Project	Project #	Date
LRFD Design Methodology	08110.00	9/24/09

GRAVITY WALL LRFD DESIGN METHODOLOGY
STONE STRONG PRECAST MODULAR BLOCK

Evaluate according to industry practice following AASHTO analytical techniques – refer to:

AASHTO LRFD Bridge Design Specifications, 4th Edition 2007

Additional analytical methods and theories are taken from previous AASHTO specifications and other FHWA guidelines – refer to:

AASHTO Standard Specifications for Highway Bridges 2002, 17th Addition

Mechanically Stabilized Earth Walls and Reinforced Slopes design and Construction Guidelines, NHI-00-043

Properties of Soil/Aggregate

soil and material properties should be determined for the specific materials to be used.

unit fill - γ_a = 110 pcf (max, see AASHTO 2002 5.9.2) & ϕ_u

leveling base – aggregate base typical γ_b & ϕ_b (or concrete base may be substituted)

retained soil - γ & ϕ by site conditions

foundation soil - γ ϕ & c by site conditions

interface angle - $\delta = ½ \phi$ (see AASHTO LRFD Table C3.11.5.9-1)

Geometric Properties

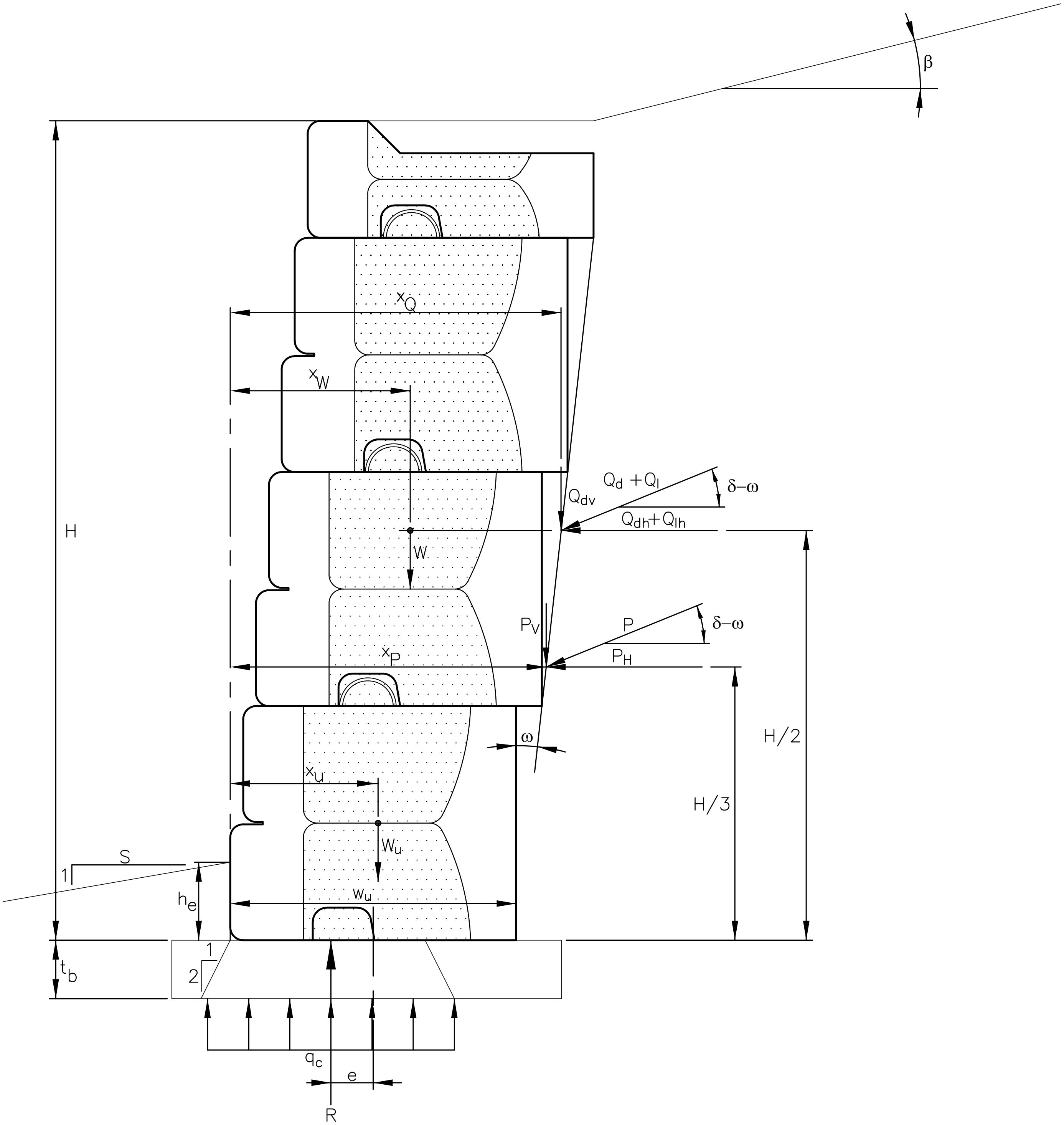
Effective weight of unit

block weight	24 SF unit – 750 lb/ft of wall
	6 SF unit – 450 lb/ft of wall
weight of aggregate	24 SF unit – 596 lb/ft of wall
	6 SF unit – 296 lb/ft of wall

Only 80% of the weight of aggregate and soil is included in the overturning calculations, W' (see AASHTO LRFD 11.11.4.4).

Project	Project #	Date
LRFD Design Methodology	08110.00	9/24/09

Typical gravity wall configuration:



Unit Width/Center of Mass

The nominal unit width is 44 inches for both 24 SF and 6 SF blocks. The combined center of mass of the concrete block and the unit fill is at 22.7 inches from the face.

w_u = 3.67 ft

x_u = 1.89 ft

Wall batter

The wall system is based around the 24 SF block that is 36 inches of height. The next block atop a 24 SF block will batter back 4 inches. The 6 SF block is 18 inches tall, and the next block atop a 6 SF block will batter 2 inches.

4 in. setback per 24 SF block (36 in. tall)

2 in. setback per 6 SF block (18 in. tall)

$\omega = \tan^{-1}(4/36) = 6.34°$

$\omega' = \tan^{-1}(4/36) = 6.34°$ (batter along back face matches the batter along the front)

Base Thickness/Embedment

The type and thickness of wall base or leveling pad and depth of embedment can vary by site requirements. A granular base with a thickness of 9 inches is commonly used, but the thickness can be adjusted to reduce the contact pressure. A concrete leveling pad or footing can also be used. The required embedment to the top of the base is related to the exposed height of the wall and by the slope at the toe, as well as other factors. The required embedment can be calculated for slopes steeper than 6H:1V using the following equation (see AASHTO LRFD Table C11.10.2.2-1):

$h_e = H'/(20*S/6)$

where S is the run of the toe slope per unit fall and H' is the exposed height

A minimum embedment of 12 inches for level toe and 24 inches for toe slopes of 4H:1V or steeper is recommended for highway applications (AASHTO LRFD C.11.10.2.2)

Tail Extension Adjustments

The gravity wall capability can be increased by using a precast Mass Extender block (limited to approximately 12 additional inches, for a total block width of 56 inches) or a cast-in-place tail extension (width is not limited – recommend height be at least 2 times the width to provide shear through the tail openings).

