SECTION 929 MECHANICALLY STABILIZED EARTH (MSE) WALLS:

929-1 Description:

929-1.01 General:

The work under this section consists of designing, furnishing all materials and constructing Mechanically Stabilized Earth (MSE) retaining walls in accordance with these specifications and in compliance with the lines and grades, dimensions and details shown on the project plans and as directed by the Engineer.

The contractor shall provide the MSE wall designer with a complete set of project plans and specifications and shall ensure that the wall design is compatible with all other project features that can impact the design and construction of the wall.

The terms used in this specification for identification of various entities responsible for MSE Wall designs are defined in table 929-1:

TABLE 929-1

Term	Entity Responsibilities
Wall Manufacturer/Supplier	The entity contractually retained by the contractor to provide materials and construction support services for an accepted MSE wall system as identified in Subsection 929-1.03.
Wall Designer	The entity contractually retained by the contractor to provide internal design of an accepted MSE wall system as identified in Subsection 929-1.03. The Wall Designer is also responsible for evaluating certain aspects of external stability as discussed herein using the geotechnical information provided by the Geotechnical Engineer. The Wall Designer may be a representative of the Wall Manufacturer/Supplier. Internal design includes evaluation of compound stability, which is defined as a failure mode passing through the reinforced soil mass and the retained fill and/or foundation. Geotechnical properties for the retained fill and foundation are to be obtained from the Geotechnical Engineer. The aspects of external stability as discussed below for Geotechnical Engineer that are the responsibility of the Wall Designer to evaluate are as follows: (1) Verify the bearing pressures do not exceed the

	bearing resistance of the foundation soils shown on the bearing resistance charts provided by the Geotechnical Engineer (2) Estimate the settlements along the length of the accepted MSE wall system, as identified in Subsection 929-1.03, using the Service I limit state settlement curves shown on the bearing resistance charts provided by the Geotechnical Engineer. (3) Evaluate limited eccentricity and sliding of the accepted MSE wall system, as identified in Subsection 929-1.03, using the geotechnical properties for the retained fill and foundation material provided by the Geotechnical Engineer.
Geotechnical Engineer	The entity responsible to evaluate or provide geotechnical information needed for the Wall Designer to evaluate certain aspects of external stability of the accepted MSE wall system as identified in Subsection 929-1.03. External stability includes the analysis of: 1. Bearing Capacity 2. Settlement (short term and post construction) 3. Limited Eccentricity 4. Sliding 5. Global slope stability The bearing capacity and settlement (short term) shall be evaluated by the Geotechnical Engineer and provided to the Wall Designer in the form of a bearing resistance chart developed in accordance with ADOT SF-1 (2010) Memorandum (3). Bearing resistance charts shall be developed for each boring advanced along the length of the proposed MSE walls. Long-term settlements (post construction) shall be evaluated by the Geotechnical Engineer and provided to the Wall Designer so that the Wall Designer can account for such settlements in their design. Geotechnical properties of the retained fill and foundation material shall be provided by the Geotechnical Engineer to the Wall Designer to allow the Wall Designer to evaluate limited eccentricity and sliding of the accepted MSE wall system, as identified in Subsection 929-1.03.
Notes: (1) For design build (DB)/ CMAR/ P3 projects, both the Wall Designer and Geotechnical Engineer shall be contractually retained by the contractor to provide the	

responsibilities defined herein.

(2) The geotechnical properties for the retained fill provided by the Geotechnical Engineer to the Wall Designer are minimum properties based on global stability analysis performed by the Geotechnical Engineer, and the Wall Designer may elect to use material exceeding those minimum property values for design. In such case, the geotechnical properties used by the Wall Designer exceeding those provided by the Geotechnical Engineer shall become the required geotechnical properties for the retained fill during construction.

(3) ADOT SF-1 (2010): Development of Factored Bearing Resistance Chart by a Geotechnical Engineer for Use by a Bridge Engineer to Size Spread Footings on Soils for Service and Strength Limit States Based on Load and Resistance Factor Design (LRFD) Methodology, Memorandum from N. H. Wetz and J. D. Wilson to J. Lawson, Dated March 19, 2008 (Revision 1).

929-1.02 Certifications:

(A) Certification of Review of Geotechnical Report(s):

The contractor shall be responsible to review all available geotechnical investigation reports, and the contractor's signature on the proposal form shall certify that this review has been performed and that this specification and any relevant geotechnical information has been provided to the firms designing and supplying the MSE wall.

The geotechnical investigation reports are available on the Contracts and Specifications Section current advertisement website.

(B) Certification of Design Parameters:

See Subsection 929-2.01 herein specified.

(C) Certification of Materials:

See Subsections 929-3.04, 929-3.06 and 929-3.09 herein specified.

929-1.03 Accepted Systems:

The contractor shall select one of the appropriate ADOT pre-approved earth retaining systems to be constructed for the MSE walls designated on the plans.

Pre-approved systems are listed on the ADOT Bridge Group website:

https://azdot.gov/business/engineering-and-construction/bridge/guidelines/geotech-services

The features of the system(s) furnished, including design and configuration of precast elements, fasteners, connections, soil reinforcements, joint fillers, geotextile filter, and other necessary components shall be those that meet the requirements of Subsection 929-2.

Heights and lengths of earth retaining MSE walls may vary from, but shall not be less than, those shown on the plans. The height and length to be used for any system shall be the minimum for that system that will effectively retain the earth behind the wall for the loading conditions and the contours, profile, or slope lines shown on the plans, in accordance with all relevant internal and external stability design criteria.

929-1.04 Unlisted Systems Acceptance Process:

If the contractor elects to use an earth retaining systems not listed on the ADOT Bridge Group website, the approval process for such systems is as follows:

(1) No consideration will be given to a request for approval of an unlisted system prior to contract award. After award, and in time to allow for consideration without delaying work, the contractor shall submit a written request for approval of a new system.

(2) If the contractor wishes to propose multiple systems, separate written requests shall be submitted for each system. All requests must be received within the timeframes specified herein.

(3) The contractor's progress schedule shall indicate when the proposed system is to be used on the project. The schedule shall include time for the Department to evaluate the proposed system and shall demonstrate that there will be no impacts to the critical path. If, in the opinion of the Engineer, the schedule shows that the evaluation and approval timeframe of the proposed system is not reasonable, the Department will not consider the proposed system.

(4) A request for the use of an unlisted system shall include all information necessary to determine that a system is an equal, including samples for testing, if required. Unlisted systems will not be entertained as Value Engineering (VE) Proposals.

(5) The Department will evaluate the information submitted, perform tests when necessary and make comparisons. The Engineer will then make the final decision as to whether the proposed system is an equal. The Department will neither be liable for any delay in acting upon any request nor for any failure to approve a request pursuant to the use of an unlisted system.

(6) The Department will review the contractor's request for the use of an unlisted system within 45 days of the contractor's submittal and inform the contractor in writing if the request is rejected, approved, or if the Department will take additional time for evaluation. Any additional information needed to evaluate the proposed system shall be submitted in a timely manner. Untimely submittals of additional information shall result in rejection of the proposed system.

(7) The contractor shall not be entitled to additional compensation or an extension of contract time resulting from the Department's acceptance or rejection of a proposed system. Bid prices shall not to be based on the anticipated approval of a proposed system.

