Basics of Retaining Wall Design

with Matt Jensen, PE

WEBINAR
WEBINAR
WEBINAR
WEBINAR
WEBINAR

Outline

- Introduction and Purpose
- What is a Precast Modular Block
- Design Inputs
- Loads on the Wall
- Stability Analysis
- Detailing
- Best Practices

What is the importance of PMB Walls?

Introduction and Purpose

Big blocks have been used to construct walls for ages. There is something inherently simple about stacking large blocks on top of each other that just makes sense. If the blocks are big and heavy enough, they can be used to safely support retained earth and anything else that might be on top of the wall.

Recently large precast concrete blocks, often called precast modular blocks or PMBs, have become widely available and are used to build retaining wall structures. PMB walls have been used in several innovative ways, such as constructing traditional walls, walls with large batter angles, PMB-faced structures, and freestanding walls that act as fences or barriers.

PMB units are used in public projects, commercial projects, and at private projects and even though the basic concepts are simple and PMB retaining walls are easy to construct, the engineers who design them are quite unique. They must possess a wide range of skills including a firm grasp of geotechnical engineering principles, a good working knowledge of structural engineering, an understanding of site engineering, and a strong background in construction.

What is a PMB?

What is a Precast Modular Block?

- Precast Modular Block (PMB)
    - Name commonly used to describe a large retaining wall block
    - Produced from first purpose, wet-cast concrete
    - Produced per ASTM Standard Specification C1776 - Standard Specification for Wet-Cast Precast Modular Retaining Wall Units
    - Generally have water / cement ratio of between 0.40 and 0.45
    - Minimum compressive strength of 4,000 psi

What is a Precast Modular Block?

PMB units vary in size, but generally range between a few hundred pounds to several thousand pounds each. PMB units are almost exclusively set by large construction equipment.

What is a Precast Modular Block?

- Precast Modular Block (PMB)
  - Can be
    - Solid
    - Slotted
    - Hollow
  - Often they have some form of interlocking mechanism for
    - Block-to-block shear
    - Establish horizontal setback between rows

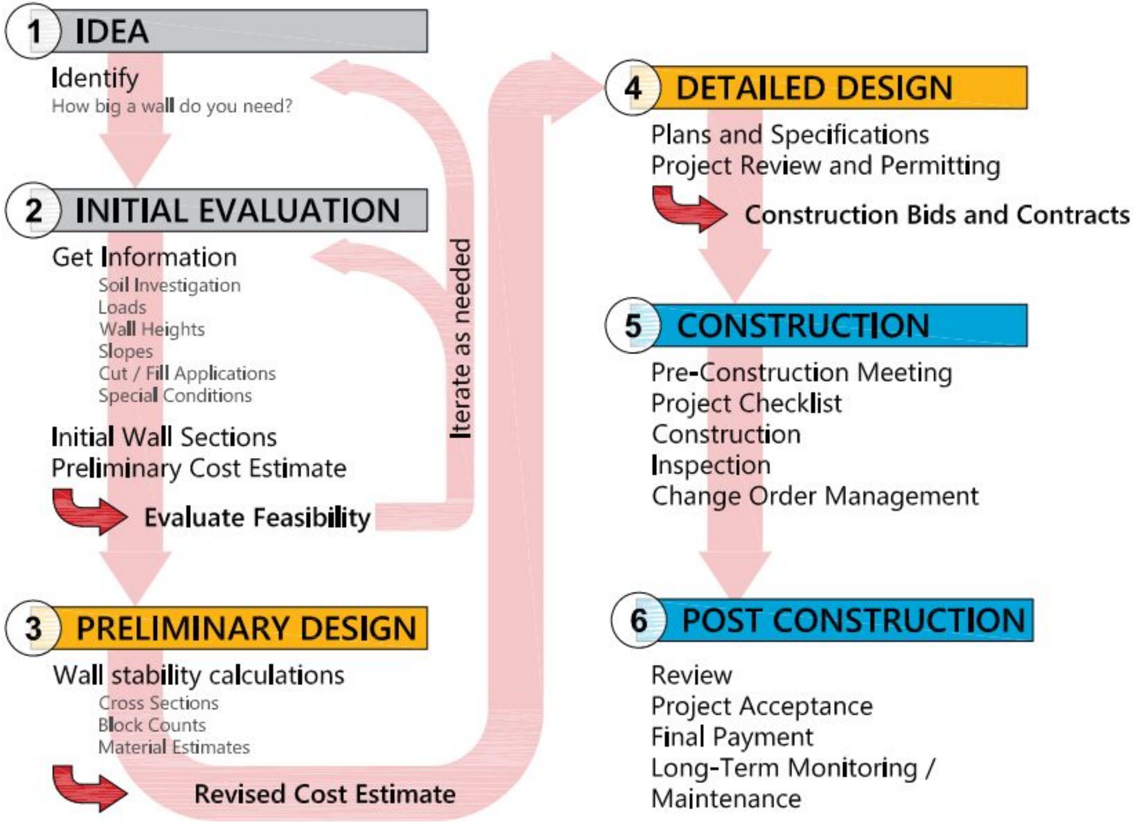
What is a Precast Modular Block?

- PMB units area typically tapered on the sides to accommodate curved wall installations.
- There are also special units which allow for construction of corners.

What are the inputs for PMB wall design?

Design Inputs

Typical Steps for Designing and Construction of a Wall



1 IDEA

Identify
How big a wall do you need?