If tail extensions are used, the following adjustments are made:

Wall batter

Wall batter is recalculated along the back of the wall from the rear of the tail extension to the rear of the top of the wall. Use ω' in Coulomb equation and earth pressure component calculations. To calculate ω' it is necessary to know the effective setback width, w_s, which in the horizontal distance between the back edge of the top block and the back edge of the mass extender at the bottom. w_s is the batter of the front face minus the length of tail extension, w_{te}. w_s is negative when the mass extender projects further than the back of the top block. Knowing this distance and the height of wall:

$$\omega' = \arctan(w_s / H_w)$$

Interface Angle

$$\delta = \tfrac{3}{4}\,\phi$$ (see AASHTO LRFD Table C3.11.5.9-1)

Weight of Wall

The weight of the wall includes the contributions of the mass extender and the soil wedge atop the mass extender. A typical concrete unit weight is 145 pcf. Use the soil unit weight for the soil wedge.

$$W_{te} = (w_{te} * H_{te}) * 145 \text{ pcf}$$

where w_{te} is the width of the tail extension and H_{te} is the height of the extension (both in ft)

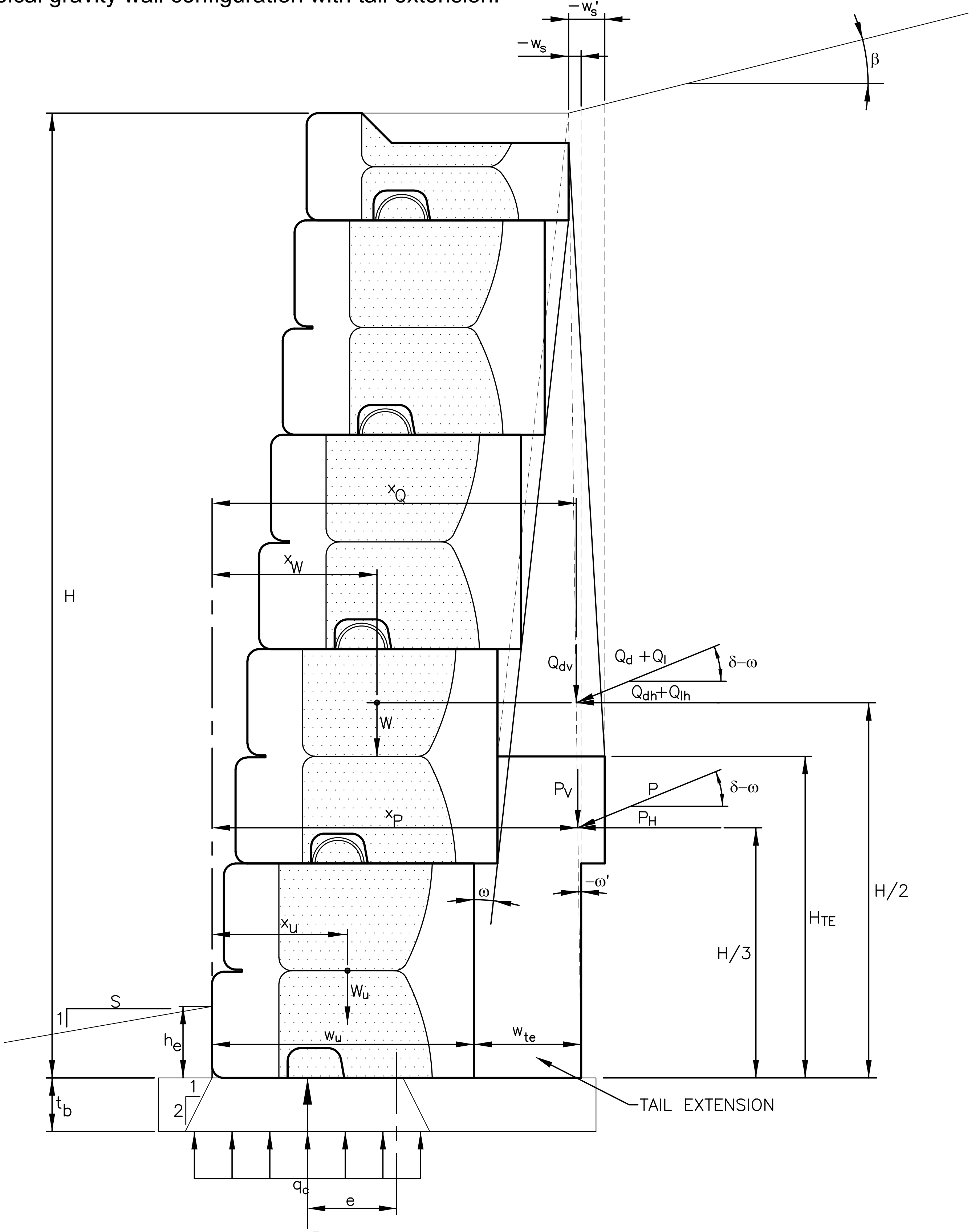
The weight of the soil triangle is calculated using the following equation:

$$W_s = (H - H_{te}) * \gamma * w_{te}/2$$

Note: The soil wedge is defined by the limit of the tail extension and not by the simplified batter of the back of the wall. The simplified batter is used in the earth pressure analysis. Since the minimum width of the tail extension is typically maintained, it may project beyond the extension at the first course.

Project	Project #	Date
LRFD Design Methodology	08110.00	9/24/09

Typical gravity wall configuration with tail extension:



Calculate Forces

Coulomb active earth pressure coefficient (see AASHTO LRFD 3.11.5.3)

$$K_a = \frac{\cos^2(\phi + \omega')}{\cos^2(\omega')\cos(\omega' - \delta)\left[1 + \sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\beta)}{\cos(\omega'-\delta)\cos(\omega'+\beta)}}\right]^2}$$

Earth load components (see AASHTO LRFD 11.10.5.2)

Vertical Forces:

$P_v = 0.5\ K_a \gamma H^2 \sin(\delta - \omega')$

$Q_{dv} = K_a Q{*}H{*}\sin(\delta - \omega')$ where Q is the effective surcharge in psf

Horizontal Forces:

$P_h = 0.5\ K_a \gamma H^2 \cos(\delta - \omega')$

$Q_{dh} = K_a Q{*}H{*}\cos(\delta - \omega')$ where Q is the effective surcharge in psf

$Q_{lh} = K_a Q{*}H{*}\cos(\delta - \omega')$ where Q is the effective surcharge in psf

Note: Surcharge loads may be divided into dead and live load components. The vertical component of the live load (Q_{lv}) is a stabilizing force and should be neglected as conservative. For the example calculations, the surcharge is treated as a dead load consistent with its use in the seismic calculations.

