS PROPOSED SOIL REINFORCEMENT DEVIATES FROM THE STANDARD PLANS.** The test report shall be prepared and certified by an independent laboratory. The panel to reinforcement connection test method shall conform to the industrial standards. The report shall provide data on the ultimate as well as service limit state.
- (d) *Report for Soil to Reinforcement Interface Pullout Test.* **NOT REQUIRED UNLESS PROPOSED SOIL REINFORCEMENT DEVIATES FROM THE STANDARD PLANS.** 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 defined by wall design heights.
- (e) *Certification of Facial Panel to Wire Basket Long-Term Connection Strength.* **NOT REQUIRED UNLESS SPECIFIED IN THE PLANS.** Certification shall include calculations to demonstrate that the facial panel to reinforcement connection meets or exceeds current AASHTO 75 years design life requirements.
- (f) *Certification of Reinforcement Pullout.* **NOT REQUIRED UNLESS PROPOSED SOIL REINFORCEMENT DEVIATES FROM THE STANDARD PLANS.** Certification shall be provided with detail calculations to demonstrate that reinforcement pullouts meet or exceed current AASHTO requirements. For metal reinforcement breakage and pullout, calculations shall include a combination of 75 years material depletion of carbon steel and galvanization loss.
- (g) *Report and Certification for the Initial Concrete Compression Strength, Shipping and Handling Stress.* Cylinder compressive test is acceptable to verify the initial concrete strength of panel at time of shipping. Concrete tensile stress shall not exceed the modulus of rupture. Report shall include calculations of panel cracking stress according to the proposed method of lifting and shipping. Before panel shipping from precast yard to wall site, the Engineer will approve the time of shipping, method of lifting and supporting condition during shipping as well as storage condition at the site before panel installation. Products shall conform to PCI MNL 117, 120, 122, and 127 as applicable.
- (h) *Calculations.* **NOT REQUIRED UNLESS PROPOSED SOIL REINFORCEMENT DEVIATES FROM THE STANDARD PLANS.** Calculation of the LTDS of reinforcement shall conform to AASHTO LRFD requirements.
- (i) *Efflorescence and Air Content Test.* Panel shall be visually efflorescence free. Efflorescence control agent shall be used in concrete mix design. When fly ash is used as the efflorescence control agent, the fly ash shall be ASTM C618 Class F fly ash and shall be a minimum of 20 percent by weight of the total cementitious material content. Air

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Content shall be determined in accordance with AASHTO T152. Concrete shall be tested a minimum of the first three batches each day and then once per five batches for the rest of the day to assure specified air entrainment.

(j) *Submittal Checklist.* The Contractor shall submit the Panel Faced MSE (or as approved for GRS) Wall Submittal Checklist, Form 1402 with the Certifications, Calculations and Testing Report submittal package included with the shop drawing submittal.

504.13 Hybrid MSE Wall Systems.

Only Micropile A-Frame wall systems are allowed. System is subject to all requirements in this project special provision. Installation of micropiles through fabrics allowed with required pre-installed sacrificial pilot pipes.

Construction Requirements

504.14 Approval and Qualifications of GRS (or MSE equivalent) Wall Installer. The job site wall foreman shall have experience in construction of at least five transportation related GRS walls within the last three years. Transportation related GRS 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 in 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 time during which the work is being done.

504.15 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 504.15 below. 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.

504.16 Technical Representative of Wall Product Supplier. NOT REQUIRED UNLESS SPECIFIED IN THE PLANS. The Contractor shall arrange for a technical representative (Tech Rep) of the manufacturer of the selected wall products to be present during the construction of each wall test segment. If the selected 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 four layers of primary soil reinforcement and backfill,

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

504.17 Facial Panel Quality Control, Placing Plan and Daily Placement Logs. Before the start of wall construction, the Contractor shall provide a panel-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 panels placed, and the serial numbers of the panels placed. The panel quality control shall contain multiple submittals if required by subsections 504.12(g) and (h). Panels shall be

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labeled with serial number for each panel and corresponding certification with one set of random samples tested for each 220 panels or 5500 square foot of wall face. At least one certification with supporting test results is required for each wall. Test results will be reviewed and pre-approved by the Engineer before shipment. The Contractor shall coordinate and mark the panel and backfill placing sequence on the daily placement logs. The log serves as means for the Engineer to identify where each panel was placed.

504.18 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 corner panel, sequence of panel 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 panels with random cracks, the Contractor shall install vertical slip joints as shown on the shop drawings.

504.19 Excavation and Backfill. The base of leveling pad shall receive the same compaction as cut area required by subsection 203.07. The Contractor shall report to the Engineer in writing density test results for any unsatisfactory bearing material that does not meet 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.

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 panels shall not exceed 4 inches. The triangular or trapezoidal portion behind the concrete panels 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 be in even increments up to 8 inches thick. 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

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material under the wall and on-site material as allowed by subsection 504.08 shall be compacted to a density of at least 95 percent of the maximum density 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 percent T180.

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 of the wall face. 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 panels including partial height panels 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. 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.

504.20 Reinforcement. Geosynthetic reinforcement shall be slightly pre-tensioned. The minimum coverage ratio for woven fabric reinforcement shall be 100 percent and an overlap between rolls is not required. Soil reinforcement shall not be cut to avoid obstruction unless shown on the shop drawings. Equivalent strength geogrid may be used above the waterproofing membrane.

