EMERY SAPP & SONS, INC

O: 816.221.3500
F: 816.421.9333

140 WALNUT STREET
KANSAS CITY, MO 64106

WWW.EMERYSAPP.COM

Letter of Transmittal

Attention: **Brock Worthley, PE**
1301 Burlington, Suite 100
North Kansas City, MO 64116

Project: **Osage 3rd Plat** **ESS JOB# 1421047** **Date:** **11/17/21**

New Submittal ____X____________ **Transmittal No.** ____6__________

Resubmittal ________________ **Previous Transmittal No.**_________

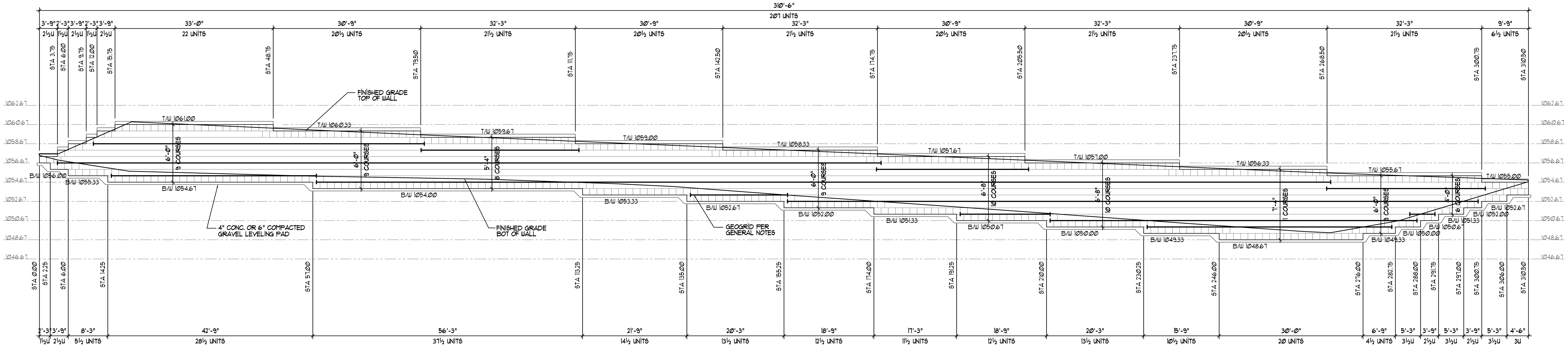
Specification Section	Description	Supplier	Action
City of Lee Summit	Reinforced Soil Retaining Wall Structural Engineering and Product Data	BC Hardscapes	For Review

Signed: *Jonathan Myers*

Contractor: Emery Sapp and Sons, Inc.

Remarks:

Reviewed By: ______________________________ **Date:** ____________________



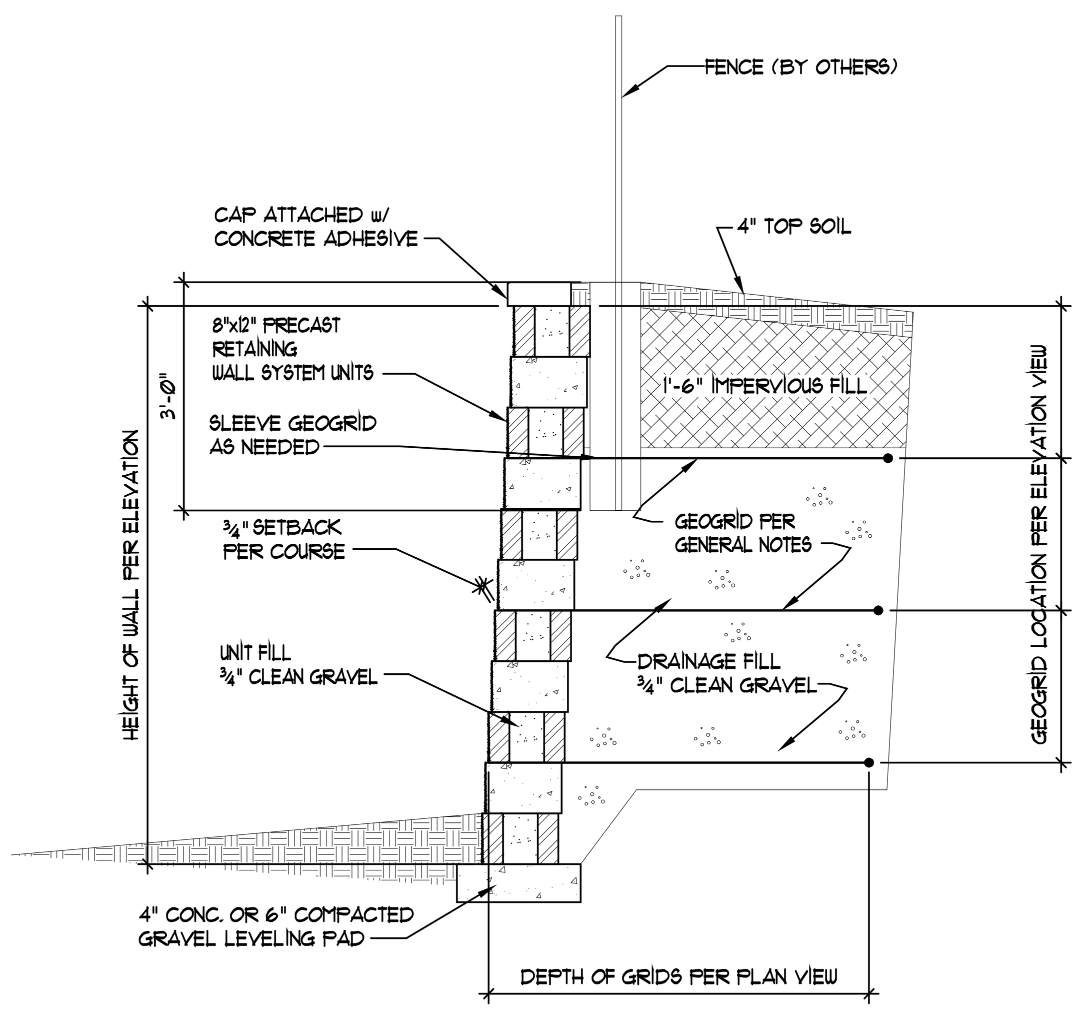
REINFORCED SOIL RETAINING WALL ELEVATION

SCALE: 1"=10'-0" HORIZ.
1"=5'-0" VERT.