Resisting forces

Vertical Forces:

W_b – Weight of wall units

W_{te} – Weight of concrete tail extension, if used

W_a – Weight of infill aggregate (use 80% aggregate weight for overturning)

W_s – Weight of soil atop tail extension (use 80% aggregate weight for overturning)

The center of gravity of the components of the wall can be calculated by laying out the components of the wall and taking a weighted average of their weight and distance from the hinge point of the block (see AASHTO 2002 5.9.2). Alternately, the center of mass can be calculated using the following equations:

The center of mass of the stack of blocks is calculated as:

$x_b = x_u + (H - h_u)/2 * \tan(\omega)$

The center of mass of the soil triangle over the tail is;

$x_s = w_u + (H_{te} - h_u) * \tan(\omega) + 2 * w_{te}/3 - w_s'/3$

The center of mass of the tail extension can be calculated with the following equation:

$x_{te} = w_u + w_{te}/2$

This leads to an overall adjusted center of mass of:

$x_w = [[x_u + (H - H_u)/2 * \tan(\omega)] * (W_b + W_a) + x_{te} * W_{te} + x_s * W_s]/(W_b + W_a + W_{te} + W_s)$

Note: the height of unit, h_u, is taken as 3 ft. based on the 24 SF unit instead of 1.5 ft. based on the 6 SF unit to produce the more conservative result (units can be stacked with either unit as the bottom course).

The resultants of the earth load components are calculated as follows:

$x_{Pv}=(H/3)*\tan(\omega') + w_u + w_{te}$

$x_{Qdv}=(H/2)\ )*\tan(\omega') + w_u + w_{te}$

$x_{Ph}=H/3$

$x_{Qdh}=H/2$

$x_{Qlh}=H/2$

Table of Unfactored Forces & Moments

	Force (lb)	**x (ft)**	**Moment about toe (lb*ft)**
Vertical Forces			
weight of wall	$W_b + W_a + W_{te} + W_s$	x_w	$(W_b + W_a + W_{te} + W_s) * x_w$
modified weight	$W_b + 0.8*W_a + W_{te} + 0.8*W_s$	x_w	$(W_b + 0.8*W_a + W_{te} + 0.8*W_s) * x_w$
earth pressure	P_v	x_{Pv}	P_v*x_{Pv}
DL surcharge	Q_{dv}	x_{Qdv}	$Q_{dv}*x_{Qdv}$
Horizontal Forces			
earth pressure	P_h	x_{Ph}	P_h*x_{Ph}
DL surcharge	Q_{dh}	x_{Qdh}	$Q_{dh}*x_{Qdh}$
LL surcharge	Q_{lh}	x_{Qlh}	$Q_{lh}*x_{Qlh}$

Project	Project #	Date
LRFD Design Methodology	08110.00	9/24/09

Table of Load and Resistance Factors for the relevant load cases
(based on AASHTO LRFD Tables 3.4.1-1 and 3.4.1-2)

	Strength I-a	**Strength I-b**	**Strength IV**	**Extreme I (EQ)**	**Service I**
Load Factors					
DL/ES	1.50	1.00	1.50	1.50	1.00
LL	1.75	1.75	0.00	0.00	1.00
EH	1.50	1.50	1.50	1.00	1.00
EQ	0.00	0.00	0.00	1.00	0.00
Resistance Factors					
DC	0.90	1.25	1.50	1.00	1.00
EV	1.00	1.35	1.35	1.00	1.00
BC	0.50	0.50	0.50	0.60	0.50

For each of the 5 load cases, the unfactored vertical and horizontal forces are multiplied by the corresponding load and resistance factors for each.

Table of Calculated Factored Forces and Moments

	Force (lb)	**Moment (lb*ft)**
Vertical Forces		
block weight	$(W_b + W_{te})*DC$	$(W_b + W_{te})*x_w *DC$
aggregate weight	$(W_a + W_s)*EV$	$(W_a + W_s)*x_w *EV$
modified agg weight	$0.8*(W_a + W_s)*EV$	$0.8*(W_a + W_s)*x_w *EV$
earth pressure	P_v*EH	$P_v*x_{Pv}*EH$
DL surcharge	$Q_{dv}*DL/ES$	$Q_{dv}*x_{Qdv}*DL/ES$
Horizontal Forces		
earth pressure	P_h*EH	$P_h*x_{Ph}*EH$
DL surcharge	$Q_{dh}*DL/ES$	$Q_{dh}*x_{Qdh}*DL/ES$
LL surcharge	$Q_{lh}*LL$	$Q_{lh}*x_{Qlh}*LL$

Project	Project #	Date
LRFD Design Methodology	08110.00	9/24/09

Overturning/Eccentricity

For overturning, the modified weights using 80% of the aggregate weight (including the soil over the tail extension) are used for all overturning calculations.

Although not an explicit requirement of the AASHTO specification, the driving and resisting overturning moments should be compared:

M'_V	Σ factored moments from vertical forces (using 80% W_s & W_a)
M_H	Σ factored moments from horizontal forces

For each load case, the factored overturning resistance should be greater than the factored overturning load

Check that $M'_V > M_H$

This behavior rarely controls. The AASHTO specification uses eccentricity to evaluate overturning. The resultant of the vertical forces must fall within the center ½ of the base, so the eccentricity must be less than 1/4 times the base width

$B/4 = (w_u + w_{te})/4$

Eccentricity or the location of the vertical resultant is calculated as:

F'_V	Σ factored vertical forces (using 80% W_s & W_a)
M'_v	Σ factored moments from vertical forces (using 80% W_s & W_a)
M_H	Σ factored moments from horizontal forces
e	$e = (w_u + w_{te})/2 - (M'_V - M_H)/F'_V$

For each load case, verify that the eccentricity is less than ¼ of the base width

Check that $e < B/4$

Sliding

Friction on the base of the wall is used to resist sliding failure. Frictional resistance must be determined both between the wall assembly and the base and between the base and the foundation soil (or through the foundation soil).

The unfactored sliding resistance is calculated as the smaller result of the following equations:

For base to foundation soil failure, use:

$R_{s(\text{foundation soil})} = (W + P_v + Q_{dv}) \tan \phi + B_w{*}c$

$B_w = w_u + t_b$

where ϕ represents foundation soils, B_w is base width (block width plus ½H:1V distribution through base), and c represents foundation soil cohesion

For block to base material sliding, use:

$R_{s(\text{footing})} = \mu_b (W + P_v + Q_{dv})$

where μ_b represents a composite coefficient of friction for the base

The composite friction coefficient is calculated using contributory areas. The base of the standard Stone Strong 24 SF unit is 80 percent open and 20 percent concrete. On a unit width basis, the contributory area is 0.73 sf of concrete and 2.94 sf of aggregate.

