ES REPORT™

ER-5435

Reissued May 1, 2002

ICBO Evaluation Service, Inc. • 5360 Workman Mill Road, Whittier, California 90601 • www.icboes.org

Filing Category: DESIGN—Masonry

MESA RETAINING BLOCK WALL SYSTEM

TENSAR EARTH TECHNOLOGIES, INC.
5883 B GLENRIDGE DRIVE, SUITE 200
ATLANTA, GEORGIA 30328

1.0 SUBJECT

Mesa Retaining Block Wall System.

2.0 DESCRIPTION

2.1 General:

The Mesa Retaining Block Wall System uses modular concrete units for the construction of conventional and reinforced-soil retaining walls. The wall system is assembled in running bond without mortar or grout, using Mesa connectors to provide a structural, end-bearing, block-to-geogrid connection and shear connection, and to provide alignment of the units. For reinforced-soil retaining walls, the system includes horizontal layers of Tensar geogrid reinforcement in the backfill soil mass.

2.2 Components:

2.2.1 Mesa Units: Mesa concrete units are available in a variety of shapes and sizes. Various types include the High Performance Unit, the Landscape Unit, the Standard Unit, the XL Unit, the 2000 Unit, the SierraStone Plantable Unit and the Cap Unit. The units are produced with either a smooth face, or a straight split face and/or a radius split face. The SierraStone plantable units are produced with open bottoms. The units are summarized in Table 1 and Figures 1 through 7.

All units must comply as Grade N, Type II, in accordance with ASTM C 90-99, with a minimum 28-day compressive strength of 4,000 psi (27.56 MPa) on the net area and a maximum water absorption by weight of 8 percent. A certificate based on tests conducted by an independent testing agency, verifying the block compressive strength, must be submitted to and approved by the local building official prior to commencing construction. Block tolerances must comply with Section 7 of ASTM C 90-99.

2.2.2 Connectors: The Mesa Connectors are made with fiberglass-reinforced, high-density polyethylene (HDPE). The types include the Standard and High Performance connectors. The connectors are used on each block course to provide a structural, end-bearing, block-to-geogrid connection and shear connection, and to provide alignment of the units. The angle of wall inclination is determined by the direction of the “flags” on the connector. If a nearly vertical wall is desired, the flags on the connector shall face forward, toward the front of the unit. With the flags facing toward the rear of the unit, each course will automatically set back $^{5}/_{8}$ inch (15.88 mm) per course, for a 4.8-degree batter. The SierraStone units can be installed at batters, measured from the horizontal plane, of either 90 degrees or 85 degrees, by placing the Standard connector in the slot of a lower unit with the connector flags facing toward or away from the face of the wall, respectively. The upper unit is then installed such that the inside of the rear wall sits against and behind the connector. See Figure 6. A typical wall is shown in Figure 10.

2.2.3 Geogrid: Mesa geogrid reinforcement materials were developed and tested for use with the Mesa Retaining Block Wall System. The UX Mesa Series HDPE geogrids are manufactured by Tensar Earth Technologies, Inc. (TET). A summary of properties is presented in Table 2.

Geogrids must be stored at temperatures higher than –10°F (–20°C). Contact with mud or wet cement, or epoxy or any other adhesive materials, shall be avoided.

2.3 Design:

2.3.1 General: The design of the system depends on the weight and geometry of the soil mass and Mesa Units to resist lateral earth pressures and other lateral pressures. Lateral earth pressures are determined following either Coulomb or Rankine earth-pressure theory. The design must include evaluation of both external and internal stability of the structure and include consideration of external loads such as surcharges and seismic forces. Global stability must also be evaluated. External stability analysis is similar to that required for conventional retaining walls. Minimum safety factors are as follows:

Sliding: 1.5

Overturning: 2.0

Bearing Capacity: 2.0

Internal stability analysis of reinforced-soil retaining wall systems must consider the maximum allowable reinforcement tension, pullout resistance of the reinforcement behind the active failure plane, internal sliding and the connection strength of the geogrid to the Mesa unit. Table 2 shows the long-term design strength (LTDS) and the long-term allowable design strength (T_a) for Mesa geogrids. The allowable design strengths, T_a, in the table have been reduced by a safety factor of 1.5. Additional safety factors have been incorporated into the table to include creep reduction, installation damage for sand-silt and clay, and chemical and biological damage. Soil interaction and direct sliding coefficients are described in Table 3.