REINFORCED SOIL RETAINING WALL PLAN

NORTH

SCALE: 1"=10'-0"



REINFORCED SOIL RETAINING WALL SECTION

SCALE: 1/2" = 1'-0"

RETAINING WALL GENERAL NOTES

1. GENERAL REQUIREMENTS
   - A. Design and construction work for this project shall conform to the requirements of the 2018 International Building Code as amended by the local jurisdiction.
   - B. Design Loads:

Retained Soil	phi = 26 degrees
Live Load Surcharge	0 psf
Backslope	0 degrees
Applied Bearing Pressure	1500 psf

   - C. DRAINAGE FILL shall consist of free draining crushed stone, 3/8" to 3/4", or coarse gravel. No more than 5% shall pass the No. 200 sieve with a maximum size of 1". A minimum of 12 inches of drainage fill must extend behind the wall units to within 18 inches of final grade.
   - D. IMPERVIOUS FILL shall consist of material having a minimum plasticity index of 10 and a maximum plasticity index of 30. No more than 10% particles shall be retained on the No. 4 sieve and no less than 20% shall pass the No. 200 sieve. 18 inches of impervious fill shall extend over the reinforced zone.
   - E. The geogrid shall be a high density polyethylene expanded sheet or polyester woven fiber materials, specifically fabricated for use as soil reinforcement.
     GEOGRID shall be one of the following:
     - Stratagrid 200 as manufactured by Strata Systems, Inc.
     - Miragrid 3XT as manufactured by Mirafi Inc.
     - Versa-Grid 3.0 as manufactured by Versa-Lok
     - HP200 as manufactured by Geostar
   - F. Excavation shall be to the lines and grades shown on the construction drawings. Care shall be taken not to disturb embankment materials beyond lines shown.
2. RETAINING WALL BLOCK SPECIFICATION:
   - A. Modular concrete facing units shall be Brutus Retaining Wall Units having a minimum 28 Day compressive strength of 3000 psi. and a maximum moisture absorption of 8 percent.
3. FOUNDATION SOIL PREPARATION:
   - A. Foundation soil shall be excavated as required for leveling pad per drawings.
   - B. Foundation soil shall be examined by the Engineer of Record or Geotechnical Engineer to assure that the actual foundation soil strength meets or exceeds assumed design strength. Soils not meeting required strength shall be removed and replaced with acceptable material.
   - C. Over-excavated areas shall be filled with approved compacted backfill material.
2. BASE LEVELING PAD:
   - A. Leveling pad materials shall be placed as shown on the drawings, on undisturbed insitu soils to a minimum thickness of 4 inches for concrete and 6" for sand or gravel type materials.
   - B. Material shall be compacted so as to provide a level hard surface on which to place the first course of units. Compaction shall be 95% of standard proctor for sand or gravel type materials.
   - C. Leveling pad shall be prepared to insure complete contact of retaining wall unit with base.
3. UNIT INSTALLATION:
   - A. First course of concrete wall units shall be placed on the base leveling pad. The units shall be checked for level and alignment and in full contact with base.
   - B. Units shall be placed side by side for full length of wall alignment. Alignment shall be done by means of a string line or offset from base line.
   - C. The contractor shall follow manufacturer's installation instructions when making radius curves.
   - D. Compact unit fill, drainage fill, and backfill. Excess material shall be swept from top of units to install next course, insuring the area between each unit is completely filled prior to proceeding to next course.
   - E. Lay each course with the lip of the units placed against the back of the preceding course. Pull units forward as far as possible. Backfill and compact soil behind wall units.
4. GEOGRID INSTALLATION:
   - A. The geogrid soil reinforcement shall be laid horizontally on compacted backfill on top of the concrete wall units. The next course of units shall be placed such that the geogrid is aligned to the backside and under the lip of the top units. Embed the geogrid a minimum of eight inches into the units. Pull geogrid taut and anchor prior to placing backfill.
   - B. Slack in the geogrid at the wall unit connections shall be removed.
   - C. Geogrid shall be laid at the proper elevation and orientation as shown on the drawings.
   - D. Correct orientation (roll direction) of the geogrid shall be verified.
   - E. To pretension geogrid, anchored geogrid shall be pulled taut to eliminate loose folds, and secured prior to and during backfill and compaction.
   - F. In outside corners and radii provide a minimum of 3 inches of backfill or drainage fill between overlapping geogrid layers.
5. FILL PLACEMENT:
   - A. Clean gravel backfill shall be compacted by a minimum of 3 passes of a tracked construction equipment or a vibratory compactor. Placement of clean rock fill shall be monitored during placement to assure that an equivalent maximum dry density of 95% standard proctor is achieved.
   - B. Backfill shall be placed, spread, and compacted in such a manner that minimizes the development of slack or loss of pretension of the geogrid.
   - C. Backfill shall be placed from the wall rearward into the embankment to insure that the geogrid remains taut.
   - D. Compact backfill within three feet of the back of the wall to prevent displacement of modular units.
   - E. Tracked construction equipment shall not be operated directly on the geogrid. A minimum backfill thickness of 6 inches shall be maintained to operate tracked vehicles over the geogrid. Turning of tracked vehicles shall be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid.
6. CAP INSTALLATION:
   - A. Cap units shall be placed over preceding course and on a bed of construction adhesive, pulled forward, backfilled and compacted in place to finished grade.
7. PROTECTION OF WORK
   - A. At the end of each day's operation, slope backfill away from the facing to direct runoff away Prevent runoff from adjacent areas from entering the retaining wall backfill.
   - B. A minimum of three feet shall be maintained between the face of the retaining wall and the operation of heavy equipment.