If a tail extension is used, the area of the tail extension must also be calculated and the total area is also increased accordingly. Thus, the equation for composite friction coefficient across the base becomes:

$\mu_b = (2.94{*}\mu_{p\text{ - unit fill/base}} + 0.73{*}\mu_{p\text{ - block/base}} + w_{te}{*}\mu_{p\text{ - extension/base}})/(3.67 + w_{te})$

where μ_p is the partial friction coefficient for the indicated materials (dimensions in ft)

Partial friction coefficients can be interpreted from the following table:

	Coefficient of Friction
Block to Aggregate Base formed precast surface on compacted aggregate surface (includes Mass Extender)	$0.8 * \tan \phi_b$
Unit Fill to Aggregate Base screened aggregate (loose to moderate relative density - dumped) on compacted aggregate surface	lower $\tan \phi_b$ or $\tan \phi_u$
Block to Concrete Base formed precast surface on floated concrete surface (includes Mass Extender)	0.60
Unit Fill Aggregate to Concrete Base screened aggregate (loose to moderate relative density - dumped) on floated concrete surface	$0.8 * \tan \phi_u$
Concrete Tail Extension to Aggregate Base cast in place concrete on aggregate surface	$\tan \phi_b$
Concrete Tail Extension to Concrete Base cast in place concrete on floated concrete surface	0.75
Concrete Tail Extension Directly on Foundation Soil (Sand) cast in place concrete on granular soil	$\tan \phi_f$

Note: These typical values may be used for evaluation of base sliding at the discretion of the user. The licensed engineer of record is responsible for all design input and for evaluating the reasonableness of calculation output based upon his/her knowledge of local materials and practices and on the specific design details.

Since the unit fill aggregate is typically placed to a moderately loose state, the friction angle for the screened unit fill aggregate typically controls for the interface between the unit fill and the base aggregate.

If actual test data for the project specific materials is not available, or for preliminary design, the following conservative friction angles are suggested for base material:

	Friction Angle (degrees)		
	Well Graded, Densely Compacted	Screened Aggregate, Compacted	Screened Aggregate, Loose to Moderate Relative Density
Crushed Hard Aggregate >75% w/ 2 fractured faces, hard natural rock	42	40	36
Crushed Aggregate >75% w/ 2 fractured faces, medium natural rock or recycled concrete	40	38	35
Cracked Gravel >90% w/ 1 fractured face	36	35	32

Note: Physical testing of specific aggregates is recommended. When test data is not available, these typical values may be used at the discretion of the user. The licensed engineer of record is responsible for all design input and for evaluating the reasonableness of calculation output based upon his/her knowledge of local materials and practices and on the specific design details.

For each load case, the minimum value for sliding resistance is calculated. A resistance factor of 0.8 is used for a cast in place interface (concrete base or a cast in place tail extension), and a factor of 0.9 is used in all other cases.

F_H	Σ factored horizontal forces
F_V	Σ factored vertical forces (using 100% W_s & W_a)
$R'_{s\ (footing)}$	$\mu_b F_V * \phi_\tau$
$R'_{s\ (foundation\ soil)}$	$[F_V * \tan(\phi) + B_w * c] * \phi_\tau$
ϕ_τ	0.8 for cast in place base or extension, 0.9 for other cases
min R'_s	smaller of $R'_{s\ (footing)}$ or $R'_{s\ (foundation\ soil)}$

For each load case, the factored sliding resistance should be greater than the sum of factored horizontal forces

check that min $R'_s > F_H$

Bearing

Load Case Strength I-b generally controls bearing.

B_f' is the equivalent bearing area. This is the base block width adjusted for eccentricity, and including a ½H:1V distribution through granular base or 1H:1V distribution through concrete base.

$B_f' = w_u + w_{te} + t_b - 2*e$ or $B_f' = w_u + w_{te} + 2*t_b - 2*e$ (for concrete base)

F_V	Σ factored vertical forces (using 100% W_s & W_a)
surcharge over wall	$q_{DL}*w_u*DL/ES + q_{LL}*w_u*LL$
weight of base	$t_b * \gamma_b*EH$
M_v	Σ factored moments from vertical forces (using 100% W_s & W_a)
M_H	Σ factored moments from horizontal forces
e	$(w_u + w_{te})/2 - (M_V - M_H)/F_V$
B_f' (granular base)	$w_u + w_{te} + t_b - 2*e$
B_f' (concrete base)	$w_u + w_{te} + 2*t_b - 2*e$
contact pressure q_c	$(F_V + q_{DL}*w_u*DL/ES + q_{LL}*w_u*LL)/B_f' + t_b*\gamma_b*EH$
bearing resistance q_b	$[c*N_c + (h_e + t_b)*\gamma_{found}*N_q+0.5*\gamma_{found}*B_f'*N_\gamma]*BC$

For each load case, the factored bearing resistance should be greater than the factored contact pressure

Check that $q_b > q_c$

Seismic Design

Seismic components of force are calculated according to the procedures in FHWA 4.2h.

The maximum acceleration $A_m = (1.45 - A)*A$ where A is the peak horizontal ground acceleration.

The seismic earth pressure coefficient is calculated with the following equation:

$$K_{ae} = \frac{\cos^2(\phi + \omega - \xi)}{\cos(\xi)\cos^2(-\omega)\cos(\delta - \omega + \xi)\left[1 + \sqrt{\frac{\sin(\phi + \delta)\sin(\phi - \xi - \beta)}{\cos(\delta - \omega + \xi)\cos(\omega + \beta)}}\right]^2}$$

where $\xi = \arctan[K_h/(1 - K_v)]$. K_v is generally taken as 0. K_h is the maximum horizontal acceleration of the wall, and is a function of the maximum allowable displacement of the wall during a seismic event. It is calculated with the following equation:

$K_h = 1.66 * A_m * [A_m/(d*25.4)]^{0.25}$

with d = 2 inches, the conservatively assumed maximum horizontal displacement

The horizontal inertia force P_{ir} is calculated as follows:

$P_{ir} = 0.5 * K_h * \gamma * H_2 * H + 0.125 * K_h * \gamma * H_2^2 * \tan(\beta)$

where H_2 is the height of backfill at the back of the block.

The seismic thrust is calculated as follows:

$P_{ae} = 0.5 * \gamma * H_2^2 * (K_{ae} - K_a)$

$P_{aeh} = 0.5 * \gamma * H_2^2 * (K_{ae} - K_a) * \cos(\delta - \omega)$

In overturning analysis, the inertial force is applied at half the height of the wall, while the seismic thrust is applied at 60% of the wall height. By AASHTO LRFD requirements, the full inertial force is applied along with 50% of the seismic thrust (AASHTO LRFD 11.10.7.1).

The only load case affected by the seismic forces is Extreme I (EQ).

The total overturning moment is increased as shown in the following equation:

$M_H + P_{ir}*H/2*EQ + (P_{aeh}/2)*(0.6*H)*EQ$

The total horizontal sliding force is increased as shown in the following equation:

$F_H + P_{ir}*EQ + (P_{aeh}/2)*EQ$

For load case Extreme 1, EQ = 1.0

All behaviors should be verified as for the other load cases, including sliding, overturning/eccentricity, and bearing.