2 INITIAL EVALUATION

Get Information
- Soil Investigation
- Loads
- Wall Heights
- Slopes
- Cut / Fill Applications
- Special Conditions

Initial Wall Sections
Preliminary Cost Estimate

Evaluate Feasibility

Iterate as needed

3 PRELIMINARY DESIGN

Wall stability calculations
- Cross Sections
- Block Counts
- Material Estimates

Revised Cost Estimate

4 DETAILED DESIGN

Plans and Specifications
Project Review and Permitting

Construction Bids and Contracts

5 CONSTRUCTION

Pre-Construction Meeting
Project Checklist
Construction
Inspection
Change Order Management

6 POST CONSTRUCTION

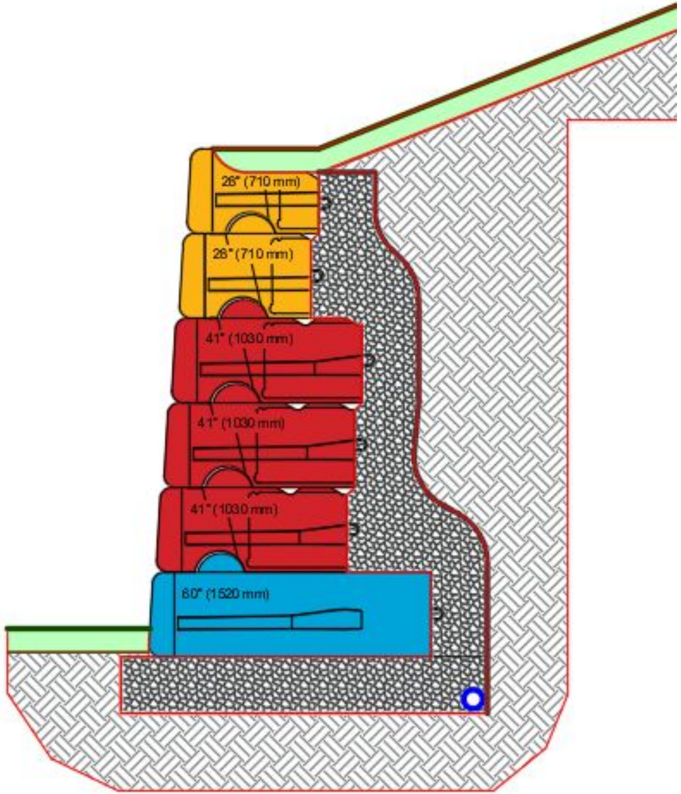
Review
Project Acceptance
Final Payment
Long-Term Monitoring / Maintenance

Design Inputs

- Information Required to Design a Wall
    - The more information available in planning and design of a retaining wall, the more likely the wall will be properly designed to meet project requirements. Design and construction of a wall with limited, incomplete, or missing information requires someone to guess at conditions. Even if missing information does not lead to a wall failure, it often results in a wall that is either underdesigned for the actual conditions and does not provide the desired level of reliability or is overdesigned and costs more than it should.

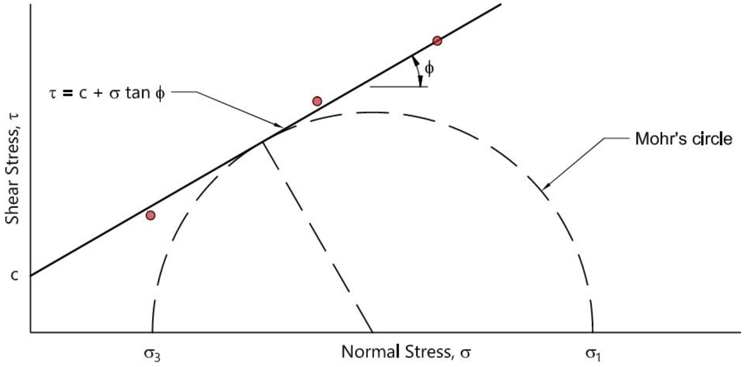
Design Inputs

- Information Required to Design a Wall
  - Wall Geometry and Site Grading
  - Detailed Geotechnical Information
  - Wall Loading
  - Leveling Pad Requirements
  - Design Requirements
  - Water Conditions
  - Unusual / Special Conditions or Requirements
  - Top of Wall Requirements
  - Site Utilities



Design Inputs

- Information Required to Design a Wall
    - Soils
        - Soils are the largest single factor that impact the wall's design, construction, and performance.
            - Unit Weight (pcf)
            - Internal Angle of Friction (°)
            - Cohesion (psf)
    - Shear Strength
        - It is the soils resistance to mass deformation from a combination of particle rolling, sliding, and crushing.
        - It is measured in terms of two parameters, internal angle of friction and cohesion, both of which can be shown by plotting a Mohr-Coulomb diagram.



Design Inputs

- Information Required to Design a Wall
  - Shear Strength
    - Internal angle of friction (Φ)
      - Is the resistance of slip between particles in the soil. Care must be taken to use an appropriate value of internal angle of friction for fine-grained soils.
    - Cohesion (c)
      - Is the measure of attraction between soil particles at no normal stress.
      - It changes with pore pressure and/or movement of the soil.
      - As a result, most wall designers ignore cohesion in wall design.

Design Inputs

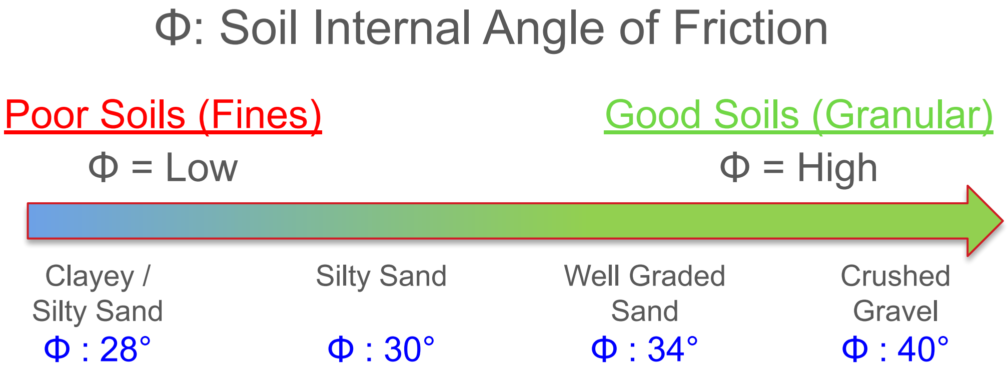
- Information Required to Design a Wall
  - Unit Weight, Density, and Compaction

    Soils are made up of solids, water, and air. The proportions of each impacts the engineering behavior of the soil. Unit weight, density, and compaction are concepts that help describe soils.

    - Unit weight - the total weight of the soil particles and water in a given volume.
    - Relative density - Often just called density of the soil is the ratio of the soil's in-place density to its maximum density.
      - Soils, especially fill soils, can be compacted to make them denser – increasing their strength and reducing potential for settlement.
      - Dense soils tend to have higher shear strength than loose soils.
      - Water plays an important role in compaction of soils, with a soil being easier to compact to a higher density at a specific “optimum” water content.