STATE OF MISSOURI
PROFESSIONAL ENGINEER
11/17/2021

ISSUE DATE:
PERMIT 11/17/2021
REVISIONS:

JOB NO:
DRAWN BY:
DESIGNED BY:

VAN DEURZEN & ASSOCIATES, P.A.
11011 KING STREET, SUITE 130
OVERLAND PARK, KS 66210
(913) 451-6305 FAX (913) 451-1021
WEB PAGE WWW.VANDEURZENASSOC.COM
E-MAIL VDA@VANDEURZENASSOC.COM

BRUTUS

B HARDSCAPES

REINFORCED SOIL RETAINING WALL FOR:
OSAGE THIRD PLAT
LEE'S SUMMIT, MISSOURI

SHEET NO:
RW1.1

G:\Projects\020-21000_RW Prelim 2021\020-21215_Osage 3rd Plat\RW Sheets.dwg Plotted: 7/16/2021

Osage Third Plat
Lee’s Summit, Missouri

VAN DEURZEN AND ASSOCIATES, P.A.
CONSULTING STRUCTURAL ENGINEERS
11011 KING STREET, SUITE 130
COMMERCE TERRACE BUILDING D
OVERLAND PARK, KANSAS 66210
(913) 451 - 6305   FAX (913) 451 - 1021

Reinforced Soil Retaining Wall Design

VAN DEURZEN AND ASSOCIATES, P.A.
November 17, 2021

Segmental Retaining Wall Design Calculations per NCMA

Wall Geometry

Height	Backslope	Dead Load	Live Load	Distance to Slope	Wall below grade at toe
$H := 7.67 \cdot ft$	$\beta := 0.0 \cdot deg$	$q_d := 0 \cdot psf$	$q_l := 0 \cdot psf$	$Z := 1.0 \cdot ft$	$H_{emb} := .67 \cdot ft$

Soil Properties

Reinforced Soil (Internal)	Retained Soil (External)	Drainage Fill	Foundation Soil	Pullout
$\gamma_i := 110 \cdot pcf$	$\gamma_e := 120 \cdot pcf$	$\gamma_d := 110 \cdot pcf$	$\gamma_f := 120 \cdot pcf$	$C_i := 0.7$
$\phi_i := 32 \cdot deg$	$\phi_e := 26 \cdot deg$	$\phi_d := 32 \cdot deg$	$\phi_f := 26 \cdot deg$	
$C_{dsi} := 0.8$	$C_{dse} := 1.0$		$c_f := 0.0 psf$	

Segmental Unit Properties

Height	Length	Width	Setback	Center of Gravity	Batter
$H_u := 8 \cdot in$	$L_u := 18 \cdot in$	$W_u := 12 \cdot in$	$\Delta_u := 0.75 \cdot in$	$G_u := 6 \cdot in$	$\omega := atan\left(\frac{\Delta_u}{H_u}\right)$

$\omega = 5.356 \cdot deg$

Infilled Unit Weight

$\gamma_u := 120 \cdot pcf$

Hinge Height

$$H_h := if\left[\tan(\omega) = 0, H, \left[2 \cdot \frac{(W_u - G_u)}{\tan(\omega)}\right]\right] \Rightarrow H_h = 10.667\ ft$$ [Eq. 4-1]

Internal Interface Friction Angle

$\delta_i := \frac{2}{3} \cdot \phi_i$ $\quad \delta_i = 21.33 \cdot deg$ [Eq. 3-17]

Internal Active Earth Pressure

$$Ka_i := \frac{\cos(\phi_i + \omega)^2}{\cos(\omega)^2 \cdot \cos(\omega - \delta_i) \cdot \left[1 + \sqrt{\left(\frac{\sin(\phi_i + \delta_i) \cdot \sin(\phi_i - \beta)}{\cos(\omega - \delta_i) \cdot \cos(\omega + \beta)}\right)}\right]^2}$$

[Eq. 3-11] $\quad Ka_i = 0.239$

External Interface Friction Angle

$\delta_e := if(\phi_i > \phi_e, \phi_e, \phi_i)$ $\quad \delta_e = 26 \cdot deg$ [Eq. 3-16]

External Active Earth Pressure

$$Ka_e := \frac{\cos(\phi_e + \omega)^2}{\cos(\omega)^2 \cdot \cos(\omega - \delta_e) \cdot \left[1 + \sqrt{\left[\frac{\sin(\phi_e + \delta_e) \cdot \sin((\phi_e - \beta))}{\cos(\omega - \delta_e) \cdot \cos(\omega + \beta)}\right]}\right]^2}$$

[Eq. 3-11] $\quad Ka_e = 0.304$

Orientation of Critical Internal Failure Surface

$$\alpha_i := atan\left[\frac{-\tan(\phi_i - \beta) + \sqrt{(\tan(\phi_i - \beta)) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega)) \cdot (1 + \tan(\delta_i - \omega) \cdot \cot(\phi_i + \omega))}}{1 + \tan(\delta_i - \omega) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega))}\right] + \phi_i$$

[Eq. 3-14]

$\alpha_i = 55.153 \cdot deg$

Orientation of Critical External Failure Surface

$$\alpha_e := atan\left[\frac{-\tan(\phi_e - \beta) + \sqrt{\tan(\phi_e - \beta) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega)) \cdot (1 + \tan(\delta_e - \omega) \cdot \cot(\phi_e + \omega))}}{1 + \tan(\delta_e - \omega) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega))}\right] + \phi_e$$

[Eq. 3-14]

