EVALUATION REPORT ER-5448 Issued February 1, 2002
ICBO Evaluation Service, Inc. – 5360 Workman Mill Road, Whittier, California 90601

Terraforce L18 Block Retaining Wall System

Terraforce (PTY) LTD.
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1.0 SUBJECT

Terraforce L18 Block Retaining Wall System.

2.0 DESCRIPTION

2.1 General:

The Terraforce L18 Block Retaining Wall System utilizes segmental concrete blocks filled with soil infill to construct conventional gravity and soil-reinforced retaining walls. Construction of reinforced soil-retaining walls is achieved with the combination of the block units, geosynthetic reinforcement and compacted soil. The wall system is assembled in a running bond without mortar our grout, and with horizontal layers of geosynthetic reinforcement in the backfilled soil mass. Figures 4 and 5 show typical Terraforce conventional gravity and reinforced soil-retaining walls, respectively.

2.2 Materials:

2.2.1Terraforce Blocks: A standard L18 block weighs approximately 45 pounds (20kg) without infill soil, and is reversible. The unit is nominally 11 inches (nominal 280 mm) wide, 13.75 inches (nominal 350 mm) long, and 8 inches (nominal 200 mm) high. See figure 1 for dimensions. Block units must comply with ASTM C 90-99, with a minimum 28-day compressive strength of 3,000 psi (20 Mpa) on the net area and a maximum water absorbtion of 7 percent. Evidence of compliance with ASTM C 90-99 must be furnished to the local building official for approval prior to construction. Block tolerances must comply with Section 7 Of ASTM C 90-99.

2.2.2 **Wall Shear Keys (Optional)P**: Wall shear keys of 2,200 psi (15 Mpa) concrete or Class 1 mortar, shown in Figure 2, provide positive vertical interlock in addition to that provided when blocks are filled with soil. Horizontal interlock in the wall plane is achieved through ball-and-socket effect of the uniquely shaped Terraforce units.

2.2.3 **Geogrids:** Miragrid geogrid grades 2Xt and 5Xt, manufactured by Mirafi, Inc., are compatible with the Terraforce L18 blocks for soil-reinforced retaining-wall construction. The goegrids consist of polyester yarns with an acrylic latex coating, formed into a grid shape. Geogrids are to be stored at temperatures not lower than –10ºF (-23ºC); must not be subjected to prolonged exposure to sunlight, to prevent UV degradation; and must avoid contact with mud, wet cement, epoxy and other adhesive materials. Applicable design properties are shown in Tables 1A and 1B. The geogrid connection capacities to the block units are shown in Table 2.

2.3 Design:

The system is designed as a conventional gravity or soil-reinforced retaining wall system, which depends upon its weight and geometry to resist lateral earth pressures and other lateral forces. Lateral earth pressures must be determined using the Coulomb theory. The design must include evaluation of both external and internal stability, along with consideration of external loads generated by surcharges and seismic activity. While external stability analyses are to be similar to those required for conventional gravity retaining walls, internal stability analyses of reinforced walls must consider allowable reinforcement tension pullout resistance behind the active failure zone, and the reinforcement connection strength at the facings. Also, the assessment of the global stability must be evaluated. Minimum safety factors are shown in the following table:

Sliding	1.5
Overturning	2.0
Bearing Capacity	2.0

Required seismic safety factors are 75 percent of the minimum allowable static safety factors.

A foundation investigation in accordance with Section 1804 of the 1997 *Uniform Building Code*™ (UBC) or Section 1802 of the 2000 *International Building Code*® (IBC) is required for each site. The investigation determines the soil properties and the values for design. The design method is primarily based on accepted engineering principles and judgement. Design details are in the Terraforce Design and Installation Manuals (1992) and (1995); the National Concrete Masonry Association (NCMA) Design Manual for Segmental Retaining Walls (First Edition, 1993, and Second Edition, 1997); ASSHTO Standard Specifications for Highway Bridges (1996); and Federal Highway Administration Demonstration Project 82 Reinforced Soil Structures MSEW and RSS (1996).