929-1.05 Manufacturer's Field Representative:

The manufacturer's field representative performing the work described in this specification shall have, in the past three years, successfully installed at least four MSE retaining walls of heights, lengths and complexity similar to those shown on the plans and meeting the tolerances specified herein. The manufacturer's field representative may make field changes subject to the approval of the Engineer. Any such changes shall be documented in writing within 24 hours of the approved changes. This written document shall be sealed by the manufacturer's design engineer, who is registered as a Civil Engineer in the State of Arizona.

929-1.06 MSE Pre-Activity Meeting:

A pre-activity meeting will be scheduled prior to commencement of MSE wall construction activity. As a minimum, this meeting shall be attended by the Engineer, contractor (including wall construction crew chiefs), the MSE wall sub-contractor, MSE wall manufacturer's and MSE Wall designer's representatives. No wall construction activity shall be performed until the contractor's final submittals have been approved as having satisfactorily resolved all review comments and the pre-activity meeting has been held.

929-1.07 Wall Aesthetics:

Wall aesthetics shall be as specified in the project plans and special provisions.

929-2 Submittals (Working Drawings and Design):

929-2.01 Submittals:

The submittals required shall include working drawings, construction procedures, supporting design calculations, verification of experience, and a transmittal letter. The transmittal letter shall only list the documents included in the submittal. No technical information shall be included in the transmittal letter.

Working drawings and calculations shall be signed and sealed by a Professional Engineer, who is registered as a Civil Engineer in the State of Arizona. The MSE wall designer/supplier shall document on the working drawings all assumptions made in the design. The following statement shall be included near the P.E. seal on the first sheet of the working drawings: "All design assumptions are validated through notes or details on these drawings".

Working drawings, design calculations, and MSE wall supplier's construction procedures modified as necessary by the contractor and wall designer for site-specific conditions shall be submitted to the Engineer for review. The Engineer shall have 15 calendar days after

receiving the submittal to finish a review. The revised package shall be resubmitted to the Engineer for review. The Engineer shall have 5 calendar days to complete this review. This review process shall be repeated until the entire submittal is accepted by the Engineer.

The Department assumes no responsibility for errors or omissions in the working drawings. Acceptance of the final working drawings submitted by the contractor shall not relieve the contractor of any responsibility under the contract for the successful completion of the work.

Construction of the wall shall not commence until the contractor receives a written Notification to Proceed (NTP) from the Engineer. The NTP will be issued once the complete wall package (drawings, calculations, and construction procedures) is accepted. Fabrication of any of the wall components before the NTP shall be at the sole risk of the contractor.

929-2.02 Working Drawings:

The contractor shall submit complete working drawings and specifications for each installation of the system in accordance with the requirements of Subsection 105.03 as modified herein.

Working drawings shall include the following at a minimum:

(1) Layout of the wall including plan and elevation views;

(2) All design parameters and assumptions including design life;

(3) Existing ground elevations and utilities impacted by the wall shall be field verified by the contractor for each location;

(4) Complete details of all elements and component parts required for the proper construction of the system at each location and any required accommodations for drainage systems, foundation subgrades or other facilities shown on the contract documents;

(5) The working drawing submittal shall clearly detail any special design requirements. These special design requirements may include, but are not limited to; structural frames to place reinforcements around obstructions such as deep foundations and storm drain crossings, drainage systems within the reinforced backfill, placement sequence of drainage and unit core fill with respect to reinforced (structure) fill behind a wall face using modular block facing units, guardrail post installation, scour protection, foundation subgrade modification, all corner details (acute, obtuse and 90 degrees), slip joints, connection details of MSE walls with other cast-in-place structures, wedges, shims and other devices such as clamps and bracing to establish and maintain vertical and horizontal wall facing alignments;

(6) A complete listing of components and materials specifications; and

(7) Other site-specific or project specific information required by the contract.

929-2.03 MSE Wall Design:

(A) General:

The working drawings shall be supplemented with all design calculations for the particular installation as required herein.

The proposed design shall satisfy the design parameters shown on the project plans and listed in these specifications, and comply with the design requirements of the following documents:

- FHWA (2009), "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes; Publication No. FHWA-NHI-10-024 and FHWA-NHI-10-025; Authors: Berg, R. R., Christopher, B. R., and Samtani, N. C.

- AASHTO (2017), "AASHTO LRFD Bridge Design Specifications", 8th Edition, including latest Interims.

All references made to AASHTO (2017) herein shall mean "AASHTO LRFD Bridge Design Specifications", 8th Edition, including latest Interims.

Maximum reinforcement loads shall be calculated using the "Simplified Method" as presented in AASHTO (2017) and as per the requirements specified herein. No other design method will be allowed.

Sample analyses and hand-calculations shall be submitted, if requested by the Engineer, to verify the output from software used by the MSE wall designer. Sample analyses and hand calculations shall be required for complex walls having geometries and loading conditions that are not readily amenable to computer analysis. Failure modes, including circular, non-circular, and multi-part wedge shall be analyzed for compound stability to verify the most critical failure case (slip surface with lowest factor of safety) within each section of the wall where the length of the reinforcement changes. For compound stability, all potential slip surfaces for each failure mode passing through all Three Search Zones shown in Figure 929-2.03(A) shall be analyzed to determine the most critical failure case. Each failure mode shall be analyzed individually and not be forced to mimic the results of other failure modes. The compound stability analyses are required for all wall geometries including walls with level ground in front of wall and level backfill behind wall. Global stability requirements are contained in the MSE wall design summary plan sheet.

The contractor and wall designer shall identify the specific locations on working drawing plan and profiles based on subgrade evaluation and at other key locations to control the deformation along the wall. The soil reinforcement attached to the slip joints shall be oriented perpendicular to the slip joint panels and shall be the full design length. Special connection and compaction details shall be provided on the working drawings.

At all corners formed by two MSE walls, the leveling pad along the shorter wall forming the corner shall be at the same elevation as the leveling pad for the taller wall for a distance of at least 80 percent of the height of the taller wall or a distance of 10 feet, whichever is greater.

Unless otherwise specified in the contract, all structures shall be designed to conform to the requirements shown in Table 929-2 and other requirements specified herein.

TABLE 929-2
DESIGN PARAMETERS

Description	Limit State	Value	Note
1. Design Life	All limit states	75 Years	
2. Effective (Drained) Friction Angle			
a. Retained Backfill	All limit states	(Project specific as detailed in the MSE wall design summary sheet)	1
b. Reinforced Backfill	All limit states	34^{o} ,110 pcf	1
3. Length of soil reinforcement, B	All limit states	0.7H min or 8-ft whichever is more	2
4. Limiting eccentricity	Strength (all)	B/3 (soil), 0.45B (rock)	
	Service I	B/6 (soil), B/4 (rock)	
5. Coefficient of Sliding Friction	Strength (all)	$\tan[\min(\phi_r, \phi_f, \phi_i)]$	3
6. Resistance factors			
a. Sliding	Strength (all)	1.0	4
b. Bearing	Strength (all)	0.65	5
c. Overall (slope) stability			
I. Deep Seated Stability	Service I	0.65	6
II. Compound Stability	Service I	0.65	6
d. Pullout resistance			
I. Static	Strength (all)	0.90	7
II. Combined static/earthquake	Strength (all)	1.20	7
e. Tensile resistance of metallic reinforcements and connectors			
I. Static - Strip reinforcement - Grid reinforcement	 Strength (all) Strength (all)	 0.75 0.65	 8 8,9
II. Combined static/earthquake - Strip reinforcement - Grid reinforcement	Strength (all) Strength (all)	1.00 0.85	8 8,9
f. Tensile resistance of geosynthetic reinforcements and			

	connectors			
	I. Static	Strength (all)	0.90	
	II. Combined static/earthquake	Strength (all)	1.20	