$\alpha_e = 50.164 \cdot deg$

External Stability Analysis

Sliding

Given

$$1.5 = \frac{\min\left[\begin{matrix} C_{dse}\cdot\left[q_d\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right] + L\cdot\gamma_e\cdot H \;\ldots \\ + \frac{1}{2}\cdot\gamma_e\cdot(L - W_u - Z)\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\tan(\phi_e) \\ C_{dse}\cdot\left[q_d\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right] + L\cdot\gamma_e\cdot H \;\ldots \\ + \frac{1}{2}\cdot\gamma_e\cdot(L - W_u - Z)\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\tan(\phi_d) \\ C_{dse}\cdot\left[c_f\cdot L + \left[q_d\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right] + L\cdot\gamma_e\cdot H \;\ldots \\ + \frac{1}{2}\cdot\gamma_e\cdot(L - W_u - Z)\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\right]\cdot\tan(\phi_f) \end{matrix}\right]}{\left[\frac{1}{2}\cdot Ka_e\cdot\gamma_e\cdot\left[H + \left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]^2\cdot\cos(\delta_e - \omega)\right] \;\ldots \\ + (q_d + q_l)\cdot Ka_e\cdot\left[H + \left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\cos(\delta_e - \omega)}$$

$L_{sliding} := \text{Find}(L)$ $\quad L_{sliding} = 3.352\ ft$

Overturning

Given

$$2.0 = \frac{\left[(L\cdot\gamma_e\cdot H)\cdot\left[\frac{1}{2}\cdot(L + H\cdot\tan(\omega))\right]\right] \;\ldots \\ + \left[\frac{1}{2}\cdot\gamma_e\cdot(L - W_u - Z)\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\left[\left[H\cdot\tan(\omega) + W_u + Z + \frac{2}{3}\cdot(L - W_u - Z)\right]\cdots \\ + q_d\cdot\left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\left[\frac{Z + \left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]}{2} + H\cdot\tan(\omega) + \cdots\right.}{\left[\frac{1}{2}\cdot Ka_e\cdot\gamma_e\cdot\left[H + \left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]^2\cdot\cos(\delta_e - \omega)\right]\cdot\left[\frac{1}{3}\cdot\left[H + \left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\cdots}{1 - \tan(\beta)\cdot\tan(\omega)}\cdots\right.\right.\right. \\ + (q_d + q_l)\cdot Ka_e\cdot\left[\left[H + \left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\cos(\delta_e - \omega)\right]\cdot\left[\frac{1}{2}\cdot\left[H + \left[(L - W_u - Z) + \frac{(L - W_u - Z)\cdot\tan(\cdots}{1 - \tan(\beta)\cdot\cdots}\right.\right.\right.}$$

$L_{overturning} := \text{Find}(L)$ $\quad L_{overturning} = 2.998\ ft$

$$L := \max\left(\begin{pmatrix} L_{sliding} \\ L_{overturning} \\ 0.6\cdot H \end{pmatrix}\right) \qquad L = 4.602\ ft$$

Based on Overturning and Sliding: $L := 5.0\cdot ft$ *(Round up L)*

Eccentricity

$L' := L - W_u - Z$ | $L' = 3 \cdot ft$ | [Fig. 2-10] [Eq. 5-1]

$L'' := \dfrac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$ 7 | $L'' = 0\ ft$ | [Fig. 2-10] [Eq. 5-2]

$L_\beta := L' + L''$ | $L_\beta = 3\ ft$ | [Fig. 2-10] [Eq. 5-3]

$h := L_\beta \cdot \tan(\beta)$ | $h = 0\ ft$ | [Fig. 2-10] [Eq. 5-4]

$W_{ri} := L \cdot \gamma_i \cdot H$ | $W_{ri} = 4218.5 \cdot plf$ | [Eq. 5-15]

$X_{ri} := \dfrac{1}{2} \cdot (L + H \cdot \tan(\omega))$ | $X_{ri} = 2.86\ ft$ | [Eq. 5-19]

$W_{r\beta} := \dfrac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$ | $W_{r\beta} = 0 \cdot plf$ | [Eq. 5-16]

$X_{r\beta} := H \cdot \tan(\omega) + W_u + \dfrac{2}{3} \cdot L_\beta + Z$ | $X_{r\beta} = 4.719\ ft$ | [Eq. 5-20]

$X_{q\beta} := \dfrac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$ | $X_{q\beta} = 3.719\ ft$ | [Eq. 5-21]

Actual Heigth of wall:

$H_s := (H + h)$ | $H_s = 7.67\ ft$

Earth Pressures:

$P_{sH} := \left[\dfrac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega)\right]$ | $P_{sH} = 1003.112 \cdot plf$ | [Eq. 5-6]

$Y_s := \dfrac{1}{3} \cdot (H + h)$ | $Y_s = 2.557\ ft$ | [Eq. 5-9]

$P_{qH} := (q_d + q_l) \cdot Ka_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$ | $P_{qH} = 0 \cdot plf$ | [Eq. 5-8]

$Y_q := \dfrac{1}{2} \cdot (H + h)$ | $Y_q = 3.835\ ft$ | [Eq. 5-10]

$$e := \frac{\left[P_{sH} \cdot Y_s + P_{qH} \cdot Y_q - W_{ri} \cdot \left(X_{ri} - \frac{L}{2}\right) - W_{r\beta} \cdot \left(X_{r\beta} - \frac{L}{2}\right) - q_d \cdot (L_\beta) \cdot \left(X_{q\beta} - \frac{L}{2}\right)\right]}{W_{ri} + W_{r\beta} + q_d \cdot (L_\beta)}$$

$e = 0.2484\ ft$ | [Eq. 5-25]

Check $e := \text{if}(e \le 0, 0.075L, e)$ | $e = 0.248\ ft$

Surcharge is applied over: $(L' + L'') = 3\ ft$ | $B := L - 2 \cdot e$ | $B = 4.503\ ft$ | [Eq. 5-24]