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504.21 Leveling Pad. The foundation of the leveling pads shall meet the requirement of subsection 504.09 for steel and concrete. The leveling pad shall be level within the tolerance of $\frac{1}{8}$ inch for any two points along the length of a panel, and within $\frac{1}{4}$ inch for any two points 10 feet apart. If the wall is not level, the panels will bind against each other causing spall of the edges and corners.

Cushion or shimming material (Expansion Joint Material, Concrete Mortar Grout, Roofing Felt or Geosynthetic Reinforcement) shall be used to support panels directly founded on the leveling pad. Before starting a new course of panels, the Contractor shall take steps to ensure that the wall elevations are matched at the neighboring panels. Cushion or shimming material shall be used to obtain necessary panel elevations at next leveling pad step. No more than 2 shims (each $\frac{3}{16}$ inch thick) should be required to level the panels on the leveling pad.

504.22 Wooden Wedges. Wooden wedges are used to help to hold the panels at the correct batter during the backfill operation. The wooden wedges shall be made from hard wood (such as oak, maple or ash). Wooden wedges shall be removed as soon as the precast panels above the wedged panels are completely erected and backfilled. There shall not be more than three rows of wooden wedges in place at one time. Panels that crack or spall due to failure to remove the wooden wedges shall be repaired or replaced.

504.23 Panel Facing. For walls that support a roadway, the wall layout line at the leveling pad shall be setback and pre-measured with appropriate batter (5 to 8 percent) from the top of the panels 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. Unless otherwise noted on the plans for battered walls, the final wall face shall be vertical, or have a positive batter of not greater than 5 percent for construction control purpose. The surface of the wall face shall be tested with a 10-foot straightedge laid along the surface in horizontal and vertical directions. Except as necessary for horizontal alignment of the wall, convex deviation of the wall face from the straightedge (belly wall) shall not be allowed, and concave deviation from the straightedge shall be less than $\frac{1}{2}$ inch.

Walls without a rail-anchoring slab, cast-in-place reinforced concrete coping with uniform exposed height is required to match the required finished elevations as well as to retain the panels' lateral deformation.

For walls with rail anchoring slabs, the top of panel elevations shall be within 8 inches of the bottom of the anchoring slab. Cast-in-place concrete or saw-cut partial height panels may be used to accomplish this.

Where the Geomembrane for drainage interferes with the continuation of reinforcement, the panels beyond the termination shall be reinforced with the same grade of additional soil reinforcing material to maintain the total amount of reinforcement per panel. To avoid

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leaking or soil erosion through the joint, a filter fabric at least 12 inches wide shall be glued to the panels behind all vertical joints.

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

For completed wall or parts of completed wall, before final payment any damages including blemish and discoloring of panel shall be replaced or repaired. Sand blasting may be used if accepted by the Engineer.

504.24 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

504.25 GRS 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, concrete panel 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.

- (1) The panel 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 geogrid reinforcement of soil quantity was calculated for the total volume of the reinforced zone as shown on the plans.
- (5) Geomembrane required is site specific as to ensure the longevity and stability of the wall and shall be determined by the designer of record.

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- (6) Concrete Class D (Wall) quantity was calculated for the total volume of Leveling Pad, Precast coping, FRP bar stopper, and Collector and down pipe.
- (7) Reinforcing Steel (Epoxy Coated) quantity was calculated for total pound of steel placed in precast coping.

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

504.26 The accepted quantity 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
Panel 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 panel facing MSE wall. Miscellaneous items such as dual track welding of Geomembrane, drainage ditches, rundowns, filter material, filter fabric, grout, pins, shimming material, ¼ inch thick expansion joint material, concrete coating and providing a technical representative will not be measured and paid for separately but shall be included in the work.

504.27 Panel Facing Payment Reductions. In this subsection, a “panel” refers to either a concrete panel or a hybrid unit. Each of the following shall be considered a defect:

- (1) Dislocated Panel. A dislocated panel is an individual panel, or its corner located outward more than 1/4 inch from the adjacent panels.
- (2) Cracked Panel. A cracked panel is an individual panel with any visible crack when viewed from a distance equal to the wall height in natural light.

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- (3) **Corner Knock Off.** A corner knock-off is a panel with any missing facial corners or architectural edges.
- (4) **Substandard panel.** Substandard panels are concrete panels installed in any wall segments that do not meet the certified values for compressive strength. Each substandard panel counts as one defect.
- (5) **Oversize Joints.** Panels with oversize joints are two adjacent panels that do not meet the required values in subsection 504.07(f).
- (6) **Panels Failing the 10-Foot Straightedge Test.** Straightedge test failures are joints that deviate from even by more than ¼ inch when measured by placing a 10-foot straightedge across the joint.

Defects shared by two adjacent panels such as oversized joint, dislocated panel and panels not passing 10-foot straight edge test will be count as one defect. In the completed wall or completed portion of the wall the number of defects, as described above, in each 40 foot section (horizontal or arc length) will be counted. If there are defects, the number of defects in the 40 foot section will be considered for price reduction according to the table below. For panels subjected 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 elect to repair and reduce the percent of price reduction. A walkthrough inspection shall be made as requested by the Contractor before final payment.

No. of Defects in 40 Foot Section	2	3	4	5	> 5
% Of Price Reduction for that section	3	9	15	21	Rejection

When the number of defects exceeds 5, the Engineer will reject the entire wall or portions thereof. The Contractor shall replace the rejected wall at his own expense.