Under the 1997 *Uniform Building Code*™ (UBC), structural walls over 4 feet (1219 mm) in height and installed in Seismic Zone 3 or 4 shall be designed for seismic loads. A pseudostatic design procedure shall be utilized for internal and external analysis. Under the 2000 *International Building Code*® (IBC), retaining walls must be designed for seismic forces in accordance with IBC Section 1622.4.2.

A foundation investigation in accordance with UBC Section 1804 or IBC Section 1802 is required for each site, except for conventional wall applications. The foundation investigation must determine the soil properties and recommended values for design. The design of the Mesa Retaining Wall must be based on accepted geotechnical principles for conventional and soil-reinforced retaining wall systems. Design is based on the "Design Manual for Segmental Retaining Walls, First Edition," published by the National Concrete Masonry Association (NCMA), dated 1993, or the American Association of State Highway Transportation Officials (AASHTO) Standard Specification for Highway Bridges, dated 1997. Specifics of design are found in Tensar Technical Note TTN: RW1.1m.

Mesa Retaining Block Wall Systems are designed as follows:

2.3.1.1 Conventional Retaining Walls: A conventional wall system relies on the weight and geometry of the Mesa units to resist lateral earth pressures. Conventional wall design is based on standard engineering principles for modular concrete retaining walls. Maximum design heights are typically 2.5 to 3 times the depth of the Mesa unit being used. A typical wall is shown in Figure 8.

2.3.1.2 Reinforced-soil Retaining Walls: A reinforced-soil retaining wall system relies on the weight and geometry of the reinforced-soil mass to act as a coherent gravity mass to resist the lateral earth pressures. The design of a reinforced-soil structure is based on the Mesa unit selected, the soil properties, and geometry. A typical wall is shown in Figure 9.

2.3.2 Structural Analysis: For each wall system installed, structural calculations must be sealed by a registered professional engineer and shall be submitted to and approved by the building official. Details in this evaluation report are limited to application in areas outside groundwater. Footings in groundwater are contingent on appropriate soil and engineering analysis reports being submitted to the building official for approval. The structural analysis must be based on accepted engineering principles, UBC or IBC Section 2107, as applicable, and the "Design Manual for Segmental Retaining Walls, First Edition," except as otherwise specified in this report. All contact surfaces of the units must be maintained in compression. The maximum compression stress under working stress design is 100 psi (689 kPa). A net resultant tension force is not permitted in any portion of the retaining wall. The shear resistance between units is provided by connectors in each course, and is determined by the following equations:

Standard Connector: $V_u = 13.1666 + 1.855\ W_w$

For **SI:** $V_u = 192.15 + 1.855\ W_w$

HP Connector: $V_u = 1{,}223 + 1.913\ W_w$

For **SI:** $V_u = 17\,848 + 1.913\ W_w$

where:

V_u = Shear resistance, lb./ft. (N/m).

W_w = Weight of wall above interface, lb./ft. (N/m).

2.3.2.1 External Stability Analysis:

1. The minimum length of the reinforced mass shall be 0.6 times the height of the wall (as measured from the top of the leveling pad to the top of the wall), or as required to satisfy a safety factor of 1.5 for sliding at the base of the wall, whichever is greater.
2. The minimum safety factor for overturning the reinforced mass shall be 2.0.
3. Global stability analysis must be provided for walls with slopes below the toe of the wall, walls on soft foundations, walls with submerged conditions and tiered walls.
4. Sliding along the base of the reinforced soil mass must be checked, including shearing, through the connection at the face of the wall.
5. Shear failure or excessive deformation of the foundation due to loads exceeding the bearing capacity must be checked.

2.3.2.2 Internal Stability Analysis:

1. Geogrid spacing is based on local stability of the Mesa units during construction. A safety factor of 2.0 must be used for cantilevered units supported by the soil forces alone. Vertical spacing between reinforcement layers is typically 3 units or $2^1/_2$ times the depth of the unit, whichever is less.
2. Tension calculations for each layer of reinforcement must be provided. Tension is based on the earth pressure and surcharge calculated from halfway to the layer below to halfway to the layer above. Calculated tensions for the geogrids listed in Table 2 shall not exceed the long-term allowable design strength, T_a, for each respective layer.
3. The connection capacities of each geogrid-to-Mesa unit are set forth in Table 4. The tabulated capacity must be equal to or greater than the calculated tension of each layer.
4. A calculation check must be made on the pullout of the upper layers of reinforcement from the soil zone beyond the failure plane. The soil interaction coefficients are presented in Table 3.