Bearing Capacity

$$Q_a := \frac{\left[W_{ri} + W_{r\beta} + (q_d + q_l)\cdot(L' + L'')\right]}{B}$$ $Q_a = 936.785 \cdot psf$

$$N_q := \tan\left(45 \cdot deg + \frac{\phi_f}{2}\right)^2 \cdot \exp(\pi \cdot \tan(\phi_f))$$ $N_q = 11.854$ [Fig. 4-5]

$$N_c := if\left[\phi_f = 0, 5.14, (N_q - 1)\cdot \cot(\phi_f)\right]$$ $N_c = 22.254$ [Fig. 4-5]

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi_f)$$ $N_\gamma = 12.539$ [Fig. 4-5]

$$Q_{ult} := c_f \cdot N_c + \frac{1}{2} \cdot \gamma_f \cdot B \cdot N_\gamma + \gamma_f \cdot H_{emb} \cdot N_q$$ $Q_{ult} = 4340.945 \cdot psf$ [Eq. 4-20]

$$FS_{bearing} := \frac{Q_{ult}}{Q_a}$$ $FS_{bearing} = 4.634$ [Eq. 4-19]

Internal Stability

Reinforcement Properties

Geogrid Design Data

Backfill Soil $Type := (gravel)$

	1	2	3	4	5	6	7	8	9
$Type^T =$	411	834	1199	1336	2004	2508	3011	3873	7914
$inter^T =$	1145	1145	1145	1145	1145	1145	0		
$slope^T =$	38	38	38	38	38	38	0		
$maxc^T =$	4540	4540	4540	4540	4540	4540	0		

Geogrid Number $GN1 := 4$ $GN2 := 2$

$x := 4..1$ x is the number of grids at the top of the wall of a different type

$T_a := Type_{GN1} \cdot plf$ $T_a = 1336 \cdot plf$ $T_{a2} := Type_{GN2} \cdot plf$ $T_{a2} = 834 \cdot plf$

$a_{cs} := inter_{GN1} \cdot plf$ $a_{cs} = 1145 \cdot plf$ | $\lambda_{cs} := slope_{GN1} \cdot deg$ $\lambda_{cs} = 38 \cdot deg$ | $V_{csmax} := maxc_{GN1} \cdot plf$ $V_{csmax} = 4540 \cdot plf$

$a_{cs2} := inter_{GN2} \cdot plf$ $a_{cs2} = 1145 \cdot plf$ | $\lambda_{cs2} := slope_{GN2} \cdot deg$ $\lambda_{cs2} = 38 \cdot deg$ | $V_{csmax2} := maxc_{GN2} \cdot plf$ $V_{csmax2} = 4540 \cdot plf$

Tension in Geogrid

Number of Grids:	Grig Spacing (ft):	# of grids for that spacing:	Depth of first grid (ft):	Length of grids:		
$n_g := 3$	$Spacing1 := 2$	$n_1 := 2$	$h_1 := 3.67$	$L_1 := 5.0$	$L_2 := 5.0$	$L_r := \frac{L}{ft}$
	$Spacing2 := 1.33$	$n_2 := 1$				

Make all zero when using one geogrid

Note: make sure that the elevations don't excide the height of the wall (H) $H = 7.67\,ft$

$top := length(E) \quad p := 2..top \quad top = 3$

$grids := length(E) \quad n := 1..top \quad l := 1..grids - 1$

$E = \begin{pmatrix} 3.67 \\ 5.67 \\ 7 \end{pmatrix} ft$

$T_{a_x} := T_{a2} \quad T_{a_x} = \begin{pmatrix} 834 \\ 834 \\ 834 \\ 834 \end{pmatrix} \cdot plf$

$T_a := \overrightarrow{\frac{L \cdot T_a}{L}} \quad T_a = \begin{pmatrix} 1336 \\ 1336 \\ 1336 \end{pmatrix} \cdot plf$

$L = \begin{pmatrix} 5 \\ 5 \\ 5 \end{pmatrix} ft$

$T_a^T = (834 \;\; 834 \;\; 834 \;\; 834) \cdot plf$

$D_p := \frac{E_{p-1} + E_p}{2} \quad D_1 := 0 \cdot ft \quad D_{grids+1} := H$

$D^T = (0 \;\; 4.67 \;\; 6.335 \;\; 7.67)\,ft$

Total Applied Tensile Strength in the Geosynthetic reinf.:

$$F_{g_n} := \int_{D_n}^{D_{(n+1)}} \left(\gamma_i \cdot D + q_l + q_d\right) \cdot Ka_i \cdot \cos\left(\delta_i - \omega\right) dD$$ [Eq. 5-36]

$F_g^T = (275.327 \;\; 231.323 \;\; 236.036) \cdot plf$

Safety factor:

$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}} \qquad FS_{ten}^T = (3.029 \;\; 3.605 \;\; 3.533)$

Pullout Capacity

Anchorage Length of Geosynthetic

$$La_n := L_n - W_u - \left[(H+h) - E_n\right]\cdot\tan\left(90\cdot deg - \alpha_i\right) + \left[(H+h) - E_n\right]\cdot\tan(\omega)$$ [Eq. 5-46]

$La^T = (1.59 \quad 2.795 \quad 3.596)\ ft$

Note: If the anchorage length is less than 1ft then there is not enough embedment length and it has to be increased. Note that in some cases it might just be the top two grids.