Design Inputs

- Information Required to Design a Wall
- Soil Properties
  - Unit Weight (γ)
    - Typical range for design
      - 100 pcf to 145 pcf
  - Internal angle of friction (Φ)
    - Typical range for design
      - 15° to 40°
  - Cohesion (c)
    - Typical range for design
      - 0 psf to 2,000+psf
      - However, cohesion is typically ignored in retaining wall design



Φ: Soil Internal Angle of Friction

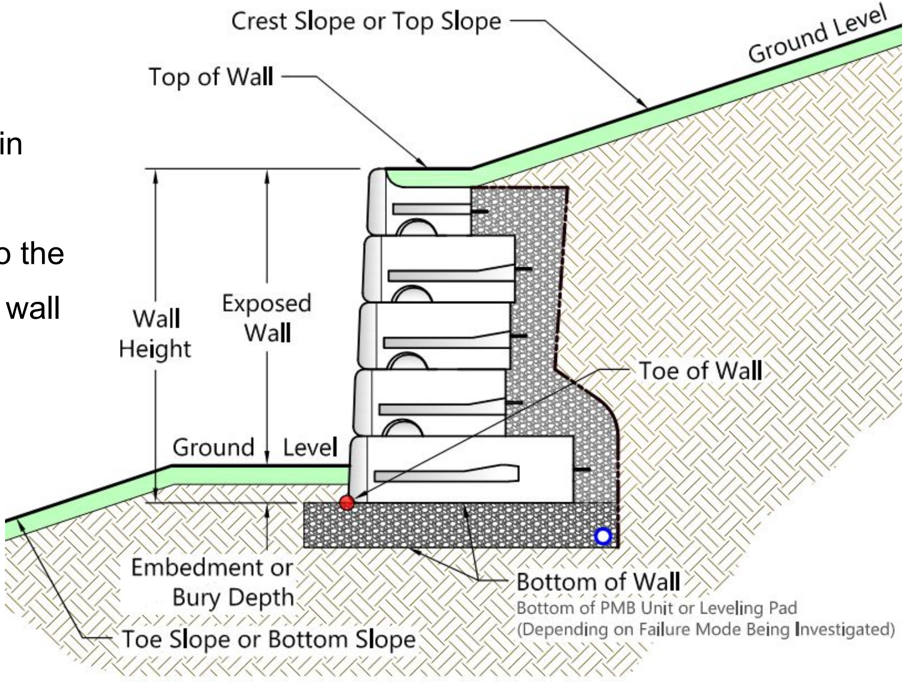
Poor Soils (Fines)
Φ = Low

Good Soils (Granular)
Φ = High

Clayey / Silty Sand	Silty Sand	Well Graded Sand	Crushed Gravel
Φ : 28°	Φ : 30°	Φ : 34°	Φ : 40°

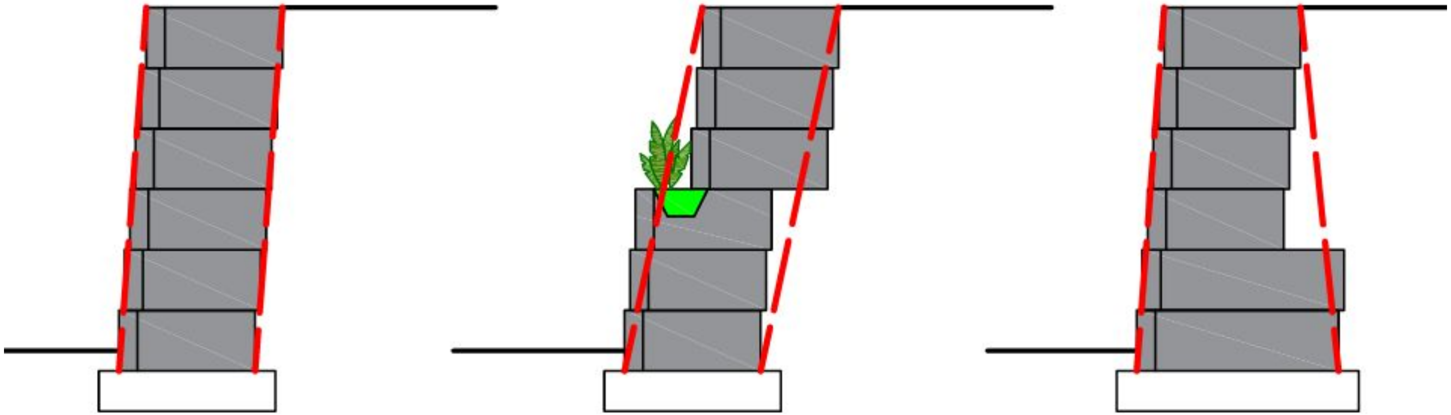
Design Inputs

- Information Required to Design a Wall
  - Wall Geometry - Nomenclature for PMB walls is similar to that used for most wall types.
    - “Top of Wall” is defined as the top of the highest PMB unit
    - “Toe of the Wall” is considered the front corner of the lowest PMB unit
    - “Embedment” or “bury depth” is the height of soil in front of the wall near the toe
    - Wall height is measured from the top of the wall to the bottom of the wall and includes both the exposed wall height and the embedment.
    - A slope at the top of the wall is called the “crest slope” or “top slope”.
    - A slope at the bottom of the wall is referred to as a “toe slope” or the “bottom slope”.



Design Inputs

- Information Required to Design a Wall
  - Batter is the average slope of the face or back of the wall.
    - There are many different block configurations. As a result, a PMB wall may have different face-of-wall and back-of-wall batters.



Design Inputs

- Information Required to Design a Wall
  - Embedment - PMB walls are designed with a minimum amount of “embedment” or bury on the bottom of the wall and aids in.
    - Bearing Resistance
    - Settlement
    - Stability.