2.4 Installation:

1. The site shall be excavated for the leveling pad and reinforced soil zone.
2. A 6-inch-deep (152 mm) leveling pad, extending 6 inches (152 mm) beyond the front and rear of the base course, is placed. For the XL units, a 6-inch-deep-by-34-inch-wide (152 mm by 864 mm) leveling pad is placed. The leveling pad must consist of 2,500 psi (17.3 MPa) concrete or crushed stone, compacted to 75 percent relative density as determined by ASTM D 4564.
3. The first course of Mesa units is installed. The units must be leveled from side to side, and from front to back.
4. Drainage fill behind the Mesa units is a design option, and a geosynthetic fabric may be used in lieu of drainage fill. Drainage fill is a design option. When specified, drainage fill is $^1/_2$ inch (12.7 mm) to $^3/_4$ inch (19.1 mm) nominal size, clean, crushed stone material that is placed between and behind the units. The drainage fill provides a filter to restrain the backfill soils from filtering out through the vertical joints in the face of the wall. A geosynthetic fabric, placed vertically behind the wall, may be used in lieu of the drainage fill. Typically, unit fill is not placed within the core of each individual Mesa unit.
5. The Mesa connectors are installed as specified to ensure proper batter selection.
6. The tops of the units are cleaned to remove any loose materials.
7. Additional courses of units are dry-stacked, using the structural Mesa connectors for alignment on each course.

8. At the appropriate levels, Mesa geogrid reinforcement is installed, connecting the geogrids to the units with Mesa connectors. The roll direction is the direction of the primary design strength of the reinforcement. Adjacent sections of geogrids are placed side by side; no overlap is required.
9. To remove slack, prior to the placement of the backfill the geogrid is pulled taut in the direction perpendicular to the face of the wall.
10. Backfill is placed and compacted over the Mesa geogrid layer.
11. Backfill used in the reinforced fill mass must consist of suitable fine-grained or coarse-grained soils placed in lifts, compacted to at least 95 percent as determined by the standard effort test, ASTM D 698, or to 90 percent of the maximum dry density, as determined by the modified effort test, ASTM D 1557. The backfill soil properties, lift thickness, and degree of compaction must be determined by the engineer of record. If the reinforced soil has poor drainage properties, a granular drainage layer or synthetic drainage composite shall be installed to prevent buildup of hydrostatic pressures behind the reinforced soil mass. Provisions for adequate subsurface drainage must be determined by the engineer.
12. Placement of units, connectors, drainage fill, reinforced fill and geogrids is repeated as shown on the permit plans, to the finish grade.
13. To finish the wall, the Mesa Caps are attached to the Mesa units, using a Tensar-approved exterior concrete adhesive.

2.5 Special Inspection:

Special inspection in accordance with UBC Sections 1701.5.7.1 and 1701.5.13 or IBC Sections 1704.5 and 1704.7 is required to:

1. Monitor installation of foundations, and retained and reinforced fill soils.
2. Observe uncompacted lift thickness and compaction procedures.
3. Verify the proper Mesa geogrid type, placement with respect to the elevation, orientation and connector placement.
4. Observe the proper tensioning of geogrids to remove any slack.
5. Verify fill placement procedures over geogrids.
6. Check for the type of Mesa units used and proper placement and elevation of the Mesa units.
7. Verify unit compliance with ASTM C 90-99, including compressive strength and water absorption as described in Section 2.2 of this report.

2.6 Identification:

Each roll of Mesa geogrid must be labeled to identify the TET name and address; the evaluation report number (ICBO ES ER-5435); the name of the product; and the product designation. A letter of certification for the Mesa connectors must be furnished by TET.

3.0 EVIDENCE SUBMITTED

Reports of tests on geogrid strength, geogrid durability, geogrid-soil interaction, geogrid pull-out, and unit shear; engineering calculations; and installation instructions.

4.0 FINDINGS

That the Mesa Retaining Block Wall System described in this report complies with the 1997 *Uniform Building Code*™ (UBC) and the 2000 *International Building Code*® (IBC), subject to the following conditions:

4.1 The system is designed and installed in accordance with this report, the Tensar Technical Note, the AASHTO 1997 interim guidelines, or the NCMA design manual.