Average Depth of overburden on Anchorage length

$$d_n := E_n + \left[\left(H - E_n\right)\cdot\tan\left(90\cdot deg - \alpha_i\right) + \frac{La_n}{2} - \left(Z + H\cdot\tan(\omega) - \Delta_u\right)\right]\cdot\tan(\beta)$$ [Eq. 5-47]

$d^T = (3.67 \quad 5.67 \quad 7)\ ft$

Anchorage Capacity

$$AC_n := 2\cdot La_n\cdot C_i\cdot\left(d_n\cdot\gamma_i + q_d\right)\cdot\tan\left(\phi_i\right)$$ [Eq. 5-45]

$AC^T = (561.551 \quad 1525.034 \quad 2422.524)\cdot plf$

$F_g^{\ T} = (275.327 \quad 231.323 \quad 236.036)\cdot plf$

Safety Factor

$$FS_{po} := \overrightarrow{\frac{AC}{F_g}}$$ [Eq. 5-44]

$FS_{po}^{\ T} = (2.04 \quad 6.593 \quad 10.263)$

Internal Sliding

Reduced reinforcement length

$$\Delta L_{l+1} := \begin{cases} \left[\left(E_{l+1} - E_l\right)\cdot\left(\dfrac{1}{\tan\left(\alpha_e\right)} - \tan(\omega)\right)\right] & \text{if } n_g > 2 \\ Spacing1\cdot ft\cdot\left(\dfrac{1}{\tan\left(\alpha_e\right)} - \tan(\omega)\right) & \text{if } n_g = 2 \\ 0 & \text{if } n_g = 1 \end{cases}$$ [Eq. 5-51]

$\Delta L^T = (0 \quad 1.481 \quad 0.985)\ ft$

$$L'_{s_n} := L_n - W_u - \Delta L_n$$ [Eq. 5-50]

$L'_s{}^T = (4 \quad 2.519 \quad 3.015)\ ft$

Length of sloping ground

$$L_{s\beta_n} := L'_{s_n} + \frac{\left(L'_{s_n} - W_u\right)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)} - Z$$ [Eq. 5-53 & 5-52]

$L_{s\beta}^T = (3 \;\; 1.519 \;\; 2.015)\ ft$

Height of slope above crest of wall

$h'_n := L_{s\beta_n} \cdot \tan(\beta)$ [Eq. 5-54]

$h'^T = (0 \;\; 0 \;\; 0)\ ft$

Weight of reduced reinforced area

$W'_{ri_n} := L'_{s_n} \cdot E_n \cdot \gamma_i$ [Eq. 5-55]

$W'_{ri}^T = (1615 \;\; 1571 \;\; 2322) \cdot plf$

Weight of wedge beyond reinforced soil zone

$W'_{r\beta_n} := \frac{1}{2} \cdot \left(\left(L_{s\beta_n} \cdot h'_n \right) \right) \cdot \gamma_i$ [Eq. 5-56]

$W'_{r\beta}^T = (0 \;\; 0 \;\; 0) \cdot plf$

Friction developed by weight

$R'_{s_n} := C_{dsi} \cdot \left[q_d \cdot \left(L_{s\beta_n} + Z \right) + W'_{ri_n} + W'_{r\beta_n} \right] \cdot \tan\left(\phi_i\right)$ [Eq. 5-49]

$R'_s{}^T = (807 \;\; 785 \;\; 1161) \cdot plf$

Shear capacity of facing elements

$V_{u_n} := \min\left[V_{csmax}, a_{cs} + \left(\text{if}\left(E_n > H_h, H_h, E_n\right) \cdot \gamma_u \cdot W_u \right) \cdot \tan\left(\lambda_{cs}\right) \right]$ [Eq. 4-25]

$V_u^T = (1489 \;\; 1677 \;\; 1801) \cdot plf$

Driving Forces

From retained soil

$P_{s_n} := \left[\frac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot \left(E_n + h'_n\right)^2 \cdot \cos\left(\delta_e - \omega\right) \right]$ [Eq. 5-6]

$P_s^T = (230 \;\; 548 \;\; 836) \cdot plf$

From surcharge

$P_{q_n} := \left(q_d + q_l\right) \cdot Ka_e \cdot \left(E_n + h'_n\right) \cdot \cos\left(\delta_e - \omega\right)$ [Eq. 5-8]

$P_q^T = (0 \;\; 0 \;\; 0) \cdot plf$

Factor of safety against internal sliding

$P_{a_n} := P_{s_n} + P_{q_n}$ [Eq. 5-11]

$P_a^T = (230 \;\; 548 \;\; 836) \cdot plf$

$FS_{sl_n} := \frac{R'_{s_n} + V_{u_n}}{\left(P_{a_n}\right)}$ [Eq. 5-48]

$FS_{sl}^T = (9.999 \;\; 4.491 \;\; 3.545)$

Local Stability of Facing Units

Facing Connection Strength

$$T_{conn_n} := \min\left[V_{csmax_n}, a_{cs_n} + \left(\text{if}\left(E_n > H_h, H_h, E_n\right)\cdot\gamma_u\cdot W_u\right)\cdot\tan\left(\lambda_{cs_n}\right)\right]$$ [Eq. 5-59]

$T_{conn}^T = (1489 \quad 1677 \quad 1801)\cdot plf$

$$FS_{conn_n} := \frac{T_{conn_n}}{F_{g_n}}$$

$FS_{conn}^T = (5.408 \quad 7.248 \quad 7.631)$

Resistance to Bulging

Shear capacity at each geogrid layer

$$V_{u_n} := \min\left[V_{csmax}, a_{cs} + \left(\text{if}\left(E_n > H_h, H_h, E_n\right)\cdot\gamma_u\cdot W_u\right)\cdot\tan\left(\lambda_{cs}\right)\right]$$ [Eq. 4-25]

$V_u^T = (1489 \quad 1677 \quad 1801)\cdot plf$

Driving Force at each geogrid layer

$$P_{a_n} := \left[\frac{1}{2}\cdot Ka_i\cdot\gamma_i\cdot\left(E_n\right)^2\cdot\cos\left(\delta_i - \omega\right)\right] + \left(q_d + q_l\right)\cdot Ka_i\cdot\left(E_n\right)\cdot\cos\left(\delta_i - \omega\right)$$ [Eq. 5-11]