Notes:

1	Retained backfill requirements shall be project specific as noted on the MSE wall summary plan sheet developed by the Geotechnical Engineer.
2	H is the design height of the wall and is defined as the difference in elevation between the finished grade at top of wall and the top of leveling pad. The top of the leveling pad shall always be below the minimum embedment reference line as indicated on the plans for that location. The length of the soil reinforcement, B, is measured from the backface of the wall facing unit. In case of grid type reinforcements the length of the soil reinforcement is measured from the backface of the wall to the last full transverse member. For modular block facing units, the total length of the reinforcement, BT, as measured from the front face of the wall is the length B as defined above plus the width of the modular block unit (the horizontal dimension of the block unit measured perpendicular to the wall face). Depending on the configuration of the reinforcements and properties of the various actual fills selected by the contractor, the minimum length of the reinforcement may need to be increased to satisfy the required resistance factors for compound stability analyses.
3	ϕ_r= friction angle of reinforced wall fill. ϕ_f = friction angle of foundation soil (As reported on the MSE wall design summary plan sheet). ϕ_l = friction angle of the interface between reinforcement and soil for cases of sheet reinforcement such as geotextiles. All friction angles are effective (drained) friction angles. Refer to the MSE wall design summary plan sheet for friction angle and unit weight of foundation soil.
4	Passive resistance shall not be considered in evaluation of sliding resistance.
5	For all limit states, the design loading for the MSE retaining wall system shall not exceed the factored general and local bearing resistances specified in the Geotechnical Report(s).
6	For earthquake loading condition, a resistance factor of 0.90 shall be used.
7	Live load due to vehicular traffic shall be included in the computations to determine the maximum tensile forces in reinforcement layers, but shall be neglected in the computations for pullout resistance. Intensity of live load shall be considered as a uniform surcharge using the equivalent height of soil in accordance with Section Article 3.11.6.4 of AASHTO (2017).
8	Apply to gross cross-section less sacrificial area. For sections with holes, reduce gross area in accordance with Article 6.8.3 of AASHTO (2017) and apply to net section less sacrificial area.
9	Applies to grid reinforcements connected to a rigid facing element, e.g., a concrete panel or block. For grid reinforcements connected to a flexible facing mat or which are continuous with the facing mat, use the resistance factor for strip reinforcements.
1	Unless otherwise specified, all resistance factors shall be taken as 1.0 when

0	investigating an extreme event limit state.

(B) Subsurface Drainage Systems:

Walls shall be provided with subsurface drainage measures as shown on the project plans and specifications. As a minimum, an underdrain system shall be provided for leading subsurface and surface water away from the backfill and outside the limits of the wall. Geocomposite drains, if used for subsurface drainage, shall be in accordance with Subsection 203-5.02 and 203-5.03(C) of the specifications.

The Wall Designer is responsible for drainage measures within the reinforced backfill. Drainage measures outside the MSE wall backfill shall be designed by the project civil designer.

(C) Obstructions in Backfill:

(1) General:

Where obstructions, such as deep foundations or storm drains crossings, are located in the reinforced backfill zone, cutting of reinforcements to avoid obstructions shall not be permitted. A minimum offset of one diameter but not less than 3 feet shall be maintained between the face of any pipe crossings and the back face of MSE retaining wall panels. A minimum clearance of 3 feet shall be maintained between the face of any other obstruction and the back face of MSE retaining wall panels.

(2) Horizontal Deflection of Reinforcements:

In the horizontal plane at a reinforcing level, a deviation up to 15 degrees from normal to the face of the wall may be allowed for strip reinforcement and bolted connection. This deviation is herein referred to as the splay angle. Grid reinforcements may not be splayed, unless connection has been specifically fabricated to accommodate a splay and connection detail has been approved by the Department. If used, the splay in grid reinforcements is limited to five degrees. For obstructions that cannot be accommodated with splayed reinforcement, structural frames and connections shall be required, and shall be designed in accordance with Section 10 (“Steel Structures”) of AASHTO (2017) for the maximum tension in the reinforcements. The structural frame design shall be such that bending moments are not generated in the soil reinforcement or the connection at the wall face. The design, along with supporting calculations, shall be included in the working drawings.

(3) Vertical Deflection of Reinforcements:

Vertical deflection of the reinforcement to avoid obstructions such as utilities along the wall face shall be limited to a maximum of 15 degrees from normal to face of wall. Bends in the reinforcement shall be smooth and gradual to ensure that galvanization remains intact.

(D) Hydrostatic Pressures:

As determined by the Engineer and/or as noted on the plans, for walls potentially subject to inundation, such as those located adjacent to rivers, canals, detention basins or retention basins, a minimum hydrostatic pressure equal to three feet shall be applied at the high-water level for the design flood event. Effective unit weights shall be used in the calculations for internal and external stability beginning at levels just below the equivalent surface of the pressure head line. Where the wall is influenced by water fluctuations, the wall shall be designed for rapid drawdown conditions which could result in differential hydrostatic pressure greater than 3 feet. As an alternative to designing for rapid drawdown conditions, Size 57 coarse aggregate, as specified in AASHTO M 43, shall be provided as reinforced backfill for the full length of the wall and to the maximum height of submergence of the wall. Separation fabric shall be class I needle-punched polypropylene non-woven geotextile with the highest permittivity shown in AASHTO M 288. The fabric shall be provided at the interface of the Size 57 coarse aggregate and reinforced backfill above it, and at the interface of the retained backfill behind it. Adjoining sections of separation fabric shall be overlapped by a minimum of 12 inches.

(E) Acute Angle Corners:

Wall corners with an included angle of less than 70 degrees shall be designed for bin-type lateral pressures for the extent of the wall where the full length of the reinforcement cannot be installed without encountering a wall face. Acute angle corner structures shall not be stand-alone separate structures. Computations shall be provided that demonstrate deformation compatibility between the acute angle corner structure and the rest of the MSE wall. Full-height vertical slip joints shall be provided at the acute angle corner and after the last column of panels where full length of the reinforcements can be placed. The soil reinforcement attached to the slip joints shall be oriented perpendicular to the slip joint panels and shall be the full design length. Special connection and compaction details shall be provided on the working drawings.

(F) Slip Joints:

For walls with precast concrete panels, vertical slip joints shall be included in the wall face at the following locations and as shown on the plans, whichever is more stringent:

(1) Boundaries of limits where differential settlement exceeds 1/100.

(2) All locations where a wall height changes by more than 5 feet.

(3) All corners within an MSE wall.

(4) Each side of a stiff element such as a reinforced concrete box culvert (RCBC), abutment wing walls, or any other wall face penetration larger than 5 feet.

(5) Each side of a drilled shaft foundation constructed prior to and within 8 feet of the face of wall. Approximate locations of slip joints are shown on the project plans.

(G) Spacing of Metallic Reinforcement for Flexible Face Wall Systems:

For permanent walls, vertical and horizontal spacing of metallic reinforcements for flexible face (welded wire or similar) wall systems shall not exceed 18 inches. The stiffness of the facing and spacing of reinforcements shall be such that the maximum local deformation between soil reinforcement layers shall be limited to less than 1½ inches. Facing elements shall not yield in bending and tension.

For temporary walls, i.e., walls with less than 36 months service life, the contractor may adjust the stiffness of the facing and spacing of the reinforcements such that the local deformation between the reinforcement is within the elastic range in bending and tension, and the overall geometry meets the line and grade requirements for the temporary walls.