4.2 Copies of the Tensar Technical Note, NCMA, and AASHTO documents are submitted to the building official.

4.3 At the discretion of the building official, engineering design may be required for Mesa conventional walls 4 feet (1219 mm) or less in height. Reinforced-soil Mesa retaining walls more than 4 feet (1219 mm) in height must be designed by a registered professional engineer and designs must be submitted to and approved by the building official.

4.4 The Mesa concrete units are produced by a Mesa licensee or by a certified manufacturer approved by Tensar Earth Technologies, Inc. Mesa units must comply with this report and ASTM C 90-99.

4.5 A foundation investigation in accordance with UBC Section 1804 or IBC Section 1802 must be provided for each project site. Lateral loads shall be determined using accepted geotechnical engineering principles appropriate for the soil and geometric conditions specific to the wall, and must address the applicability of the Mesa Retaining Block Wall System to seismically active areas. Under the UBC, compliance with UBC Section 1610.2 is also required.

4.6 Special inspection is provided in accordance with Section 2.5 of this report.

This report is subject to re-examination in one year.

TABLE 1—MASONRY UNIT DESCRIPTION

BLOCK TYPE	DIMENSIONS	WEIGHT (pounds)
Mesa Standard	8 inches by 18 inches by 11 inches	75
Mesa High Performance	8 inches by 18 inches by 11 inches	85
Mesa XL	8 inches by 18 inches by 22 inches	105
Mesa 2000	8 inches by 18 inches by 12 inches	85
SierraStone	8 inches by 18 inches by 18 inches	110
Mesa Landscape	4 inches by 18 inches by 11 inches	40
Mesa Cap	4 inches by 18 inches by 11 inches	35

For **SI:** 1 inch = 25.4 mm, 1 pound = 0.0454 kg.

TABLE 2—GEOGRID DESCRIPTION

GEOGRID TYPE	APERTURE LENGTH (inches)	THICKNESS (inch)		LONG-TERM DESIGN STRENGTH (LTDS)[1] (lbs./ft.)	LONG-TERM ALLOWABLE DESIGN STRENGTH, T_a[2] (lbs./ft.)
		Rib	Junction		
UXMESA 1	6.5	0.020	0.075	625	417
UXMESA 2	13.5	0.029	0.085	784	522
UXMESA 3	14.5	0.052	0.155	1,390	927
UXMESA 4	14.5	0.066	0.20	2,317	1,544
UXMESA 5	14	0.089	0.27	2,988	1,922
UXMESA 6	14	0.104	0.32	3,799	2,533

For **SI:** 1 inch = 25.4 mm, 1 plf = 14.59 N/m.
[1]LTDS established for maximum $1^{1}/_{2}$-inch-size aggregate.
[2]Safety factor is 1.5.

TABLE 3—MESA GEOGRIDS SOIL-INTERACTION COEFFICIENT

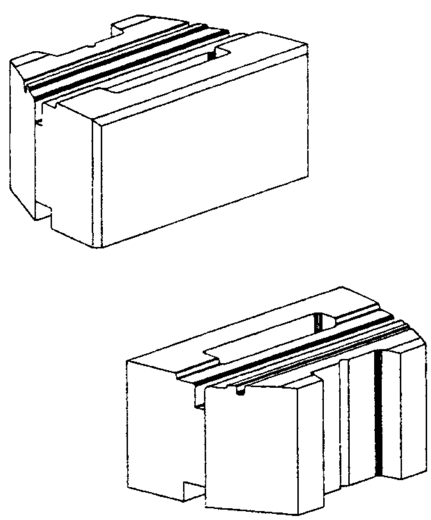
SOIL CLASS[1]	COEFFICIENT
GW and GM	0.80
SW and SM	0.75
SC and ML	0.58

[1]Classifications are described in Table 18-1-A of UBC Standard 18-1.

TABLE 4—GEOGRID TO MESA UNIT CONNECTION STRENGTH (lbf/ft.)

GEOGRID	STANDARD UNIT[1]	HP UNIT[2]
UXMESA 1	575	1,320
UXMESA 2	595	1,475
UXMESA 3	920	2,320
UXMESA 4	1,495	3,495
UXMESA 5	2,005	4,815
UXMESA 6	2,665	5,365

For **SI:** 1 plf = 14.59 N/m.
[1]Standard units include Mesa Standard, Landscape, XL, 2000 and SierraStone Plantable.
[2]High Performance Unit.