$P_a^T = (170 \quad 406 \quad 619)\cdot plf$

Sum of tension in reinforcement layers above layer being considered

$$F_{n+1} := \sum_{i=1}^{n} F_{g_i}$$

$F^T = (0 \quad 275 \quad 507 \quad 743)\cdot plf$

$$FS_{sc_n} := \frac{V_{u_n}}{P_{a_n} - F_n}$$ [Eq. 5-61]

$FS_{sc}^T = (8.757 \quad 12.844 \quad 16.09)$

Maximum unreinforced height of SRW units

$y := E_1 = 3.67\ ft$ $\quad q_l := 0\cdot psf$

Moment equilibrium

Driving Moments

$$P'_s := \left[\frac{1}{2}\cdot Ka_i\cdot\gamma_i\cdot(y)^2\cdot\cos\left(\delta_i - \omega\right)\right]$$ [Eq. 4-5]

$P'_s = 170.038\cdot plf$

$P'_q := (q_d + q_l) \cdot Ka_i \cdot (y) \cdot \cos(\delta_i - \omega)$	[Eq. 4-6]	$P'_q = 0 \cdot plf$
$P'_a := P'_s + P'_q$	[Eq. 4-4]	$P'_a = 170.038 \cdot plf$
$Y'_s := \frac{1}{3} \cdot y$	[Eq. 4-7]	$Y'_s = 1.223\ ft$
$Y'_q := \frac{1}{2} \cdot y$	[Eq. 4-8]	$Y'_q = 1.84\ ft$
$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q$	[Eq. 4-17]	$M'_o = 208.01 \cdot lbf$

Resisting Moments

$W'_w := y \cdot \gamma_u \cdot W_u$	[Eq. 4-9]	$W'_w = 440.4 \cdot plf$
$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega)$	[Eq. 4-16]	$X'_w = 0.672\ ft$
$M'_r := W'_w \cdot X'_w$	[Eq. 4-15]	$M'_r = 295.963\ ft \cdot plf$
$FS_{ot} := \frac{M'_r}{M'_o}$	[Eq. 4-14]	$FS_{ot} = 1.423$

Factor of Safety against Shear failure

$V'_u := a_{cs} + W'_w \cdot \tan(\lambda_{cs})$	[Eq. 4-25]	$V'_u = \begin{pmatrix} 1489.078 \\ 1489.078 \\ \ldots \end{pmatrix} \ldots lf$
$FS_{sh} := \frac{V'_u}{P'_a}$	[Eq. 4-27]	$FS_{sh} = \begin{pmatrix} 8.757 \\ 8.757 \\ 8.757 \\ 8.757 \end{pmatrix}$

Summary

Wall Height	$H = 7.67\ ft$	
Unreinforced Stability	$FS_{ot} = 1.423$	$FS_{bearing} = 4.634$
Applied Bearing Stress	$Q_a = 937 \cdot psf$	

Grid Elevation	Geogrid Length	Tensile Force	Geogrid Strength	Anch. Length	Anch. Capacity	FS Grid Tension (1.0)	FS Pullout (1.5)	FS Int Sliding (1.5)	FS Conn (1.5)	FS Bulging (1.5)
$E_n =$ (ft)	$L_n =$ (ft)	$\frac{F_{g_n}}{plf} =$	$\frac{T_{a_n}}{plf} =$	$La_n =$ (ft)	$\frac{AC_n}{plf} =$	$FS_{ten_n} =$	$FS_{po_n} =$	$FS_{sl_n} =$	$FS_{conn_n} =$	$FS_{sc_n} =$
3.67	5	275	834	1.59	562	3.03	2.04	10	5.41	8.76
5.67	5	231	834	2.8	1525	3.61	6.59	4.49	7.25	12.84
7	5	236	834	3.6	2423	3.53	10.26	3.54	7.63	16.09

MIDWEST BLOCK & BRICK
A Midwest Products Group Co.

4101 E. 12th Terrace
Kansas City, MO 64127-1600
www.midwestblock.com
Phone: 816.241.5197
Fax: 816.241.5279

November 15, 2021
BC Hardscapes LLC
134 E US 69 HWY
Claycomo, MO 64119

Reference: Osage Third Plat – Brutus (Straight Split) (Sandstone Blend, Charcoal Blend, and Bethany Ledge)

*** Please observe the recommended sheet attached when working with blended color as well as solid color units.**

This is a letter to certify that the **Brutus** retaining wall units manufactured at Midwest Products Group will meet ASTM C1372-99a specifications minimum **3000 psi after 28 days** curing time. These retaining wall units will be supplied to the above referenced job.

To: Eric McCormack

Enclosed is our test report for our retaining wall units.

If you have any questions or need additional information, feel free to contact me.

Respectfully,

Sam Lock
General Manager

Brutus™


Charcoal Blend


Sandstone Blend


Bethany Ledge Blend

Stable. Affordable. Architectural.

Brutus™ is your best option for high performance walls where great looks is as much a priority as great performance and great value. The straight split featured on Brutus™ gives the block a clean architectural look that complements many structures. The square foot size and rear lip connection allows for fast and easy installation.

ROMANSTONE
HARDSCAPES®

Steps to Installing Romanstone Brutus™

AMERICAN MADE

Step 1 - Foundation

Lay out your wall project with string line or spray paint. Dig a trench at least 12" deep by 24" wide and compact the soil. Add and compact a 6" layer of crushed stone to create a level footing. Do this in two 3" lifts. If the grade changes, step the leveling pad as required with the top of the pad always at least 6" below finish grade.

Step 2 - Base Course

Place and level the first course of Brutus™ wall units on the leveling pad. The rear lips on the first course of block can be removed to allow the units to lay flat on the crushed stone. Use a string line to align straight sections. Start from any corner and work out from there. Add soil in front and back of the base course and compact to finish grade. Complete the first course of wall units before installing additional courses.