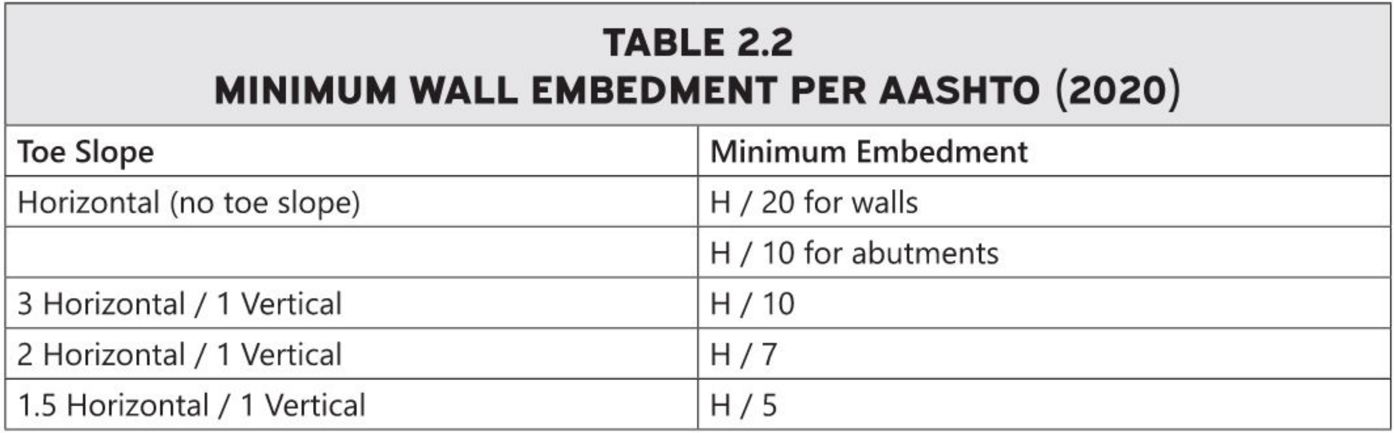


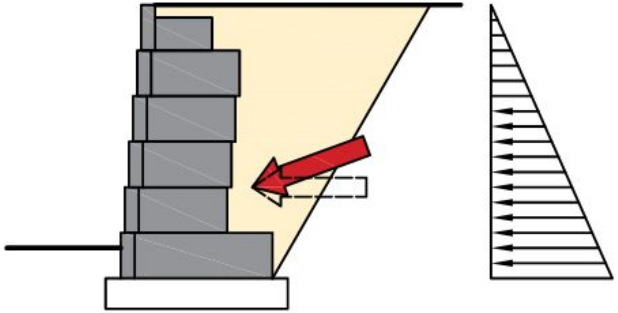
TABLE 2.2
MINIMUM WALL EMBEDMENT PER AASHTO (2020)

Toe Slope	Minimum Embedment
Horizontal (no toe slope)	H / 20 for walls
	H / 10 for abutments
3 Horizontal / 1 Vertical	H / 10
2 Horizontal / 1 Vertical	H / 7
1.5 Horizontal / 1 Vertical	H / 5

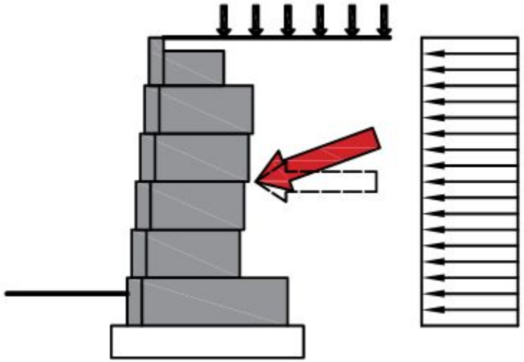
What loads act on a wall?

Loads on the Wall

- PMB Gravity walls use the weight of the wall to support retained soil and any additional loads. It can be useful to describe forces acting on the wall as either stabilizing or destabilizing.
  - Destabilizing Forces - Forces that act on the wall and attempt to move it. They include
    - Supported earth (horizontal component)
    - Surcharge loads (horizontal component)
    - Weight of supported structures (horizontal component)
    - Tiered wall systems



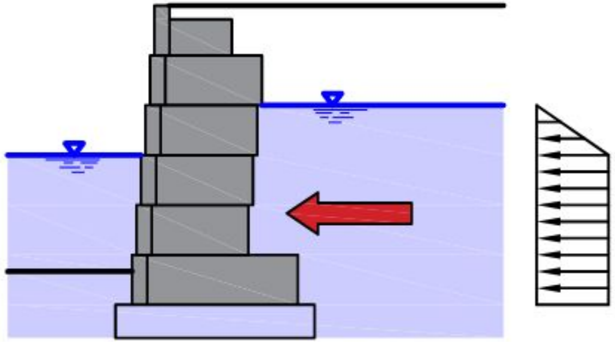
Earth Pressure (Horizontal Component)

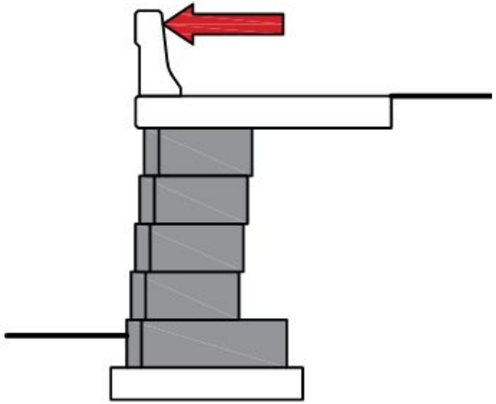


Live Load (Horizontal Component)

Loads on the Wall

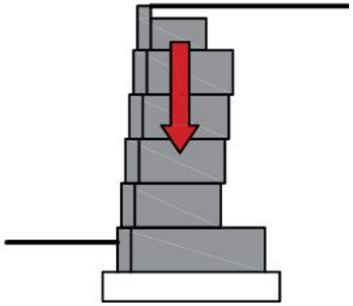
- Destabilizing Forces - Continued
    - Hydrostatic pressure
    - Impact loads from traffic barriers
    - Seismic loads
    - Forces from fences and railings that are supported by the wall


Hydrostatic Pressure

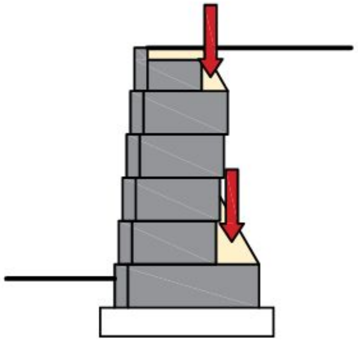

Traffic Barrier Impact

Loads on the Wall

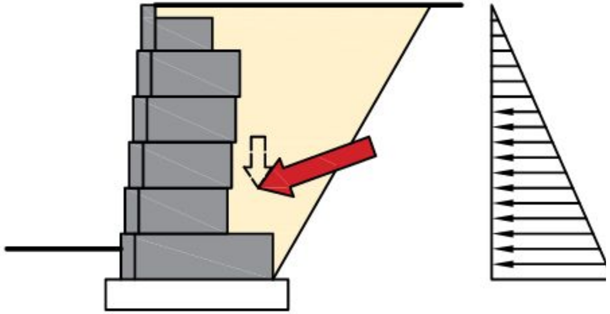
- Stabilizing Forces - Forces that act on the wall and work to keep it in place. They include.
  - Weight of PMB units (including any infill material)
  - Weight of supported soil wedges that act with the PMB units
  - Supported earth (vertical component)
  - Surcharge loads (vertical component)