2.4 Installation:

The angles of wall inclination or fascia setback angles range from 5 to 35 degrees from the vertical, toward the backfill. Maximum heights for conventional gravity retaining walls are shown in Table 3. Maximum height for soil-reinforced retaining walls is 19.6 feet (6.0 m). Depending on design, block foundation subgrade is either leveled, compacted roadbase material, or plain concrete complying with UBC Section 1922.7 or IBC Section 1805.4.2, or reinforced concrete complying with Section 1915 of the UBC or IBC Sections 1805.4.1 and 1805.4.2. Roadbase material must be at least 6 inches (152 mm) of granular fill compacted to at least 95 percent of the soil's maximum dry density as determined by ASTM D 698. Specific foundation requirement for each site must be determined by the soils engineer.

Details in this report are limited to areas beyond groundwater. Footings submerged in groundwater are contingent on appropriate soil and engineering analysis reports being submitted to the building official for approval. Backfill used in the reinforced soil mass must consist of approved material placed in compacted lifts. The backfill soil properties, lift thickness, degree of compaction and width behind the block are as determined by the soil engineer. Granular drainage layers and /or perforated drains must be installed behind the block units to prevent buildup of hydrostatic pressure behind the wall. Provisions for drainage must by determined by the soils engineer.

Blocks are aligned using builder's line and level. Each course must be set back from the underlaying course a constant, specified, distance as determined from the setback chart. All units must be filled with approximately ¾ inch (19mm) size, maximum, crushed and light compacted aggregates, or infill materials recommended by the block manufacturer, Shear keys must be placed at locations specified by design. Blocks may be assembled with concave or convex horizontal curve layout having a minimum radius of 1.6 feet (500mm).

When used, geosynthetic reinforcement is placed at the elevations specified by design. The backfill surface must be placed and compacted to a level approximately ¾ inch(19mm) below the top block-elevation to which geogrid placement is required .The geogrid is fully embedded between courses of the block units, and is pulled until taut. After unrolling, the geogrid is hand-pulled until taut, flat and free of wrinkles and anchored to the compacted backfill prior to backfilling over the grid. Adjacent geogrid rolls are butted together side-by-side without overlap, and splices must be avoided. The roll (machine) direction is in the direction of the principal reinforcement.

2.5 Structural Analysis

Structural calculations must be submitted to the building official for each wall system prior to construction. Structural analysis is based on accepted engineering principles, the Terraforce design guidelines and the NCMA Design Manual for Segmental Walls (Fist Edition 1993). All contact surfaces of the units must be maintained in compression. The compression stress is limited to a maximum of 100 psi (690kPa). A net resultant tension force is prohibited throughout the retaining wall. The shear resistance generated between units filled with maximum ¾ inch (19mm) crushed aggregates (with or without shear keys) is determined by the following equation:

$$V_{ur} = 59 + + W_w \tan 27^\circ \leq 822$$

For **SI:** $861 + W_w \tan 27^\circ \leq 11{,}995$

where:

V_{ur} = Sear resistance, lb/ft (N/m).
W_w = Weight of wall above interface, pound/foot (N/m)

2.6 Special Inspection:

Special inspection during installation must be performed in accordance with UBC Section 1701.5.7.1 or IBC Sections1704.1.1 and 1704.1.2 . The inspector's responsibilities include verifying:

1. Unit dimensions.
2. Unit compliance wit UBC Standard 21-4, including compressive strenght and water absorption as described in Section2.2.1 of this report.
3. Foundation preparation.
4. Unit placement , including alignment and inclination.
5. Geosynthetic reinforcement verification and placement with respect to elevation and orientation.
6. Backfill placement and compaction.

2.7. **Identification:**

The manufacturer's name (Terraforce), the product name and the evaluation report number (ICBO ES ER-5448) are noted on a label affixed to each shipping pallet of the blocks units. Each roll of the Miragrid geogrids must be labeled with the manufacturer's name (Mirafi.Inc.) and the address ,and the product design.

3.0 Evidence Submitted

Design manuals, calculations and test reports.

4.0 Findings

That the Terraforce L18 Block Retaining Wall System described in this report complies with 1995 *Uniform Building Code*™ 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 Terraforce design and Installation Manual (1992) and (1995) the manufacturer's instructions; and accepted engineering principles.

4.2 All units comply with this report and ASTM C90 - 99 as Grade N, Type I.

4.3 Special inspection is provided in accordance with Section2.6 of this report.

4.4 The wall design procedures and manuals are submitted to the building official for approval.

4.5 A foundation investigation in accordance with UBC Section 1804 or IBC Section 1802 is provided for each project site. Under the UBC, compliance with Section 1610.2 is also required.