(H) Soil Reinforcement for Modular Block Wall (MBW) Systems:

The soil reinforcement lengths and percent coverage at a given reinforcement level shall be in accordance with the plans. All soil reinforcement shall be positively connected to the modular block facing units by a connection that is capable of resisting 100 percent of the maximum tension in the soil reinforcements at any level within the wall. Detailed documentation for connection strength shall be submitted as noted in Subsection 929-3.09. The vertical spacing of the soil reinforcement for walls with modular block facing units shall be as follows:

(1) The first (bottom) layer of soil reinforcement shall be no further than 16 inches above the top of the leveling pad.

(2) The last (top) layer of soil reinforcement shall be no further than 20 inches on the average below the top of the uppermost MBW unit.

(3) The maximum vertical spacing between layers of adjacent soil reinforcement shall not exceed 24 inches. For walls deriving any part of 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) to assure construction and long-term stability. The top row of reinforcement shall be placed at a depth no more than two times the block height from the top of finished grade.

(I) Initial Batter of Wall:

The initial batter of the wall, both during construction and upon completion, shall be within the vertical and horizontal alignment tolerances included in this specification. The initial batter of the wall at the start of construction and the means and methods necessary to achieve the batter shall be provided on the working drawings. Subject to Engineer's approval, the initial batter may be modified at the start of construction by the manufacturer's field representative based on the evaluation of the backfill material selected by the contractor. Any such changes shall be documented in writing within 24 hours of the approved changes. This written document shall be sealed by the manufacturer's design engineer who is registered as a Civil Engineer in the State of Arizona. Details of the wedges

or shims or other devices, such as clamps and external bracing used to achieve or maintain the wall batter, shall be as shown on the working drawings and/or accompanying construction manual. Permanent shims shall comply with the design life criteria, and shall maintain the design stress levels required for the walls.

929-3 Material Requirements:

929-3.01 Precast Concrete Elements:

Precast concrete elements shall conform to the requirements for precast minor structures in Sections 601 and 1006. The concrete shall be Class S with minimum design strength of 4,000 pounds per square inch. The mix design shall conform to the requirements of Subsection 1006-3.

Prior to casting, all embedded components shall be set in place to the dimensions and tolerances designated in the plans and specifications. Rustication for wall aesthetics shall be in accordance with project plans, special provisions, and applicable requirements of Sections 601, 610, 1002 and 1006.

(A) Concrete Testing and Inspection:

Precast concrete elements shall be subjected to compressive strength testing in accordance with Subsection 1006-7, and inspected for surface conditions and dimensional tolerances in accordance with Subsections 601-3.05 and 601-4.02 respectively. Panels delivered to the site without the ADOT acceptance stamp will be rejected.

(B) Casting:

Precast concrete face panels shall be cast on a horizontal surface with the front face of the panel at the bottom of the form. Connection hardware shall be set in the rear face. The concrete in each precast concrete panel shall be placed without interruption and shall be consolidated by deploying an approved vibrator, supplemented by such hand tamping as may be necessary to force the concrete into the corner of the forms, and to eliminate the formation of stone pockets or cleavage planes. Form release agents as specified in Subsection 601-3.02(C)(1) shall be used on all form faces for all casting operations.

The contractor shall advise the Engineer of the starting date for concrete panel casting at least 14 calendar days prior to beginning the operation if the casting operation is within the State of Arizona, or 21 calendar days if the casting operation is outside the State of Arizona.

(C) Finish:

(1) Non-Exposed Surfaces:

Rear faces of precast concrete panels shall receive a Class I finish in accordance with Subsection 601-3.05.

(2) Exposed Surfaces:

The type of finish required on exposed surfaces shall be as shown in the plans.

(a) Exposed Aggregate Finish:

(i) Prior to placing concrete, a set retardant shall be applied to the casting forms in accordance with the manufacturer's instructions.

(ii) After removal from the forms and after the concrete has set sufficiently to prevent its dislodging, the aggregate shall be exposed by a combination of brushing and washing with clear water. The depth of exposure shall be between ⅜ inch and ½ inch.

(iii) An acrylic resin sealer consisting of 80 percent thinner and 20 percent acrylic solids by weight shall be applied to the exposed aggregate surface at a rate of 1 gallon per 250 square feet.

(b) Concrete Panel Finish:

Concrete panel finish shall be in accordance with Subsection 601-3.05.

(D) Tolerances:

Precast concrete elements shall comply with Subsection 601-4.02(B)(1) and 601-4.02(B)(4). Connection device placement shall be within ± ⅜ inch of the dimensions shown on the drawings. Panel squareness as determined by the difference between the two diagonals shall not exceed ½ inch.

(E) Identification and Markings:

The date of manufacture, the production lot number, and the piece mark shall be inscribed on a non-exposed surface of each element.

(F) Handling, Storage, and Shipping:

All panels shall be handled, stored, and shipped in such a manner to eliminate the dangers of chipping, discoloration, cracks, fractures, and excessive bending stresses. Panels in storage shall be supported in firm blocking to protect panel connection devices and the exposed exterior finish. Storing and shipping shall be in accordance with the manufacturer's recommendations.

(G) Compressive Strength:

Precast concrete elements shall not be shipped or placed in the wall until a compressive strength of 3,400 pounds per square inch has been attained. The facing elements shall be cast on a flat and level area and shall be fully supported until a compressive strength of 1,000 pounds per square inch has been attained.

(H) Precast Concrete Panel Joints:

(1) General:

Where the wall wraps around an inside corner, a corner block panel shall be provided with flange extensions that will allow for differential movement without exposing the panel joints. The back face of vertical and horizontal joints shall be covered with geotextile filter. Joint filler, bearing pads, and geotextile filter shall be as recommended by the wall manufacturer and shall meet the requirements shown on the approved working drawings.

If required, as indicated on the plans, flexible open-cell polyurethane foam strips shall be used for filler for vertical joints between panels, and in horizontal joints where pads are used.

All joints between panels on the back side of the wall shall be covered with a geotextile meeting the requirements for filtration applications as specified by AASHTO M 288. The minimum width shall be foot.

(2) Bearing Pads:

All horizontal and diagonal joints between panels shall include bearing pads. Bearing pads shall meet or exceed the following material requirements:

(a) Preformed EPDM (Ethylene Propylene Diene Monomer) rubber pads conforming to ASTM D2000 Grade 2, Type A, Class A with a Durometer Hardness of 70.

(b) Preformed HDPE (High Density Polyethylene) pads with a minimum density of 0.946 grams per cubic centimeter in accordance with ASTM D1505.

The stiffness (axial and lateral), size, and number of bearing pads shall be determined such that the final joint opening shall be ¾ inches within -1/8 inch unless otherwise shown on the plans. The MSE wall designer shall submit substantiating calculations verifying the stiffness (axial and lateral), size, and number of bearing pads assuming, as a minimum, a vertical loading at a given joint equal to 2.5 times the weight of facing panels directly above that level. As part of the substantiating calculations, the MSE wall designer shall submit results of certified laboratory tests in the form of vertical load-vertical strain and vertical load-lateral strain curves for the specific bearing pads proposed by the MSE wall designer. The vertical load-vertical strain curve shall extend beyond the first yield point of the proposed bearing pad.

929-3.02 Steel Components:

Steel components shall conform to the applicable requirements of Sections 605 and 1003.