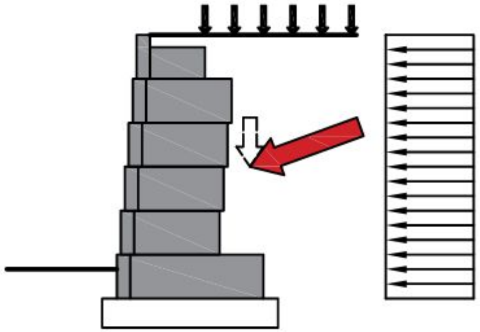
Weight of Wall



Weight of Soil Wedges



Earth Pressure (Vertical Component)



Live Load (Vertical Component)

Loads on the Wall

- Determination of Earth Pressure Acting on a Wall
  - The single most significant factor impacting the design of a retaining wall is how much pressure the retained soils exert on the wall. The most common methods for determining this pressure include
    - Equivalent Fluid Pressure
    - Rankine
    - Coulomb
    - Log-Spiral Failure Wedge
    - General Limit Equilibrium
  - For most applications, Coulomb is used to calculate active earth pressure and Rankine is used to calculate passive earth pressure.

Loads on the Wall

- Determination of Earth Pressure Acting on a Wall
    - Rankine Earth Pressure Theory
        - In 1857, Scottish engineer William Rankine developed the theory.
        - Rankine’s theory of plastic equilibrium was expanded to determine the earth pressures acting on retaining walls.
        - In the case of the wall deflecting slightly away from the soil, the soil is said to be in the active condition. The coefficient of active earth pressure, k_A, can be defined as:

$$k_A = \tan^2 (45° - \frac{\Phi'}{2})$$

where

Φ' = effective internal friction angle of the soil

Loads on the Wall

- Determination of Earth Pressure Acting on a Wall
  - Rankine Earth Pressure Theory
    - When the wall is forced into the soil (and the horizontal stress in the soil is greater than the vertical stress), the soil is said to be in the passive condition. The coefficient of passive earth pressure, k_P can then be defined as:

$$k_P = \tan^2 (45° + \frac{\Phi'}{2})$$

where

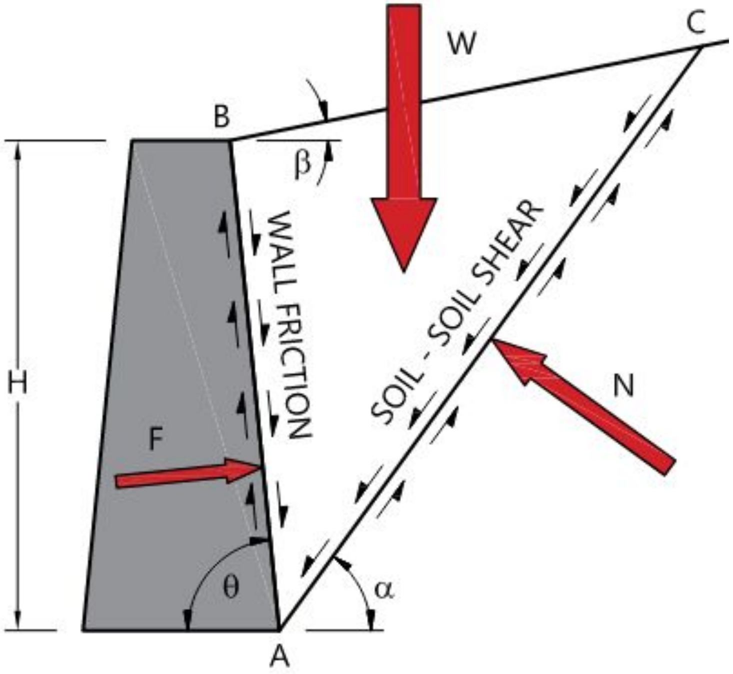
Φ' = effective internal friction angle of the soil

Loads on the Wall

- Determination of Earth Pressure Acting on a Wall
  - Coulomb Earth Pressure Theory
    - In 1776, prior to Rankine’s work on plastic equilibrium, Charles Coulomb developed a method to compute earth pressures acting on retaining walls.
    - Coulomb assumes a linear failure plane and a linear ground surface. It explicitly accounts for friction between the soil and wall, and can account for sloping backfill. Similar to Rankine’s theory, Coulomb’s theory requires that the wall move sufficiently to mobilize the shear strength of the soil.

Loads on the Wall

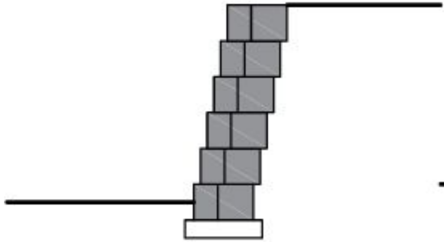
- Determination of Earth Pressure Acting on a Wall
  - Coulomb active failure condition assumes the following for a cohesionless soil
    - An assumed failure plane behind the wall at an angle α
    - The weight of the wedge of soil (W).
    - The weight of the soil wedge is resisted by the soil below the failure plane and by the wall.
    - For the wedge to form, the soil must fail in shear along the plane defined by the angle α.
    - Coulomb also considers friction between the back of the wall and the retained soil.