Step 3 - Backfill and Additional Courses

Install additional Brutus™ units over the vertical joint of the blocks in the course below it to maintain a running bond. Pull the units forward to engage the rear lips and maintain a setback from the course below. Backfill and compact clean crushed stone behind each wall course before installing the next course. Complete your wall with a cap unit secured to the wall with concrete adhesive. Cut any cap as needed to fit radius walls.

Brutus™

Romanstone Brutus™ features our improved lip design resulting in less breakage, easier installation and reduced waste. The core-fill design results in lighter weight, more square foot per truck load, and easier installation.

Notes:

Curves as small as 19" inside radius can be constructed in addition to building straight walls. Brutus units have a setback of 1 3/16" per course. This creates an 8.3° wall batter. This setback will shift the bond lines of your wall when curves are built. If the vertical joints become stacked, part of the rear lip can be removed or units can be cut to get back to a running bond.

Estimating Chart

Wall Height	Wall length				
	12′	18′	24′	36′	75′
8" (1 course)	8	12	18	24	50
16" (2 courses)	16	24	36	48	100
24" (3 courses)	24	36	54	72	150
32" (4 courses)	32	48	72	96	200
40" (5 courses)	40	60	90	120	250
48" (6 courses)	48	72	108	144	300
56" (7 courses)	56	84	126	168	350

Please Note:

Maximum wall height not to exceed 48". This chart is based on site conditions which include a level grade, granular soil, and no surcharge. Ask your Romanstone Hardscapes dealer for patented soil reinforcement guidelines on walls exceeding 48", with surcharge, or clay soils.

- Unit dimensions: 8"H x 18"W x 12"D
- Units per square foot: 1.0 block
- Unit weight: 72 lbs
- Cube Count: 48 block
- Cube Weight (w/pallet): 3500 lbs

Available at:

ROMANSTONE HARDSCAPES®

www.romanstone.com

NCMA LAB
RESEARCH & DEVELOPMENT

National
Concrete Masonry
Association
13750 Sunrise Valley Drive
Herndon, VA 20171-4662

O 703.713.1900
F 703.713.1910

ncma.org/lab

ASTM C140/C140M-20a Test Report
Sampling and Testing Concrete Masonry Units and Related Units

Job No.: 21-339-3A
Report Date: 8/2/2021

Client: Midwest Block and Brick
Address: 4101 E. 12th Terrace
Kansas City, MO 64127

Testing Agency: National Concrete Masonry Association
Research and Development Laboratory
Address: 13750 Sunrise Valley Drive
Herndon, VA 20171-4662

Unit Specification: ASTM C1372-17

Sampling Party: Midwest Block and Brick

Unit Designation/Description:
Segmental Retaining Wall Units

Date Samples Received: 7/1/2021

Summary of Test Results:

Physical Property	Tested Values	ASTM C1372-17 Required Values
Net Compressive Strength:	4060 psi	3000 psi minimum
Density:	128.9 pcf	-----
Absorption:	8.9 pcf	13 pcf maximum
Absorption:	6.9 %	-----
Variation from Specified Dimensions:	0.05 in.	0.125 in. maximum

The client delivered five full-size units to the laboratory. From each unit, a 1.6 x 3.3 x 6.7 in. coupon was saw-cut from the unit for compression testing. Also, an additional segment was taken from the unit for absorption testing in accordance with ASTM C140/C140M-20a. The results of these tests are summarized above, with individual results listed below.

Measurements of Full-Size Units

		Estimated Width* in.	Avg Height in.	Length Front in.	Length Rear in.	Rec'd Weight lb
	Unit #1	12.07	7.99	18.00	14.14	86.30
	Unit #2	12.13	8.00	18.02	14.11	87.16
	Unit #3	12.15	7.99	18.05	14.12	87.74
	Unit #4	12.11	7.99	18.00	14.09	87.08
Date Tested	Unit #5	12.16	7.97	18.05	14.14	85.44
7/2/2021	Average	12.12	7.99	18.02	14.12	86.74

Specified Dimensions

Width, in.	12
Height, in.	8
Length Front, in.	18
Length Rear, in.	14.1

Calculation of variation from specified dimensions does not include width because of split surface

*The width dimension of this unit includes a split surface. Therefore, this dimension is an estimated average rather than an average calculated from measured dimensions.

Compression Specimens

		Avg Width in.	Avg Height in.	Avg Length in.	Coupon Weight lb	Maximum Compressive Load lb	Tested Compressive Strength psi
	Unit #1a	1.67	3.30	6.66	2.77	48290	4350
	Unit #2a	1.65	3.30	6.67	2.75	50760	4610
	Unit #3a	1.66	3.31	6.67	2.76	43520	3920
	Unit #4a	1.65	3.30	6.71	2.70	42940	3880
Date Tested	Unit #5a	1.65	3.30	6.72	2.72	39080	3520
7/9/2021	Average	1.66	3.30	6.69	2.74	44920	4060

Absorption Specimens

Approximate Specimen Size 3 x 8 x 18 in.

		Received Wt, W_R lb	Immersed Wt, W_I lb	Saturated Surface-Dry Wt, W_S lb	Oven-Dry Wt, W_D lb	Absorption pcf	Absorption %	Density pcf
	Unit #1b	32.28	18.59	34.04	31.86	8.8	6.8	128.7
Date Tested	Unit #2b	33.20	19.02	34.94	32.80	8.4	6.5	128.6
7/13/2021	Unit #3b	33.76	19.45	35.54	33.30	8.7	6.7	129.1
to	Unit #4b	33.50	19.52	35.56	33.14	9.4	7.3	128.9
7/15/2021	Unit #5b	32.02	18.63	33.96	31.72	9.1	7.1	129.1
	Average	32.95	19.04	34.81	32.56	8.9	6.9	128.9

Timothy Jones
Manager, Research and Development Laboratory

Jason J. Thompson
Vice President of Engineering