4.6 Details in this report are limited to areas outside groundwater. For applications where free-flowing groundwater is encountered, or where wall systems are submerged, the installation and design of such systems shall comply with the appropriate sections of the Terraforce design manuals and the NCMA Design Manual for Segmental Retaining Walls (First Edition1993), and the recommendations Of the soils engineer. Copies of these documents shall be submitted to building official upon request.

4.7 Construction of the retaining walls is limited to Seismic Zones 0.1 and 2A under the UBC.

4.8 Retaining walls under the IBC shall be designed for seismic forces in accordance with Section 1622.4.2.

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

TABLE 1A – Miragrid properties

Grade	Roll Dimension (width x length) feet	WEIGHT oz / yd²	Long-Term Allowable Tension Load –Machine Direction[1] (pound/foot)
2XT	6.5 X200	5.0	839
5XT	10.83 X 150	6.0	1,733

For **SI** : 1 oz / yd² = 33.9g/m², 1 pound/foot = 14.6 N/m, 1foot = 304.8mm.

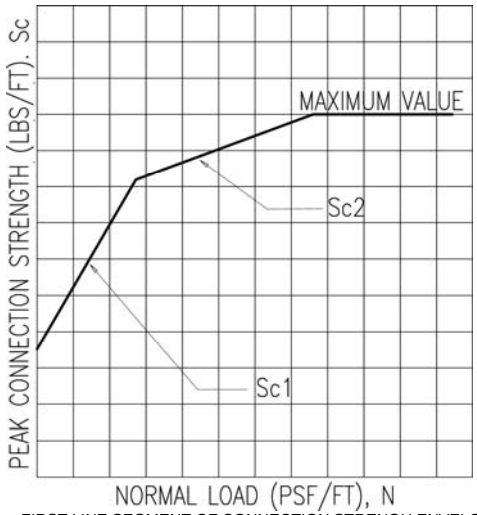
TABLE 1B – Shear Stress Interaction

Soil Type	Soil Class	Coefficient
Silty clay, sandy clay, clavey silt	ML, CL	0.7 - 0.8
Silty sands, fine to medium sands	SM, SP, SW	0.8 - 0.9
Dense well-graded sand, sand +gravel	SW, GP, GW	0.9 - 1.0

TABLE 2 – Facing Connection Capacity

Geosynthetic Reinforcement	Design Connection Capacity Equation[1,2] (pound/foot)	Maximum Design Connection Capacity (pound/foot)
Miragrid 2XT	$S_{C1} = 274 + N \tan 21°$ $S_{C2} = 525 + N \tan 7°$	1,123
Miragrid 5XT	$S_{C1} = 356 + N \tan 25°$ $S_{C2} = 635 + N \tan 9°$	1,466

For **SI:** pound/foot = 14.6 N/m
1.Equations are based on a 1,5 factor of safety applied to the peak connection capacity.
2.S_{C1} and S_{C2} = First line and second line segments of allowable connection capacity envelope, respective
N = normal load due to weight of superimposed units.



Sc1 = FIRST LINE SEGMENT OF CONNECTION STRENGH ENVELOPE
Sc2 = SECOND LINE SEGMENT OF CONNECTION STRENGTH ENVELOPE

Table 3 Maximum wall heights (in feet) for the unreinforced Terraforce L18 Block Retaining Wall System[1,2,3]

Retained Soil	Backslope Above Crest of Retaining wall	Wall Set Back From Vertical				
		15°	20°	25°	30°	35°
Firm Clay and Compact Silt	0°	4.00	4.67	6.00	7.33	8.67
	10°	3.33	4.00	5.33	6.00	7.33
	22°	2.67	3.33	4.00	4.67	6.00
Silty Sand and Sand	0°	5.33	6.67	8.67	12.00	17.33
	10°	4.67	6.00	8.00	11.33	16.67
	22°	4.00	5.33	7.33	10.00	14.67

For **S1** : 1 foot = 304.8mm
1. Wall height measured from top of foundation/leveling pad.
2.Top of foundation/leveling pad a minimum of 0.5 feet below ground level.
3.No allowance made for surcharge above wall