Internal Analysis

Internal stability analysis is conducted for each segment of block. Since bearing conditions are addressed in the external stability analysis, only overturning and shearing failures are possible.

Overturning is evaluated identically to external stability analysis, except that the eccentricity for block to block contact should be within the middle ¾ of the base as required for a rock foundation. For each load case:

check that $e < B*3/8$

Sliding resistance is calculated based on the interface shear test (see interaction test reports for complete test data)

$R'_s = [362 + (W + P_v + Q_{dv})* \tan(35.2°)]*\phi_\tau$

where $\phi_\tau = 0.90$ (precast to precast and aggregate to aggregate)

For each load case, the factored sliding resistance must be greater than the factored horizontal force:

check that $R'_s > F_H$

At a minimum, internal stability should be evaluated at each change in block width (i.e. immediately above the mass extender), any change in mass extender size and at the base of any dual-face units.

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Example section – 7.5 ft tall unreinforced wall, 4H:1V slope, Sand backfill

Uniform soil (sand) - γ = 125 pcf ϕ = 30° c = 0 psf

Wall is composed of two 24 SF blocks and one 6 SF block

ω' = arctan((2*4"+2")/(7.5ft*12"/ft)) = 6.34°   δ = ½*30° = 15°

Granular base aggregate – ϕ = 40°

Unit fill aggregate – ϕ = 35°

Weight of Wall

W_b = (2*6,000 lb)/8 ft + (1,600 lb)/4 ft = 1,900 lb/ft block

W_a = (2*43.32 ft^3*110 pcf)/8 ft + (10.75 ft^3*110 pcf)/4 ft = 1,487 lb/ft aggregate fill

Total Wall Weight = 1,900 + 1,487 = 3,387 lb/ft

Forces/Geometric Properties

Center of Gravity

x_w = [(1.89+0.5*(7.5 ft-3 ft)*tan(6.34°))*(1,900 lb+1,487 lb)]/3,387 lb = 2.14 feet

Soil force components

$$K_a = \frac{\cos^2(30^\circ + 6.34^\circ)}{\cos^2(6.34^\circ)\cos(6.34^\circ - 15^\circ)\left[1 + \sqrt{\frac{\sin(30^\circ + 15^\circ)\sin(30^\circ - 14.0^\circ)}{\cos(6.34^\circ - 15^\circ)\cos(6.34^\circ + 14.0^\circ)}}\right]^2} = 0.314$$

P_h = 0.5*(0.314)*125pcf*(7.5 ft)^2*cos(15° - 6.34°) = 1,092 lb

P_v = 0.5*(0.314)*125pcf*(7.5 ft)^2*sin(15° - 6.34°) = 166 lb

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Table of Unfactored Forces & Moments

	Force (lb)	x (ft)	Moment about toe (lb*ft)
Vertical Forces			
weight of wall	3,387	2.14	7,248
modified weight	3,090	2.14	6,613
earth pressure	166	3.94	654
DL surcharge	0	4.08	0
Horizontal Forces			
earth pressure	1,092	2.50	2,730
DL surcharge	0	3.75	0
LL surcharge	0	3.75	0

Table of Load & Resistance Factors

	Strength I-a	Strength I-b	Strength IV	Service I
Load Factors				
DL/ES	1.50	1.00	1.50	1.00
LL	1.75	1.75	0.00	1.00
EH	1.50	1.50	1.50	1.00
EQ	0.00	0.00	0.00	0.00
Resistance Factors				
DC	0.90	1.25	1.50	1.00
EV	1.00	1.35	1.35	1.00
BC	0.50	0.50	0.50	0.50

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Table of Calculated Factored Forces (lbs)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	1,900	DC	1,710	2,375	2,850	1,900
aggregate weight	1,487	EV	1,487	2,007	2,007	1,487
modified agg weight	1,190	EV	1,190	1,606	1,606	1,190
earth pressure	166	EH	249	249	249	166
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	1,092	EH	1,774	1,774	1,774	1,183
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	0	LL	0	0	0	0

Table of Calculated Factored Moments (lb*ft)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	4,066	DC	3,659	5,083	6,099	4,066
aggregate weight	3,191	EV	3,191	4,307	4,307	3,191
modified agg weight	2,552	EV	2,552	3,446	3,446	2,552
earth pressure	654	EH	984	981	981	654
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	2,730	EH	4,095	4,095	4,095	2,730
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	0	LL	0	0	0	0

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Overturning/Eccentricity

	Strength I-a	Strength I-b	Strength IV	Service I
M'_V	7,195	9,510	10,526	7,272
M_H	4,095	4,095	4,095	2,730

Check that $M'_V > M_H$

Strength Case I-a: M'_V = 3,659 + 2,552 + 984 = 7,195 lb*ft

M_H = 4,095

$M'_V > M_H$ <u>OK!!</u>

All other Load Cases: <u>OK!!</u>

	Strength I-a	Strength I-b	Strength IV	Service I
F'_V	3,149	4,230	4,705	3,256
M'_V	7,195	9,510	10,526	7,272
M_H	4,095	4,095	4,095	2,730
E	0.85	0.55	0.47	0.44

Check that e < B/4

Strength Case I-a: e = (3.67')/2 – (7,195 lb*ft – 4,095 lb*ft)/ 3,149 lb = 0.85 ft.

B/4 = (3.67')/4 = 0.92 ft.

e ≤ B/4 <u>OK!!</u>

All other Load Cases: <u>OK!!</u>

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Sliding

μ_b = ((0.8*3.67'*tan(35°)) + (0.2*3.67'*0.8*tan(40°))/(3.67') = 0.69

μ_f = tan(30°) = 0.58

	Strength I-a	Strength I-b	Strength IV	Service I
F_H	1,774	1,774	1,774	1,183
F_V	3,446	4,631	5,106	3,553
μ_b	0.69	0.69	0.69	0.69
ϕ_τ	0.8	0.8	0.8	0.8
$R'_{s\ (footing)}$	1,902	2,556	2,819	1,961
μ_f	0.58	0.58	0.58	0.58
$\phi_{\tau f}$	0.9	0.9	0.9	0.9
$R'_{s\ (foundation\ soil)}$	1,799	2,417	2,665	1,855
min R'_s	1,799	2,417	2,665	1,855

Check that min R'_s > F_H

Strength Case I-a: $R'_{s\ (footing)}$ = 0.69*3,446lb*0.8 = 1,902 lb

$R'_{s\ (foundation\ soil)}$ = 0.58*3,446 lb*0.9 = 1,799 lb

min R'_s = 1,799 lb > F_H = 1,774 lb OK!!

All other Load Cases: OK!!