(A) Galvanization:

Soil reinforcement steel shall be hot-dip galvanized in accordance with AASHTO M 111 (ASTM A123). Connection hardware steel can be galvanized by hot-dipping or other

means, provided the method satisfies the requirements of AASHTO M 111 (ASTM A123). A minimum galvanization coating of 2.0 oz./ft^2 (605 g/m^2) or 3.4 mils (85 µm) thickness is required. Soil reinforcement steel shall be adequately supported while lifting and placing such that the galvanization remains intact. Steel members with damaged (peeled) galvanization shall be repaired according to ASTM A780 and as specified in approved working drawings, at no additional cost to the Department.

(B) Metallic Reinforcing Strips and Tie Strips:

Reinforcing strips shall be hot-rolled from bars to the required shape and dimensions. The strips' physical and mechanical properties shall conform to the requirements of ASTM A572, Grade 65 minimum.

Tie strips shall be shop fabricated of hot-rolled steel conforming to the requirements of ASTM A1101, Grade 50 minimum. The minimum bending radius of the tie strips shall be ⅜ inch. Galvanization shall be applied after the strips are fabricated, inclusive of punch holes for bolts as shown on approved drawings.

(C) Metallic Reinforcing Mesh:

Reinforcing mesh shall be shop fabricated of cold-drawn steel wire conforming to the requirements of AASHTO M 32, and shall be welded into the finished mesh fabric in accordance with AASHTO M 55. Galvanization shall be applied after the mesh is fabricated. A minimum galvanization coating of 2.0 oz./ft^2 (605 g/m^2) or 3.4 mils (85 µm) thickness is required.

(D) Connector Pins:

Connector pins and mat bars shall be fabricated and connected to the soil reinforcement mats as shown in the approved working drawings. Connector bars shall be fabricated of cold drawn steel wire conforming to the requirements of AASHTO M 32.

(E) Welded Wire Fabric:

All welded wire fabric shall conform to the requirements of AASHTO M 32, AASHTO M 55, and the approved working drawings. Welded wire fabric shall be galvanized in conformance with the requirements of ASTM A123.

(F) Fasteners:

Connection hardware shall conform to the requirements shown in the approved working drawings. Connection hardware shall be cast in the precast concrete panels such that all connectors are in alignment and able to transfer full and even load to the soil reinforcement. Once the reinforcement is connected to the panel, the amount of slack shall not exceed ⅛ inch between the connector and the reinforcement during field installation. Fasteners shall be galvanized and conform to the requirements of AASHTO M 164 or equivalent.

929-3.03 Geosynthetic Reinforcement:

Geosynthetic soil reinforcement shall be limited to geosynthetics manufactured from polypropylene, high density polyethylene, and polyester. Geosynthetic reinforcement shall be evaluated through the NTPEP REGEO (National Transportation Product Evaluation Program – Geosynthetic Reinforcements) for installation damage reduction factor RF_{ID} and creep reduction factor RF_{CR}. The geogrid shall be a regular network of integrally connected polymer tensile elements, with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil. Geogrid structure shall be dimensionally stable and able to retain its geometry under manufacture, transport, and installation. Geosynthetic reinforcements other than geogrids may be utilized if an independent evaluation has been performed through NTPEP REGEO.

The nominal long-term tensile design strength (T-AL) of specific geosynthetic material shall meet or exceed the creep and durability reduction factors required by the wall manufacturer, as well as those required by AASHTO (2017). The wall designer may not select installation damage reduction factor RF_{ID} and creep reduction factor RF_{CR} to be less than the results obtained through the NTPEP REGEO program.

929-3.04 Certificate of Analysis for Soil Reinforcements:

The contractor shall furnish the Engineer with a Certificate of Analysis conforming to the requirements of Subsection 106.05 for all materials.

For geosynthetics, the Certificate of Analysis shall verify that the supplied geosynthetic is the type approved by the Engineer and as measured in full accordance with all test methods and standards specified herein. The manufacturer's certificate shall state that the furnished geosynthetics meet the requirements of the specifications, as evaluated by the NTPEP REGEO program.

For metallic wall reinforcement, a mill test report containing the ultimate tensile strength for the soil reinforcement shall be included in the certification. For metallic wall reinforcement, a mill test report containing the galvanization coverage shall be included in the certification. For metallic mesh wall reinforcement, a mill test report containing the ultimate weld strength for the soil reinforcement shall be included in the certification.

929-3.05 Reinforced and Retained Backfill Material:

(A) General:

Reinforced backfill material shall be free of shale, organic matter, mica, gypsum, smectite, montmorillonite, or other soft poor durability particles. No salvaged material, such as asphaltic concrete millings or Portland Cement Concrete rubble, etc., will be allowed.

Retained backfill material shall be project specific as noted on the MSE wall summary plan sheet developed by the Geotechnical Engineer.

(B) Soundness:

The reinforced backfill material shall have a soundness loss of 30 percent or less when tested in accordance with AASHTO T 104 using a magnesium sulfate solution with test duration of four cycles. Alternatively, the material shall have a soundness loss of 15 percent or less when tested in accordance with AASHTO T 104 using a sodium sulfate solution with test duration of five cycles. Aggregate sources with recent testing data within the past year may submit previous testing results for soundness determination.

(C) Gradation and Fractured Coarse Aggregates:

Gradations will be determined by Arizona Test Method 201 and shall be in accordance with Table 929-3, unless otherwise specified.

Material retained on the #4 and larger sieves must have a minimum of 50 percent particles with two or more mechanically induced crushed faces when tested by Arizona Test Method 212.

Table 929-3
BACKFILL GRADATION REQUIREMENTS

Sieve Size	Percent Passing
1 ½ inch	100
1 inch	95 - 100
½ inch	25 - 60
No. 4	0 - 10
No. 8	0 - 5

(D) Separation Fabric:

A class I needle-punched polypropylene non-woven separation geotextile fabric, meeting the minimum requirements for filtration applications specified in AASHTO M 288 and Subsection 1014-4 shall encapsulate the rock backfill. Adjoining sections of separation fabric shall be overlapped by a minimum of 12 inches.

(E) Limits of Reinforced Backfill:

For all walls, except back-to-back walls, the reinforced backfill shall extend to at least 2 feet beyond the free end of the reinforcement. For back-to-back walls wherein the free ends of the reinforcement of the two walls are spaced apart less than or equal to one-half the design height of the taller wall, reinforced wall fill shall be used for the space between the free ends of the reinforcements as well. The design height of the wall is defined as the difference in elevation between the top of coping and the top of leveling pad. The top of the leveling pad shall always be below the minimum embedment reference line as indicated on the plans for the location under consideration.

929-3.06 Certificate of Analysis for Reinforced Backfill Materials:

At least three weeks prior to construction of the MSE wall, the contractor shall furnish the Engineer with an 80 pound representative sample of the reinforced backfill material, and a Certificate of Analysis conforming to the requirements of Subsection 106.05 certifying that

the reinforced backfill material comply with the requirements specified herein. During construction, the reinforced backfill material shall be sampled and tested by the contractor for acceptance and quality control testing in accordance with the requirements stated in Table 929-4. A new sample and Certificate of Analysis shall be provided any time the reinforced backfill material changes as noted in Table 929-4.

Table 929-4
Sampling Frequency for Reinforced Backfill Material

Test	Frequency
Gradation (Arizona Test Method 201), Plasticity Index (AASHTO T 90) Fractured Coarse Aggregate Particles (ARIZ 212)	One per 500 CY At production facility

929-3.07 Cast-in-Place Concrete:

Cast-in-place concrete shall conform to the requirements of Sections 601 and 1006. Unless otherwise approved, all cast-in-place concrete shall be Class S with a minimum compressive strength of 4,000 pounds per square inch.