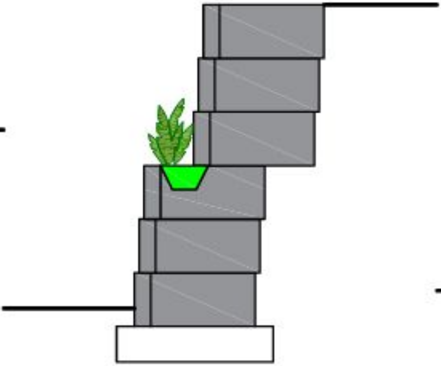

REDI-ROCK
REDI-ROCK
REDI-ROCK
REDI-ROCK
REDI-ROCK
Click to Play

Loads on the Wall

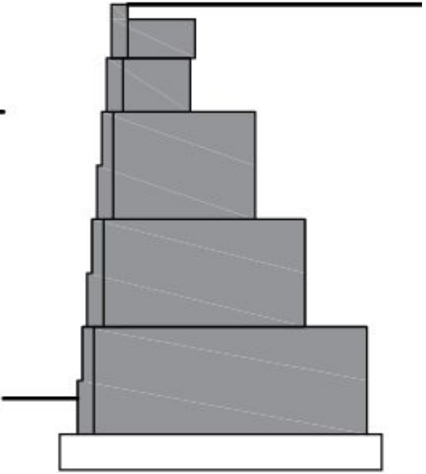
- Back-of-Wall Location
  - The earth pressure theories presented above all assume a back-of-wall condition.
  - PMB walls can have different back-of-wall conditions and the designer needs to decide how to best approximate the back of wall to determine earth pressures.



Same Size Units,
Same Unit-Unit Setbacks



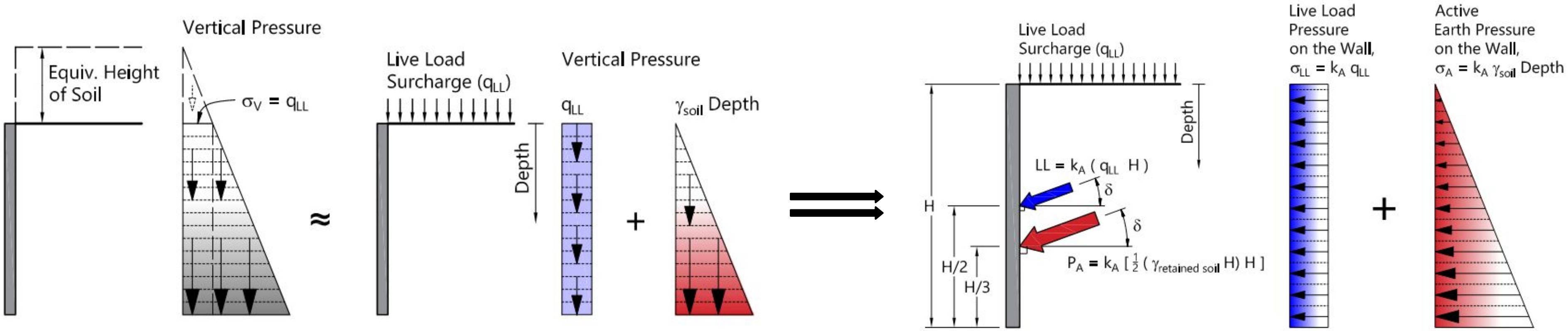
Same Size Units,
Different Unit-Unit Setbacks



Different Size Units,
Different Unit-Unit Setbacks

Loads on the Wall

- Surcharge Loads
  - Uniform Loads
    - If the loading is spread out enough that it may be considered continuous, surcharge loads can be accounted for by approximating them with an equivalent height of soil.
      - Coulomb earth pressure coefficients can be used to convert the vertical pressure to force on the retaining wall.
    - Although an equivalent height of soil is used to include the effect of surcharge loads, common practice is to separate the earth pressure and the surcharge loading in design calculations.



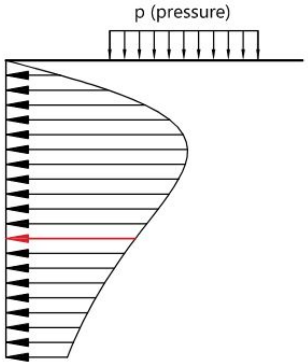
Loads on the Wall

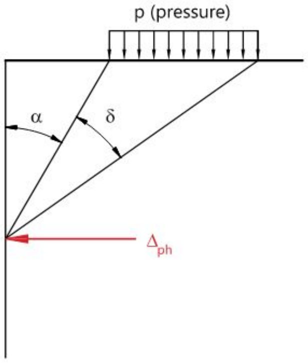
- Surcharge Loads
  - Offset Loads
    - Loads that are offset from the wall are not continuous and are not easily modeled with an equivalent height of soil. It is very common for wall designers to use Boussinesq Theory to convert strip, line, and point loads to lateral pressures.

$$\Delta_{PH} = \frac{2p}{\pi}\left[\delta - \sin\delta\ \cos(\delta + 2\alpha)\right]$$

where

Δ_{PH} = pressure on the back of the wall at a specific point (lb/ft2 or kPa)
p = uniform load intensity strip parallel to wall (lb/ft2 or kPa)
α = angle specified in Figure 3.27 (radians)
δ = angle specified in Figure 3.27 (radians)





Loads on the Wall

- Surcharge Loads
    - Offset Loads
        - Several items to note:
            - The Boussinesq equation is based on the theory of elasticity. It should not be confused with Rankine and Coulomb earth pressures which are based on the theory of plastic equilibrium.
            - The active earth pressure coefficient k_A is not used.
            - Forces are not assumed to act at the angle δ to the back of the wall.
            - The equation above is based on rigid, unyielding walls and may be very conservative for more flexible PMB walls.