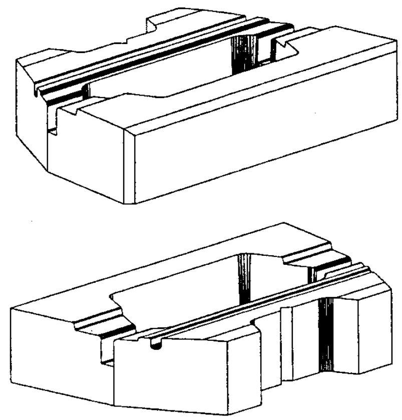


HEIGHT	8 inches
WIDTH	18 inches
DEPTH	11 inches
*WEIGHT	85 pounds
FACE AREA	1.0 square foot

*WEIGHT MAY VARY BY MANUFACTURER

For **SI:** 1 inch = 25.4 mm, 1 pound = 0.0454 kg, 1 ft.^{2} = 0.093 m^2.

FIGURE 1—MESA HIGH PERFORMANCE UNIT

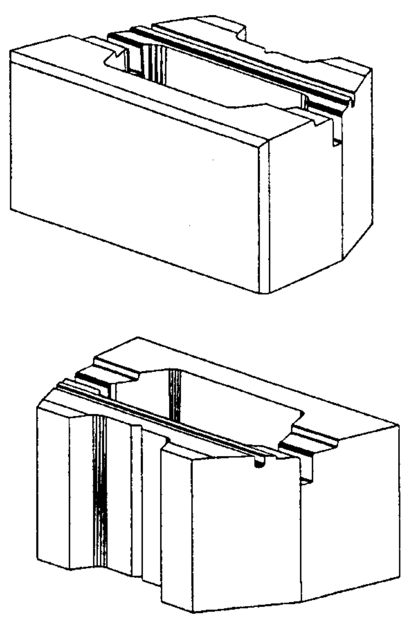


HEIGHT	4 inches
WIDTH	18 inches
DEPTH	11 inches
*WEIGHT	40 pounds
FACE AREA	0.5 square foot

*WEIGHT MAY VARY BY MANUFACTURER

For **SI:** 1 inch = 25.4 mm, 1 pound = 0.0454 kg, 1 $ft.^2$ = 0.093 m^2.

FIGURE 2—MESA LANDSCAPE UNIT

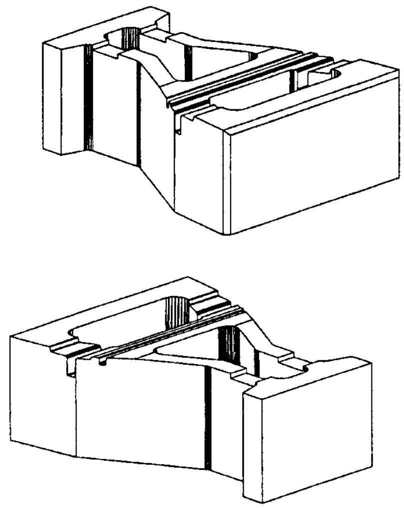


HEIGHT	8 inches
WIDTH	18 inches
DEPTH	11 inches
*WEIGHT	75 pounds
FACE AREA	1.0 square foot

*WEIGHT MAY VARY BY MANUFACTURER

For **SI:** 1 inch = 25.4 mm, 1 pound = 0.0454 kg, 1 $ft.^2$ = 0.093 m^2.

FIGURE 3—MESA STANDARD UNIT

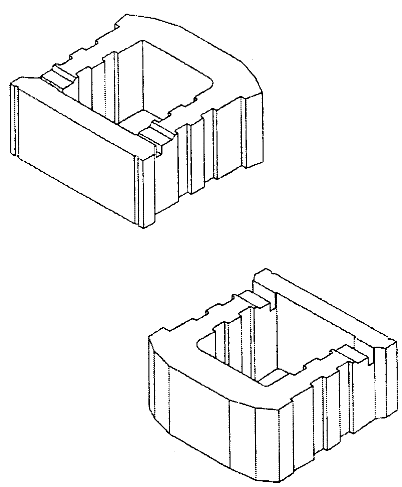


HEIGHT	8 inches
WIDTH	18 inches
DEPTH	22 inches
*WEIGHT	110 pounds
FACE AREA	1.0 square foot

*WEIGHT MAY VARY BY MANUFACTURER

For **SI:** 1 inch = 25.4 mm, 1 pound = 0.0454 kg, 1 ft.^{2} = 0.093 m^2.