929-3.08 Modular Block (Segmental) Facing Units:

This section covers dry cast hollow and solid wet cast concrete masonry structural retaining wall units, machine made from Portland cement, water, and suitable mineral aggregates. The units are intended for use as facing units in the construction of mortarless, modular block walls (MBW) also known as segmental retaining walls (SRW). Metallic or geosynthetic reinforcement specified in Section 929-3.02 and 929-3.03, respectively, may be used as soil reinforcement in the reinforced (structure) backfill zone.

(A) Casting:

Cementitious material in the modular block facing unit shall be Portland cement conforming to the requirements of ASTM C150. If fly ash is used it shall not exceed 20 percent by weight of the total cement content, and shall conform to ASTM C618. Aggregates used in concrete blocks shall conform to ASTM C33 for normal weight concrete aggregate. Efflorescence control agent shall be used in concrete mix design to prevent efflorescence on the block.

The contractor shall advise the Engineer of the starting date for concrete panel casting at least 14 calendar days prior to beginning the operation if the casting operation is within the State of Arizona, or 21 calendar days if the casting operation is outside the State of Arizona.

(B) Physical Requirements:

At the time of delivery to the work site, the modular block facing units shall conform to the following physical requirements:

(1) Minimum required compressive strength of 4,000 psi (average 3 coupons)

(2) Minimum required compressive strength of 3,500 psi (individual coupon)

(3) Minimum oven dry unit weight of 125 pcf

(4) Maximum water absorption of 5 percent after 24 hours

(5) Maximum number of blocks per lot of 2,000. Tests on blocks shall be submitted at the frequency of one set per lot.

Acceptance of the concrete block, with respect to compressive strength, water absorption and unit weight, will be determined on a lot basis. The lot shall be randomly sampled and tested in accordance with ASTM C140. As no additional expense to the Department, the manufacturer shall perform the tests at an ADOT approved laboratory and submit the results to the Engineer for approval. Compressive strength test specimens shall be cored or shall conform to the saw-cut coupon provisions of ASTM C140. Block lots represented by test coupons that do not reach an average compressive strength of 4,000 psi will be rejected.

(C) Freeze-Thaw Durability:

In areas above 3000 feet, where repeated freezing and thawing under saturated conditions occur, the units shall be tested to demonstrate freeze-thaw durability in accordance with Test Method ASTM C1262. Freeze-thaw durability shall be based on tests from five specimens made with the same materials, concrete mix design, manufacturing process, and curing method, conducted not more than 18 months prior to delivery. Specimens used for absorption testing shall not subsequently be used for freeze-thaw testing. Specimens shall comply with either or both of the following acceptance criteria depending on the severity of the project location as determined by the Department:

(1) The weight loss of four out of five specimens at the conclusion of 150 cycles shall not exceed 1 percent of its initial weight when tested in water.

(2) The weight loss of each of four out of the five test specimens at the conclusion of 50 cycles shall not exceed 1.5 percent of its initial mass when tested in a saline (3 percent sodium chloride by weight) solution.

(D) Tolerances for Modular Block Dimensions:

Modular blocks shall be manufactured within the following tolerances:

(1) The length and width of each individual block shall be within ± ⅛ inch of the specified dimension. Hollow units shall have a minimum wall thickness of 1¼ inches.

(2) The height of each individual block shall be within ± 1/16 inch of the specified dimension.

(3) When a broken (split) face finish is required, the dimension of the front face shall be within ± 1.0 inch of the theoretical dimension of the unit.

(E) Finish and Appearance:

Units that indicate imperfect molding, honeycomb or open texture concrete and color variation on front face of block due to excess form oil or other reasons shall be rejected. All units shall be visually efflorescence free. All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or significantly impair the strength or permanence of the construction. Minor cracks (e.g. no greater than 1/50 inch in width and no longer than 25 percent of the unit height) incidental to the usual method of manufacture or minor chipping resulting from shipment and delivery, are not grounds for rejection.

The exposed faces shall be free of chips, cracks or other imperfections when viewed from a distance of 30 feet under diffused lighting. Up to 5 percent of a shipment may contain slight cracks or small chips not larger than 1.0 inch.

Color and finish shall be as shown on the plans and shall be erected with a running bond configuration.

(F) Pins:

If pins are required to align modular block facing units, they shall consist of a non-degrading polymer or hot-dipped galvanized steel and be made for the express use with the modular block units supplied. Connecting pins shall be capable of holding the geogrid in the proper design position during backfilling.

(G) Cap Units and Adhesive:

The cap unit connection to the block unit immediately under it shall be of a positive interlocking type and not frictional. Cap units shall be cast to or attached to the top of modular block facing units in strict accordance with the requirements of the manufacturer of the blocks and the adhesive. The surface of the block units under the cap units shall be clear of all debris and standing water before the approved adhesive is placed. The contractor shall provide the owner in writing an acceptable 10-year warranty that the integrity of the materials used to attach the cap blocks will preclude separation and displacement of the cap blocks for the warranty period.

(H) Unit (Core) Fill:

Unit (core) fill is defined as free draining, coarse grained material that is placed within the empty cores of the modular block facing units. Unit (core) fill shall be a crushed stone or granular fill.

929-3.09 Certificate of Analysis for Modular Block Connection

For modular block facing units, a certification shall be provided with detailed calculations according to AASHTO (2017) and the results of laboratory test results performed in accordance with Section A.3 in Appendix A of FHWA NHI-00-043, dated March 2001 (“Mechanically Stabilized Earth Walls and Reinforced Soil Slopes”). Such certification shall

demonstrate that all connections, including block-to-reinforcement and block-to-block connections, and all related components meet or exceed the current AASHTO 75 year design life requirements and are capable of resisting 100 percent of the maximum tension in the soil reinforcements at any level within the wall. Long-term connection testing for extensible reinforcements is also required. The effect of wall batter and normal pressures representative of the full range of wall configurations and heights shall be incorporated in the tests.

929-4 Construction Requirements:

929-4.01 Excavation:

The contractor shall ensure that temporary slopes are safe during the period of wall construction, and shall adhere to all applicable local, state, and federal regulations. During construction of the MSE walls, the contractor shall design, construct, maintain, and when called for, remove temporary excavation support systems (shoring). Temporary excavation support systems may be left in place if approved by the Engineer. The back slope of the excavation shall be benched. Where shoring is required, the contractor shall submit to the Engineer the shoring design, and a plan outlining construction and removal procedures for review and approval prior to proceeding with the work. Shoring plans shall be prepared and submitted as part of the working drawings, as specified in Subsection 105.03, and shall bear the seal and signature of a licensed Professional Civil or Structural Engineer, registered in the State of Arizona. All shoring design shall include appropriate input and review by the contractor's Professional Engineer.

929-4.02 Foundation Preparation:

(A) General:

In the absence of specific ground improvement requirements in the plans and special provisions, the following applies:

The foundation for the reinforced and retained wall fill shall be graded level for the entire area of the base of such backfills, plus an additional 12 inches on all sides, or to the limits shown in the plans.

If soil reinforcement components are to be positioned on native soil, the top 1 foot of native soil shall meet the requirements of the reinforced backfill material specified in Subsection 929-3.05.