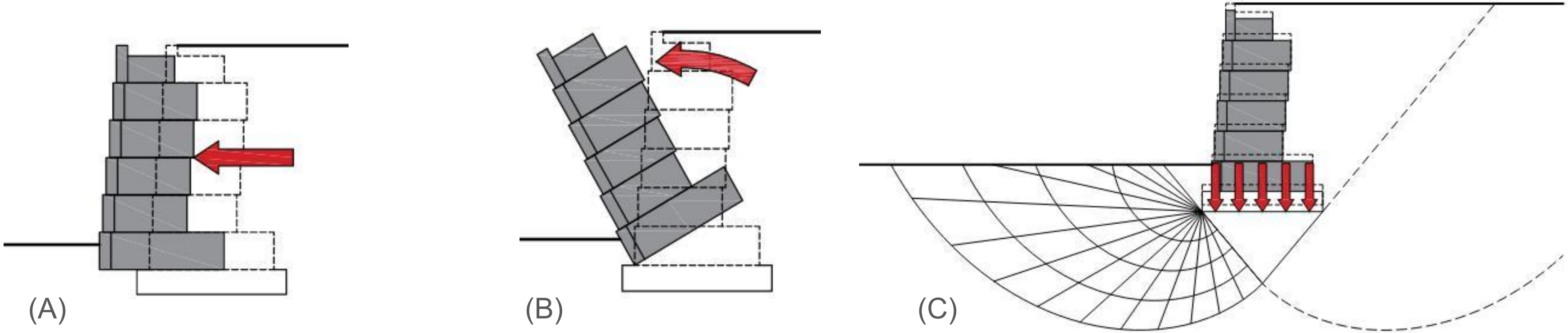
Loads on the Wall

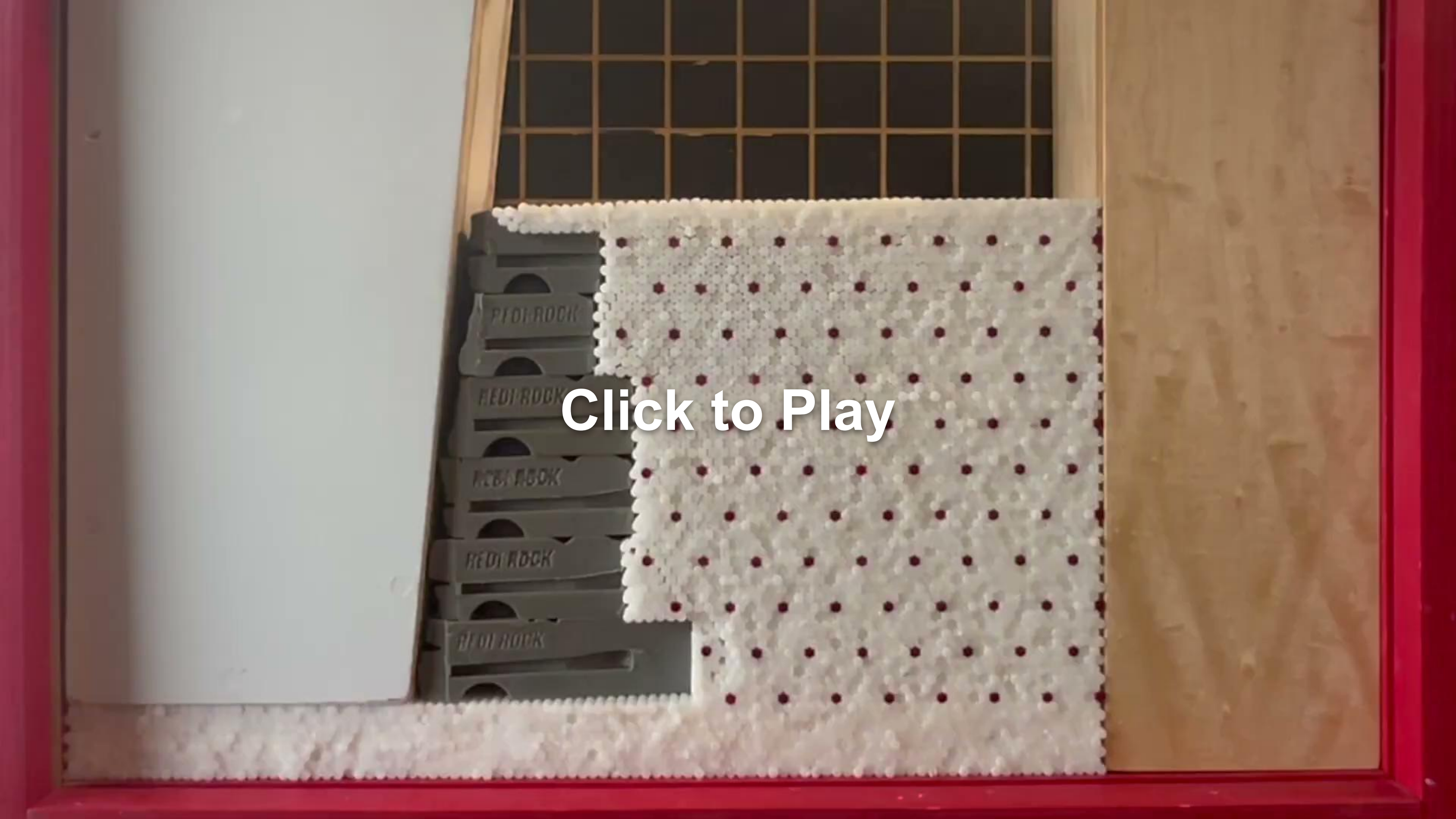
- Surcharge Loads
    - Other Loads
        - Hydrostatic Loads
        - Seismic Loads
        - Barrier Loads
            - Pedestrian Handrail Loads
            - Fences
            - Post-and-Beam Guardrails
        - Traffic Barriers for Highways
        - Buildings and Other Structures