FIGURE 4—MESA XL UNIT

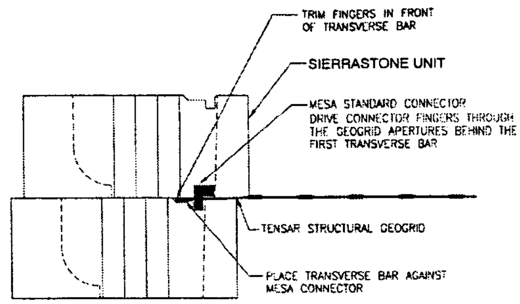


HEIGHT	8 inches
WIDTH	18 inches
DEPTH	18 inches
*WEIGHT	110 pounds
FACE AREA	1.0 square foot

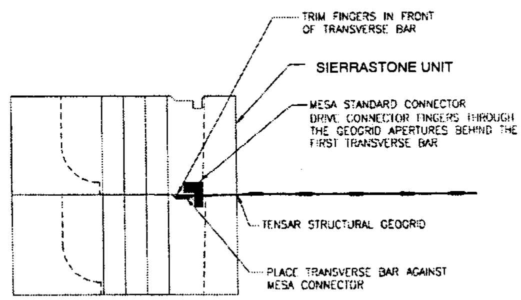
*WEIGHT MAY VARY BY MANUFACTURER

For **SI:** 1 inch = 25.4 mm, 1 pound = 0.0454 kg, 1 ft.^{2} = 0.093 m^2.

FIGURE 5—MESA SIERRASTONE PLANTABLE UNIT

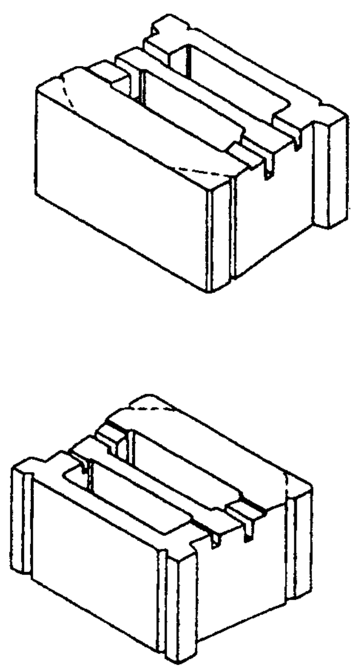


(85 DEGREE BATTER)



[90 DEGREE (VERTICAL) BATTER]

FIGURE 6—SIERRASTONE UNIT AND GEOGRID CONNECTION DETAIL

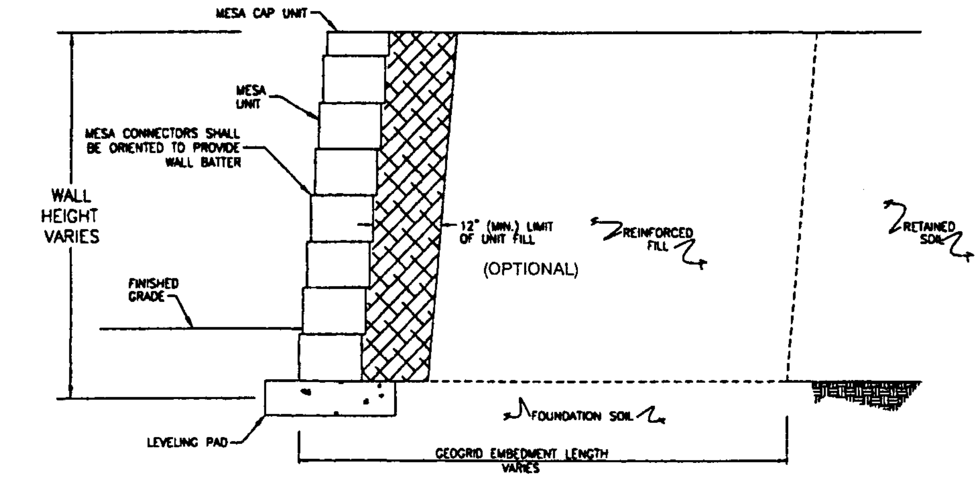


HEIGHT	8 inches
WIDTH	18 inches
DEPTH	12 inches
*WEIGHT	85 pounds
FACE AREA	1.0 square foot