If soil reinforcement components are to be positioned on native rock mass, the rock mass shall be classified as at least Class II rock mass in accordance with Subsection 10.4.6.4 of AASHTO LRFD Bridge Design Specifications, 6th edition (2012).

(B) Proof-Rolling:

Proof-rolling shall be performed to evaluate the stability and uniformity of the subgrades on which retaining wall structures will be constructed. Proof-rolling shall be performed on the entire areas at the following locations and at other locations shown on the project plans:

(1) At the bottom of the overexcavation and recompaction zones if specified;

(2) At the bottom of the overexcavation and replacement zones if specified;

(3) At the base of all retaining walls;

(4) At the base of all concrete box culverts;

(5) At the top of native soil layers that have been scarified, moisture conditioned and recompacted (if different from the bottom of the overexcavation and recompaction or overexcavation and replacement zones).

The proof-rolling shall be done immediately after subgrade compaction while the moisture content of the subgrade soil is near optimum or at the moisture content that achieved the required compaction.

If proof-rolling is performed after installation of pipe underdrains, do not use the proof-roller within 1.5 feet of the underdrains. Proof-rolling shall be performed with a pneumatic tired tandem axle roller with at least 3 wheels on each axle, a gross weight of 25 tons (50 kips) (This weight shall be determined on a project by project bases, depending on the soils and purpose of the proof-rolling), a minimum tire pressure of 75 psi and a minimum rolling width of 75 inches. A Caterpillar PS-300B (or PF-300B), Ingersoll-Rand PT-240R, BOMAG BW24R, Dynapac CP271 or equipment with equivalent capabilities shall be used for proof-rolling. The use of water trucks, scrapers, or other equipment for proof-rolling of the subgrades is not allowed.

Proof-rolling equipment shall be operated at a speed between 1.5 to 3 miles per hour or slower as required by the Engineer to permit measurements of ruts and/or pumping deformations.

Proof-rolling shall be carried out in two directions at right angles to each other with no more than 24 inches between tire tracks of adjacent passes. In cases where proof-rolling perpendicular to the wall alignment is not possible due to space constraints, proof-rolling shall be performed parallel to the wall with minimum 6-inches overlap between the tracks of adjacent passes. The contractor shall operate the proof-roller in a pattern that readily allows for the recording of deformation data and complete coverage of the subgrade.

The following actions shall be taken based on the results of the proof-rolling activity:

If rutting is less than ¼ inch; the grade is acceptable.

If rutting is greater than ¼ inch and less than 1½ inches; the grade needs to be scarified and re-compacted.

If rutting is greater than 1½ inches; the compacted area shall be removed and reconstructed.

If pumping (deformation which rebounds or materials are squeezed out of wheel's path) is greater than 1 inch; remediate as directed by the Engineer.

The contractor is responsible for maintaining the condition of the approved proof-rolled soils throughout the duration of the retaining MSE wall construction. Wall construction shall not commence until the subgrade has been approved by the Engineer.

929-4.03 Concrete Leveling Pad:

Leveling pads shall be constructed of unreinforced concrete as shown on the working drawings. Gravel leveling pads shall not be allowed. As a minimum, the concrete for leveling pads shall meet the requirements of Section 922. The elevation of the top of leveling pad shall be within ⅛ inch from the design elevation when measured by a straightedge over any 10-foot run of the leveling pad.

The minimum width of the leveling pad shall be the width of the facing unit plus 8 inches. The centerline of the leveling pad shall be within ½ inch from design location. When the facing units are centered on the leveling pad, the leveling pad shall extend approximately 4 inches beyond the limits of the facing unit as measured in the direction perpendicular to the face of the wall.

Cast-in-place leveling pads shall be cured for a minimum of 24 hours before placement of wall facing units. A geotextile shall be applied over the back of the area of any openings between the facing units and leveling pad steps. The geotextile shall extend a minimum of 6 inches beyond the edges of the opening. The opening shall be filled with concrete, conforming to Section 1006, or shall be concurrently backfilled on both sides with soil.

929-4.04 Subsurface Drainage:

Prior to wall erection, the contractor shall install a subsurface drainage system as shown on the working drawings.

929-4.05 Wall Erection:

(A) General:

Walls shall be erected in accordance with the manufacturer's written instructions. The contractor shall be responsible for ensuring that a field representative from the manufacturer is available at the site during construction of the initial 10-foot height of the full length of wall, and as called upon thereafter by the Engineer, to assist the contractor and Engineer at no additional cost to the Department. All temporary construction aids (e.g., wedges, clamps, etc.) shall be in accordance with the manufacturer's recommendations.

(B) Placement Tolerances for Walls with Rigid (Precast) Facing:

For walls with rigid facing, such as precast concrete panels, the panels shall be placed such that their final position is vertical or battered as shown on the working drawings. As wall fill material is placed, the panels shall be maintained in the correct vertical alignment by means of temporary wedges, clamps, or bracing as recommended by the manufacturer. A minimum of two, but not more than three, rows of panel wedges shall remain in place at all times during wall erection. Wedges shall be removed from lower rows as panel erection progresses, so as to prevent chipping or cracking of concrete panels. The contractor shall repair any damage to erected concrete panels as directed by the Engineer and to the Engineer's satisfaction. No external wedges in front of the wall shall remain in place when the wall is complete.

Erection of walls with rigid facing shall be in accordance with the following tolerances:

(1) Vertical and horizontal alignment of the wall face shall not vary by more than ¾ inch when measured along a 10 foot straightedge.

(2) The overall vertical tolerance (plumbness) of the finished wall shall not exceed ½ inch per 10 feet of wall height. Negative (outward leaning) batter is not acceptable.

(3) The maximum permissible out-of-plane offset at any panel joint shall not exceed ⅜ inch.

(4) The final horizontal and vertical joint gaps between adjacent facing panel units shall be within -⅛ inch and ±1/4 inch, respectively, of the design final joint opening per the approved calculations required in Subsection 929-3.01(H).

Wall sections not conforming to these tolerances shall be reconstructed at no additional cost to the Department.

(C) Placement Tolerances for Permanent Walls with Flexible Facing:

Erection of permanent walls with flexible facing (such as welded wire mesh) shall be in accordance with the following tolerances:

(1) Vertical and horizontal alignment of the wall face shall not vary by more than 2 inches when measured along a 10-foot straightedge, or as shown in the plans and specifications.

(2) The overall vertical tolerance (plumbness) of the wall shall not exceed 1 inch per 10 feet of wall height. Negative (outward leaning) batter is not acceptable.

(3) The offset limit between consecutive rows of facing shall not exceed 1 inch from planned offset.

Wall sections not conforming to these tolerances shall be reconstructed at no additional cost to the Department.

(D) Placement Tolerances for Modular Block Units:

Erection of walls with Modular Block Units shall be as per the following requirements:

(1) Vertical and horizontal alignment of the wall face shall not vary by more than ¾ of an inch when measured along a 10-foot straightedge.

(2) Overall vertical tolerance (plumbness) of the wall shall not exceed 1¼ inch per 10 feet of wall height from the final wall batter. Negative (outward leaning) batter is not acceptable.

(3) The first row of units shall be level from unit-to-unit and from front-to-back. Use the tail of the units for alignment and measurement.

(4) All units shall be laid snugly together and parallel to the straight or curved line of the wall face.

(5) Unless otherwise noted, all blocks shall be dry-stacked and placed with each block evenly spanning the joint in the row below (running bond). Shimming or grinding shall control the elevations of any two adjacent blocks within 1/16 of an inch.