Bearing

$N_q = e^{\pi * \tan(30°)} * (\tan(45°+30°/2))^2 = 18.40$

$N_c = (18.40-1)/\tan(30°) = 30.14$

$N\gamma = 2*(18.40+1)*\tan(30°) = 22.40$

	Strength I-a	Strength I-b	Strength IV	Service I
F_v	3,446	4,631	5,106	3,553
surcharge over wall	0	0	0	0
M_V	7,834	10,371	11,387	7,911
M_H	4,095	4,095	4,095	2,730
e	0.85	0.55	0.47	0.44
thickness of base t_b	0.75	0.75	0.75	0.75
B_f' (granular base)	2.72	3.32	3.48	3.54
weight of base	141	141	141	94
contact pressure q_c	1,408	1,536	1,608	1,145
bearing resistance q_b	3,917	4,337	4,449	4,491

Check that $q_b > q_c$

Strength Case I-b:

weight of base = 0.75 ft*125pcf*EH = 0.75*125*1.5 = 141 psf

B_f'= 3.67ft+0.75ft-2*0.55 ft = 3.32 ft

q_c = (4,631 lb)/3.32 ft + 141 psf = 1,536 psf

q_b = [0*30.14+(12”+9”)/12*125pcf*18.40+0.5*125pcf*3.32 ft*22.40]*0.5 = 4,337 psf

$q_b > q_c$ OK!!

All other Load Cases: OK!!

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Internal Analysis

For 4.5 ft. tall segment above the bottom course.

Table of Unfactored Forces & Moments

	Force (lb)	x (ft)	Moment about toe (lb*ft)
Vertical Forces			
weight of wall	2,041	1.98	4,041
modified weight	1,863	1.98	3,689
earth pressure	60	3.83	230
DL surcharge	0	3.92	0
Horizontal Forces			
earth pressure	393	1.50	590
DL surcharge	0	2.25	0
LL surcharge	0	2.25	0

Table of Calculated Factored Forces (lbs)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	1,150	DC	1,035	1,438	1,725	1,150
aggregate weight	891	EV	891	1,203	1,203	891
modified agg weight	713	EV	713	963	963	713
earth pressure	60	EH	90	90	90	60
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	393	EH	590	590	590	393
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	0	LL	0	0	0	0

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Table of Calculated Factored Moments (lb*ft)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	2,277	DC	2,049	2,846	3,416	2,277
aggregate weight	1,764	EV	1,764	2,381	2,381	1,764
modified agg weight	1,411	EV	1,411	1,905	1,905	1,411
earth pressure	230	EH	345	345	345	230
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	393	EH	590	590	590	393
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	0	LL	0	0	0	0

Overturning/Eccentricity

	Strength I-a	Strength I-b	Strength IV	Service I
M'_V	3,805	5,096	5,666	3,918
M_H	590	590	590	393

Check that $M'_V > M_H$

Strength Case I-a: M'_V = 2,049 +1,411 + 345 = 3,805 lb*ft

M_H = 590 lb*ft

$M'_V > M_H$ OK!!

All other Load Cases: OK!!

	Strength I-a	Strength I-b	Strength IV	Service I
F'_V	1,838	2,491	2,778	1,923
M'_V	3,805	5,096	5,666	3,918
M_H	590	590	590	393
e	0.09	0.03	0.01	0.00

Check that e < B*3/8

Strength Case I-a: e = 3.67'/2 – (3,805 lb*ft – 590 lb*ft)/ 1,838 lb = 0.09 ft.

B*3/8 = 3.67'*3/8 = 1.38 ft.

e < B*3/8 OK!!

All other Load Cases: OK!!

Interface Shear

μ = tan(35.2°) = 0.705

	Strength I-a	Strength I-b	Strength IV	Service I
F_H	590	590	590	393
F_V	2,016	2,731	3,018	2,101
ι_{ult}	362	362	362	362
μ	0.71	0.71	0.71	0.71
ϕ_τ	0.9	0.9	0.9	0.9
R'_s	1,605	2,059	2,241	1,659

Check that min $R'_s > F_H$

Strength Case I-a: R'_s = (362 lb + 0.705*2,016 lb)*0.9 = 1,605 lb

R'_s = 1,605 lb > F_H = 639 lb OK!!

All other Load Cases: OK!!

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Internal Analysis (continued)

For 1.5 ft. tall segment representing the top block.

Table of Unfactored Forces & Moments

	Force (lb)	x (ft)	Moment about toe (lb*ft)
Vertical Forces			
weight of wall	696	1.81	1,260
modified weight	637	1.81	1,153
earth pressure	7	3.72	26
DL surcharge	0	3.75	0
Horizontal Forces			
earth pressure	44	0.50	22
DL surcharge	0	0.75	0
LL surcharge	0	0.75	0

Table of Calculated Factored Forces (lbs)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	400	DC	360	500	600	400
aggregate weight	296	EV	296	399	399	296
modified agg weight	237	EV	237	319	319	237
earth pressure	7	EH	11	11	11	7
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	44	EH	66	66	66	44
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	0	LL	0	0	0	0

Project	Project #	Date
LRFD Example Calculation	08110.03	7/10/10

Table of Calculated Factored Moments (lb*ft)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	724	DC	652	905	1,086	724
aggregate weight	536	EV	536	723	723	536
modified agg weight	429	EV	429	579	579	429
earth pressure	27	EH	40	40	40	27
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	26	EH	39	39	39	26
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	0	LL	0	0	0	0

Overturning/Eccentricity

	Strength I-a	Strength I-b	Strength IV	Service I
M'_V	1,121	1,524	1,705	1,180
M_H	39	39	39	26

Check that $M'_V > M_H$

Strength Case I-a: M'_V = 652 + 429 + 40 = 1,121 lb*ft

M'_H = 39 lb*ft

$M'_V > M_H$ OK!!

All other Load Cases: OK!!

	Strength I-a	Strength I-b	Strength IV	Service I
F'_V	608	830	930	644
M'_V	1,121	1,524	1,705	1,180
M_H	39	39	39	26
e	0.06	0.05	0.04	0.04

Check that e < B*3/8

Strength Case I-a: e = 3.67'/2 – (1,121 lb*ft – 39 lb*ft)/ 608 lb = 0.06 ft.

B*3/8 = 3.67'*3/8 = 1.38 ft.

e < B*3/8 OK!!

All other Load Cases: OK!!

Interface Shear

μ = tan(35.2°) = 0.705

	Strength I-a	Strength I-b	Strength IV	Service I
F_H	66	66	66	44
F_V	667	910	1,010	703
ι_{ult}	362	362	362	362
μ	0.71	0.71	0.71	0.71
ϕ_τ	0.9	0.9	0.9	0.9
R'_s	749	903	967	772

Check that min $R'_s > F_H$

Strength Case I-a: R'_s = (362 lb + 0.705*667 lb)*0.9 = 749 lb

R'_s = 749 lb > F_H = 66 lb OK!!

All other Load Cases: OK!!