*WEIGHT MAY VARY BY MANUFACTURER

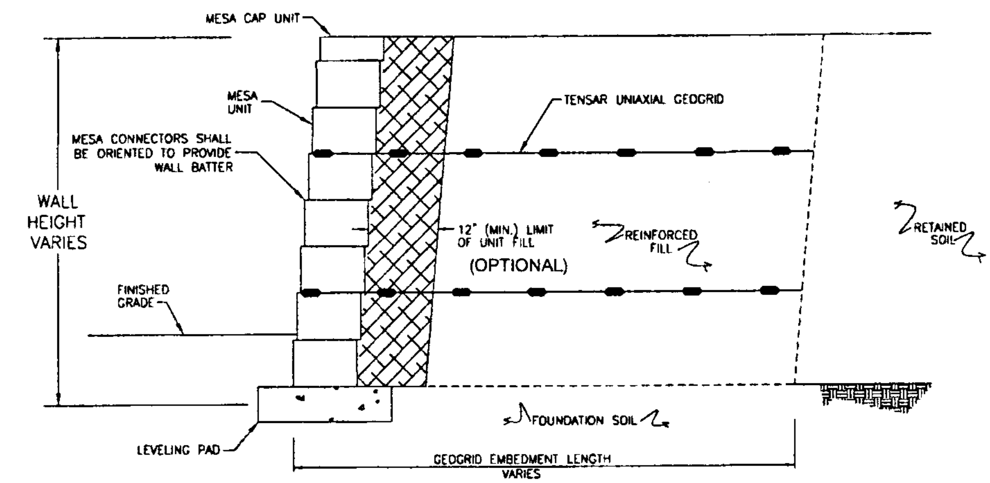
For **SI:** 1 inch = 25.4 mm, 1 pound = 0.0454 kg, 1 ft.^{2} = 0.093 m^2.

FIGURE 7—STANDARD MESA 2000 UNIT



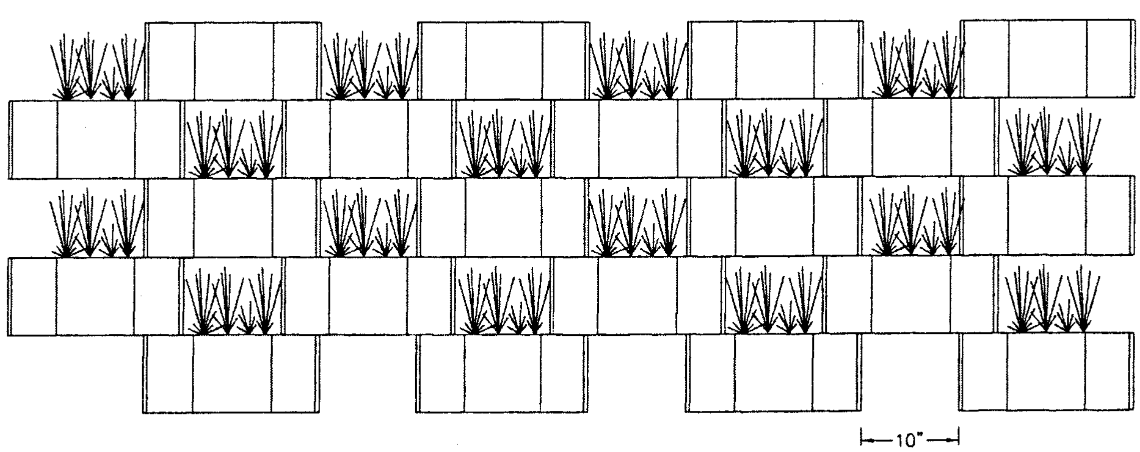
For **SI:** 1 inch = 25.4 mm.

FIGURE 8—MESA CONVENTIONAL RETAINING WALL (TYPICAL)



For **SI:** 1inch = 25.4 mm.

FIGURE 9—MESA REINFORCED-SOIL RETAINING WALL (TYPICAL)



For **SI:** 1 inch = 25.4 mm.

FIGURE 10—MESA SIERRASTONE REINFORCED-SOIL RETAINING-WALL GYPSUM (TYPICAL)
FRONT FACE ELEVATION VIEW