(6) The top of blocks shall be checked with a straight edge bubble level that is at least 3 feet long. Any high points identified by the straight edge shall be ground flat. Block front to back tilting shall be checked frequently; however correction by shimming shall be done no later than 3 completed courses.

Wall sections not conforming to these tolerances shall be reconstructed at no additional cost to the Department.

(E) Placement of Metallic Reinforcement Elements:

Metallic reinforcement elements shall be placed normal (perpendicular) to the face of the wall, unless otherwise shown on the approved plans. All reinforcement shall be structurally connected to the wall face.

At each level of the soil reinforcement, the reinforced wall fill material shall be roughly leveled and compacted before placing the next layer of reinforcement. The reinforcement shall bear uniformly on the compacted reinforced soil from the connection to the wall to the free end of the reinforcing elements. The reinforcement placement elevation shall be at the connection elevation to 2 inches higher than the connection elevation.

For geosynthetic reinforcement where overlapping of reinforcing may occur, such as at corners, reinforcing connections to panels shall be adjusted to maintain at least 6 inches of vertical separation between overlapping reinforcement.

(F) Placement of Geotextile Fabric:

All joints between precast concrete panels shall be covered with geotextile fabric on the back side of the wall. Adhesive shall be applied to panels only. Adhesive shall not be applied to geotextile fabric or within 2 inches of a joint. The contractor shall provide geotextile fabric having a minimum width of 12 inches, and shall overlap the fabric a minimum of 4 inches. For modular block walls, the placement of the geotextile fabric shall be in accordance with the plans.

(G) Joint Pads and Fillers:

The contractor shall install joint pads and fillers as shown on the working drawings.

(H) Placement of Geosynthetic Reinforcement:

Geosynthetic reinforcement shall be installed in accordance with the manufacturer's site-specific wall erection instructions.

The geosynthetic reinforcement shall be rolled out with the stronger direction perpendicular to the wall face. The reinforcement shall be continuous for their full length. Joints parallel to the wall shall not be permitted, except as shown on the working drawings.

Reinforcement coverage shall be 100 percent of embedment area unless otherwise shown in the working drawings. Adjacent sections of geosynthetic reinforcement need not be overlapped except when exposed in a wrap-around face system, at which time the reinforcement rolls shall be overlapped or mechanically connected per the manufacturer's requirements.

Geosynthetic reinforcement shall be placed to lay flat and pulled tight prior to backfilling. After a layer of geosynthetic reinforcement has been placed, suitable means, such as pins or small piles of soil, shall be used to hold the geosynthetic reinforcement in position until the subsequent soil layer can be placed.

During construction, the surface of the fill shall be kept approximately horizontal. Geosynthetic reinforcement shall be placed directly on the compacted horizontal fill surface. The reinforcement shall bear uniformly on the compacted reinforced soil from the connection to the wall to the free end of the reinforcing elements. The reinforcement placement elevation shall be at the connection elevation to 2 inches higher than the connection elevation.

929-4.06 Reinforced Wall Fill Placement:

(A) General:

Reinforced wall fill placement shall closely follow erection of each course of facing panels. Backfill shall be placed in such a manner to avoid damage or disturbance of the wall materials, misalignment of facing panels, or damage to soil reinforcement or facing

members. The contractor shall place backfill to the level of the connection and in such a manner as to ensure that no voids exist directly beneath reinforcing elements.

For walls with modular block facing units, the backfill shall not be advanced more than the height of a modular block unit until the drainage fill, core fill and all fill in all openings within the blocks at that level have been placed. The filled units shall be swept clean of all debris before installing the next level of units and/or placing the geogrid materials.

For walls with flexible facing with gabion style facing, the rock near the wall face shall be hand-placed in accordance with the recommendations of the wall manufacturer.

The maximum lift thickness before compaction shall not exceed 12 inches.

For geosynthetic reinforcements, the fill shall be spread by moving the machinery parallel to or away from the wall facing and in such a manner that the geogrid remains taut. Construction equipment shall not operate directly on the geogrid. A minimum fill thickness of ~~six~~ 6 inches over the geogrid shall be required prior to operation of vehicles. Sudden braking and sharp turning shall be avoided.

For metallic reinforcements, the fill shall be spread by moving the machinery parallel to or away from the wall facing and in such a manner that the steel reinforcement remains normal to the face of the wall. Construction equipment shall not operate directly on the steel reinforcement. A minimum fill thickness of 3 inches over the steel reinforcement shall be required prior to operation of vehicles. Sudden braking and sharp turning shall be avoided.

Wall materials which are damaged during backfill placement shall be removed and replaced by the contractor, at no additional cost to the Department. The contractor may submit alternative corrective procedures to the Engineer for consideration. Proposed alternative corrective procedures shall have the concurrence of the MSE wall supplier and designer, in writing, prior to submission to the Engineer for consideration. All corrective actions shall be at no additional cost to the Department.

(B) Compaction:

Reinforced wall fill compaction requires a minimum of 2 roller passes of a vibratory roller having a minimum dynamic force of 6,000 pounds impact per vibration, and a minimum frequency of 1,000 vibrations per minute.

The vibratory roller shall be operated at speeds less than 3 feet per second.

Backfill within 3 feet of the wall face shall be compacted utilizing a hand operated vibratory plate.

Retained backfill shall be compacted and tested per section 203-10.03 (Embankment Construction Requirements) which require 100 percent of the maximum density for an additional 50 feet beyond the limits of approach slabs.

(C) Protection of the Work:

The contractor shall not allow surface runoff from adjacent areas to enter the wall construction site at any time during construction operations. In addition, at the end of each day's operation, the contractor shall slope the last lift of backfill away from the wall facing so that runoff is directed away from the structure. If the subgrade is damaged due to water or otherwise, such that it does not meet the requirements of Subsection 929-4.02, then as directed by the Engineer, the contractor shall rework and repair the damaged subgrade at no additional expense to the Department. The criteria in Subsection 929-4.02 shall be used to judge the adequacy of the repair. Rework and repair shall extend to a depth where undamaged work is encountered.

929-5 Method of Measurement:

Mechanically Stabilized Earth (MSE) retaining walls will be measured by the square foot of completed wall, based on the vertical height and length of the retaining wall shown on the plans. The vertical height will be taken as the difference in elevation measured from the top of wall to the minimum embedment reference line as indicated on the plans.

The entire surface of retaining walls shown on the plans, including all wall terminations and cast-in-place coping, will be measured as MSE retaining wall.

929-6 Basis of Payment:

The accepted quantities of Mechanically Stabilized Earth (MSE) retaining walls, measured as provided above, will be paid for at the contract unit price per square foot of wall, complete in place. Such price shall include full compensation for furnishing all designs, design revisions, associated working drawings, engineering calculations, labor, materials, tools, equipment, and incidentals. Such price shall also include provision of manufacturer's field representative, and all work involved in constructing the MSE retaining walls, including foundation preparation, proof-rolling, footings, drainage features, wall facing, slip joints, concrete or shotcrete caps and aprons, rustication, paint or stain, grout, tendons, cables, anchors, fabric, and all hardware and reinforcing steel, complete in place as shown on the plans and as specified herein.

No separate measurement or payment will be made for excavation, reinforced backfill, and retained backfill associated with MSE retaining walls, the cost of such work being considered as included in the price paid for the MSE retaining wall.

No separate measurement or payment will be made for the design, construction, or removal of temporary excavation support systems (shoring), or associated geotechnical review, the cost of such work being considered as included in the price paid for the MSE retaining wall.