Example section – 12 ft tall wall w/ 36" mass extender, rock backfill, 250 psf surcharge

Retained soil (crushed rock) - γ = 125 pcf ϕ = 34°

Foundation soil (sand) - γ = 125 pcf ϕ = 30° c = 0 psf

Wall is composed of four 24 SF blocks w/ 36 in. mass extender to height of 6 ft

ω' = arctan((4"*(4-1)-36")/(12ft*12"/ft)) = -9.46° δ = ¾*34° = 25.5°

Granular base aggregate – ϕ = 40°

Unit fill aggregate – ϕ = 35°

Weight of Wall

W_b = (4*6,000 lb)/8 ft = 3,000 lb/ft block

W_a = (4*43.32 ft^3*110 pcf)/8 ft = 2,383 lb/ft aggregate fill

W_{te} = 36"/12*6 ft*145pcf = 2,610 lb/ft tail extension

W_s = (1/2)*(12 ft-6 ft)*(36"/12)*125 pcf = 1,125 lb/ft soil over mass extender

Total Wall Weight = 3,000 + 2,383 + 2,610 + 1,125 = 9,118 lb/ft

Forces/Geometric Properties

Center of Gravity

x_w = [(1.89+0.5*(12 ft-3 ft)*tan(6.34°))*(3,000 lb+2,383 lb)+(3.67ft+36"/2/12)* 2,610 lb+ (3.67ft+(6 ft-3 ft)*tan(6.34°)+(2/3)*36"/12+(1/3)*(-24"/12))* 1,125 lb]/ 9,118 lb = 3.54 feet

Soil force components

$$K_a = \frac{\cos^2(34° + -9.46°)}{\cos^2(-9.46°)\cos(-9.46° - 25.5°)\left[1 + \sqrt{\dfrac{\sin(34° + 25.5°)\sin(34° - 0°)}{\cos(-9.46° - 25.5°)\cos(-9.46° + 0°)}}\right]^2} = 0.331$$

P_h = 0.5*(0.331)*125pcf*(12 ft)^2*cos(25.5°-(-9.46°)) = 2,438 lb

P_v = 0.5*(0.331)*125pcf*(12 ft)^2*sin(25.5-(-9.46°)) = 1,705 lb

Q_{lh} = 0.331*(250 psf)*12 ft*cos(25.5°-(-9.46°)) = 813 lb

13478 Chandler Road, Omaha, Nebraska 68138 402/556-2171 (Fax 402/556-7831)

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Table of Unfactored Forces & Moments

	Force (lb)	x (ft)	Moment about toe (lb*ft)
Vertical Forces			
weight of wall	9,118	3.54	32,255
modified weight	8,416	3.54	29,774
earth pressure	1,705	4.11	7,008
DL surcharge	0	4.33	0
Horizontal Forces			
earth pressure	2,438	4.00	9,751
DL surcharge	0	6.00	0
LL surcharge	813	6.00	4,875

Table of Load & Resistance Factors

	Strength I-a	Strength I-b	Strength IV	Service I
Load Factors				
DL/ES	1.50	1.00	1.50	1.00
LL	1.75	1.75	0.00	1.00
EH	1.50	1.50	1.50	1.00
EQ	0.00	0.00	0.00	0.00
Resistance Factors				
DC	0.90	1.25	1.50	1.00
EV	1.00	1.35	1.35	1.00
BC	0.50	0.50	0.50	0.50

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Table of Calculated Factored Forces (lbs)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	5,610	DC	5,049	7,013	8,415	5,610
aggregate weight	3,508	EV	3,508	4,735	4,735	3,508
modified agg weight	2,806	EV	2,806	3,788	3,788	2,806
earth pressure	1,705	EH	2,557	2,557	2,557	1,705
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	2,438	EH	3,657	3,657	3,657	2,438
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	813	LL	1,422	1,422	0	813

Table of Calculated Factored Moments (lb*ft)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	19,847	DC	17,862	24,808	29,770	19,847
aggregate weight	12,409	EV	12,409	16,752	16,752	12,409
modified agg weight	9,927	EV	9,927	13,402	13,402	9,927
earth pressure	10,227	EH	15,341	15,341	15,341	10,227
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	9,751	EH	14,626	14,626	14,626	9,751
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	4,875	LL	8,532	8,532	0	4,875

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Overturning/Eccentricity

	Strength I-a	Strength I-b	Strength IV	Service I
M'_V	43,130	53,551	58,512	40,001
M_H	23,158	23,158	14,626	9,751

Check that $M'_V > M_H$

Strength Case I-a: M'_V = 17,862 + 9,924 + 15,341 = 43,130 lb*ft

M_H = 23,158 lb*ft

$M'_V > M_H$ OK!!

All other Load Cases: OK!!

	Strength I-a	Strength I-b	Strength IV	Service I
F'_V	10,412	13,357	14,760	10,121
M'_V	43,130	53,551	58,512	40,001
M_H	23,158	23,158	14,626	14,626
e	1.42	1.06	0.36	0.83

Check that e < B/4

Strength Case I-a: e = (3.67'+36"/12)/2 – (43,130 lb*ft – 23,158 lb*ft)/10,412 lb = 1.42 ft.

B/4 = (3.67'+36"/12)/4 = 1.67 ft.

e < B/4 OK!!

All other Load Cases: OK!!

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Sliding

μ_b = ((0.8*3.67'*tan(35°)) + (0.2*3.67'*0.8*tan(40°)) + (36"/12*tan(40°))) / (3.67'+36"/12) = 0.76

μ_f = tan(30°) = 0.58

	Strength I-a	Strength I-b	Strength IV	Service I
F_H	5,079	5,079	3,657	3,250
F_V	11,113	14,305	15,707	10,822
μ_b	0.76	0.76	0.76	0.76
ϕ_τ	0.8	0.8	0.8	0.8
$R'_{s\,(footing)}$	6,753	8,692	9,544	6,576
μ_f	0.58	0.58	0.58	0.58
$\phi_{\tau f}$	0.9	0.9	0.9	0.9
$R'_{s\,(foundation\ soil)}$	5,775	7,433	8,162	5,623
min R'_s	5,775	7,433	8,162	5,623

Check that min $R'_s > F_H$

Strength Case I-a: $R'_{s\,(footing)}$ = 0.76*11,113 lb*0.8 = 6,753 lb

$R'_{s\,(foundation\ soil)}$ = 0.58*11,113 lb*0.9 = 5,800 lb

min R'_s = 5,800 lb > F_H = 5,079 lb OK!!

All other Load Cases: OK!!

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Bearing

$N_q = e^{\pi * \tan(30°)} * (\tan(45°+30°/2))^2 = 18.40$

$N_c = (18.40-1)/\tan(30°) = 30.14$

$N\gamma = 2*(18.40+1)*\tan(30°) = 22.40$

Surcharge over wall = $w_u * q_{LL} * LL$ = 44"/12 * 250 psf * 1.75 = 1,604 psf

	Strength I-a	Strength I-b	Strength IV	Service I
F_v	11,113	14,305	15,707	10,822
surcharge over wall	1,604	1,604	1,604	1,604
M_V	45,612	56,901	61,863	42,483
M_H	23,158	23,158	14,626	14,626
e	1.42	1.06	0.36	0.83
thickness of base t_b	0.75	0.75	0.75	0.75
B_f' (granular base)	4.59	5.30	6.70	5.76
weight of base	141	141	141	94
contact pressure q_c	2,914	3,142	2,485	1,702
bearing resistance q_b	5,223	5,723	6,701	8,067

Check that $q_b > q_c$

Strength Case I-b:

weight of base = 0.75 ft*125pcf*EH = 0.75*125*1.5 = 141 psf

B_f'= 3.67ft+36"/12+0.75ft-2*1.06 ft = 5.30 ft

q_c = (14,305 psf + 44"/12 + 250 psf *3.67ft*1.75)/5.30ft + 141 = 3,142 psf

q_b = [0*30.14+(12"+9")/12*125pcf*18.40+0.5*125pcf*5.30ft*22.40]*0.5 = 5,723 psf

$q_b > q_c$ OK!!

All other Load Cases: OK!!

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Internal Analysis

For 6 ft. tall segment above the tail extension.

Table of Unfactored Forces & Moments

	Force (lb)	x (ft)	Moment about toe (lb*ft)
Vertical Forces			
weight of wall	2,691	2.06	5,551
modified weight	2,453	2.06	5,059
earth pressure	90	3.89	349
DL surcharge	0	4.00	0
Horizontal Forces			
earth pressure	476	2.00	952
DL surcharge	0	3.00	0
LL surcharge	317	3.00	952

Table of Calculated Factored Forces (lbs)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	1,500	DC	1,350	1,875	2,250	1,500
aggregate weight	1,191	EV	1,191	1,608	1,608	1,191
modified agg weight	953	EV	953	1,287	1,287	953
earth pressure	90	EH	134	134	134	90
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	476	EH	714	714	714	476
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	317	LL	556	556	0	317

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Table of Calculated Factored Moments (lb*ft)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	3,094	DC	2,784	3,867	4,640	3,094
aggregate weight	2,457	EV	2,457	3,317	3,317	2,457
modified agg weight	1,966	EV	1,966	2,654	2,654	1,966
earth pressure	349	EH	523	523	523	349
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	952	EH	1,429	1,429	1,429	952
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	952	LL	1,667	1,667	0	952

Overturning/Eccentricity

	Strength I-a	Strength I-b	Strength IV	Service I
M'_V	5,273	7,043	7,817	5,408
M_H	3,095	3,095	1,429	1,905

Check that $M'_V > M_H$

Strength Case I-a: M'_V = 2,784 + 1,966 + 523 = 5,273 lb*ft

M'_H = 3,095 lb*ft

$M'_V > M_H$ OK!!

All other Load Cases: OK!!

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

	Strength I-a	Strength I-b	Strength IV	Service I
F'_V	2,437	3,296	3,671	2,543
M'_V	5,273	7,043	7,817	5,408
M_H	3,095	3,095	1,429	1,905
e	0.94	0.64	0.09	0.46

Check that e < B*3/8

Strength Case I-a: e = 3.67'/2 – (5,273 lb*ft – 3,095 lb*ft)/2,437 lb = 0.94 ft.

B*3/8 = 3.67'*3/8 = 1.38 ft.

e < B*3/8 OK!!

All other Load Cases: OK!!

Interface Shear

μ = tan(35.2°) = 0.705

	Strength I-a	Strength I-b	Strength IV	Service I
F_H	1,270	1,270	714	794
F_V	2,676	3,618	3,993	2,781
ι_{ult}	362	362	362	362
μ	0.71	0.71	0.71	0.71
ϕ_τ	0.9	0.9	0.9	0.9
R'_s	2,025	2,623	2,861	2,091

Check that min $R'_s > F_H$

Strength Case I-a: R'_s = (362 lb + 0.705*2,676 lb)*0.9 = 2,025 lb

R'_s = 2,025 lb > F_H = 1,270 lb OK!!

All other Load Cases: OK!!

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Internal Analysis

For 3 ft. tall segment representing the top course.

Table of Unfactored Forces & Moments

	Force (lb)	x (ft)	Moment about toe (lb*ft)
Vertical Forces			
weight of wall	1,346	1.90	2,551
modified weight	1,227	1.90	2,325
earth pressure	22	3.78	85
DL surcharge	0	3.83	0
Horizontal Forces			
earth pressure	119	1.00	119
DL surcharge	0	1.50	0
LL surcharge	159	1.50	238

Table of Calculated Factored Forces (lbs)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	750	DC	675	938	1,125	750
aggregate weight	596	EV	596	804	804	596
modified agg weight	477	EV	477	643	643	477
earth pressure	22	EH	34	34	34	22
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	119	EH	179	179	179	119
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	159	LL	278	278	0	159

Project	Project #	Date
LRFD Example Calculation	08110.04	9/24/09

Table of Calculated Factored Moments (lb*ft)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
block weight	1,422	DC	1,280	1,777	2,133	1,422
aggregate weight	1,129	EV	1,129	1,524	1,524	1,129
modified agg weight	903	EV	903	1,220	1,220	903
earth pressure	85	EH	127	127	127	85
DL surcharge	0	DL/ES	0	0	0	0
Horizontal Forces						
earth pressure	119	EH	179	179	179	119
DL surcharge	0	DL/ES	0	0	0	0
LL surcharge	238	LL	417	417	0	238

Overturning/Eccentricity

	Strength I-a	Strength I-b	Strength IV	Service I
M'_V	2,310	3,124	3,479	2,410
M_H	595	595	179	357

Check that $M'_V > M_H$

Strength Case I-a: $M'_V = 1,280 + 903 + 127 = 2,310$ lb*ft

$M'_H = 595$ lb*ft

$M'_V > M_H$ OK!!

All other Load Cases: OK!!

	Strength I-a	Strength I-b	Strength IV	Service I
F'_V	1,185	1,614	1,802	1,249
M'_V	2,310	3,124	3,479	2,410
M_H	595	595	179	357
e	0.39	0.27	0.00	0.19

Check that e < B*3/8

Strength Case I-a: e = 3.67'/2 – (2,310 lb*ft – 595 lb*ft)/1,185 lb = 0.39 ft.

B*3/8 = 3.67'*3/8 = 1.38 ft.

e < B*3/8 OK!!

All other Load Cases: OK!!

Interface Shear

μ = tan(35.2°) = 0.705

	Strength I-a	Strength I-b	Strength IV	Service I
F_H	456	456	179	278
F_V	1,304	1,775	1,963	1,368
τ_{ult}	362	362	362	362
μ	0.71	0.71	0.71	0.71
ϕ_τ	0.9	0.9	0.9	0.9
R'_s	1,154	1,453	1,572	1,194

Check that min $R'_s > F_H$

Strength Case I-a: R'_s = (362 lb + 0.705*1,304 lb)*0.9 = 1,154 lb

R'_s = 1,154 lb > F_H = 456 lb OK!!

All other Load Cases: OK!!