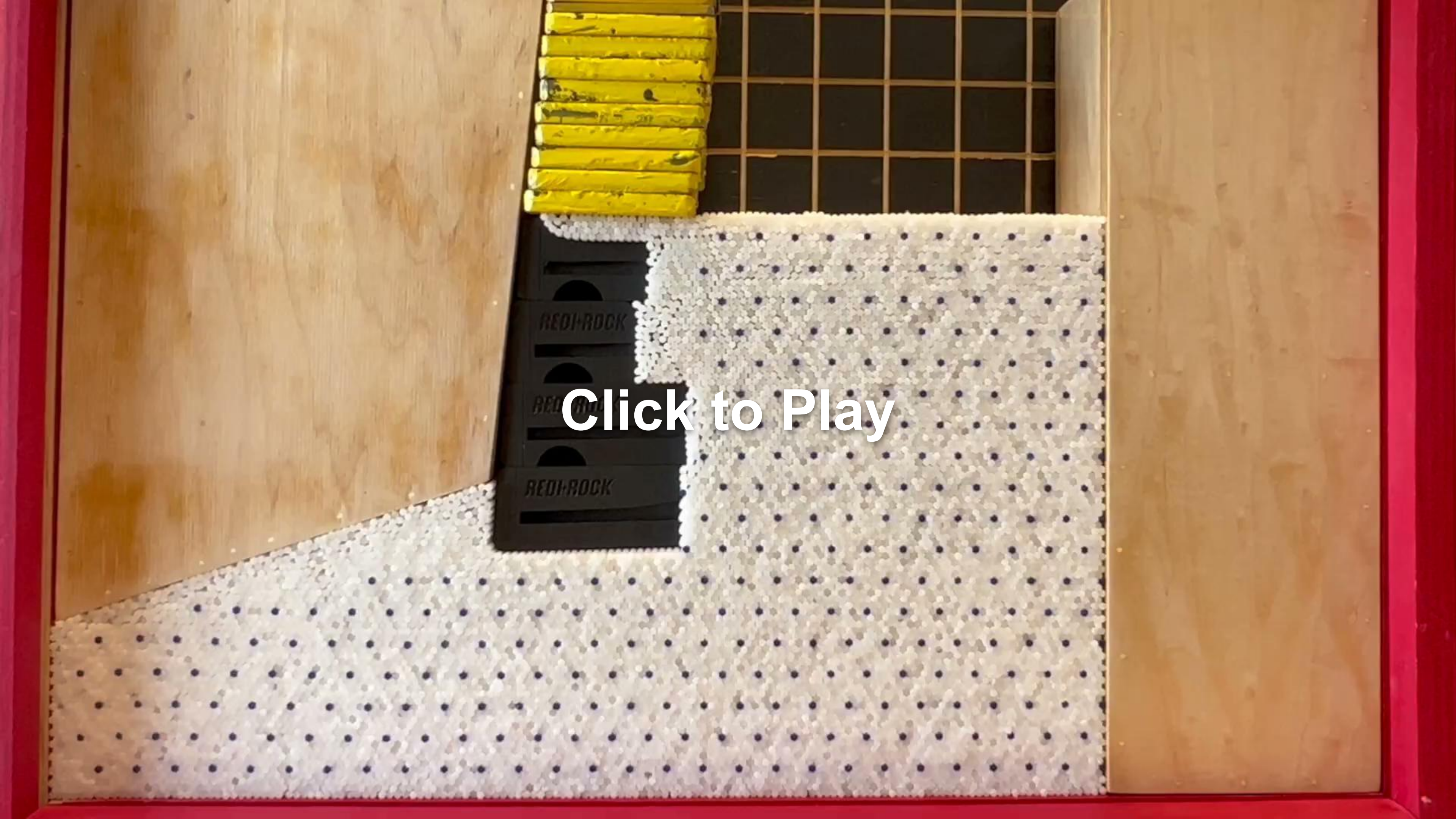
How do I analyze the stability of a wall?

Stability Analysis

- Modes of Failure
  - PMB walls use the weight of the PMB blocks and any supported soil wedges to resist destabilizing forces. Stability of the wall is analyzed by evaluating potential modes of failure. Stability can be classified as external, internal, or overall.
    - **External stability** evaluates the entire wall section. Potential external stability failure modes that must be evaluated include sliding of the wall (A), overturning of the wall (B), and bearing capacity failure of the foundation soils (C).

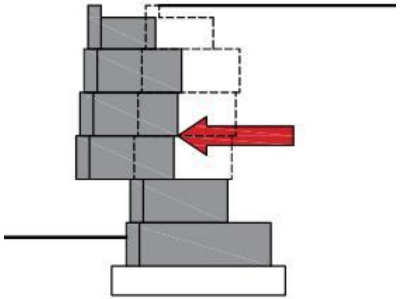



REDI ROCK
REDI ROCK
REDI ROCK
REDI ROCK
REDI ROCK
Click to Play

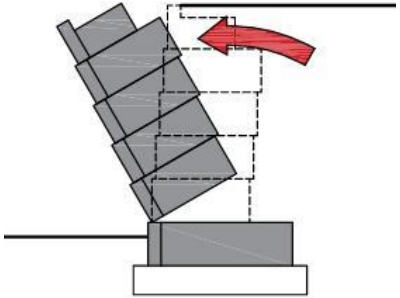

REDI-ROCK
REDI-ROCK
REDI-ROCK
Click to Play

Stability Analysis

- Modes of Failure
  - PMB Walls are made from discrete units and are not solid or rigid structures. As a result, stability needs to be analyzed at each row of PMB units.
    - **Internal stability** evaluates each section from that particular row of PMB units to the top of the wall. Potential internal stability failure modes that must be evaluated include sliding between rows of PMB units (D) and overturning of the upper section of a wall (E).



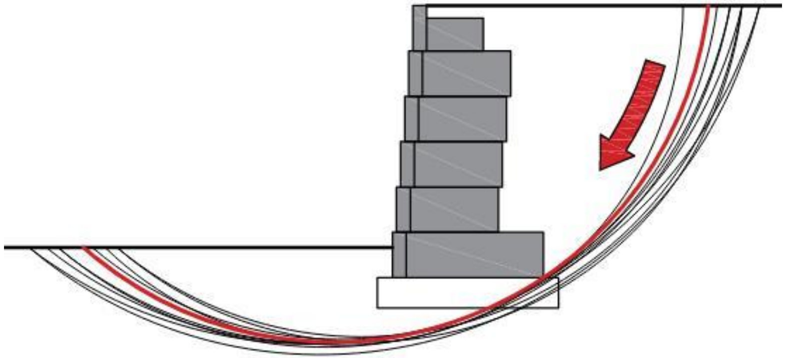
(D)



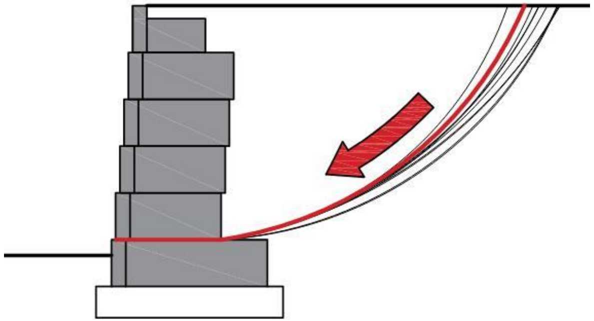
(E)

Stability Analysis

- Modes of Failure
    - **Overall stability** is also commonly referred to as “global stability” (F). Overall, or global stability evaluates the entire slope containing the wall. Potential overall stability failure modes include failure of the slope below, behind, and above the retaining wall. A subset of overall stability calculations is called “internal compound stability” (G) and considers failure of the slope above the wall, with the failure surface passing through the wall.



(F)



(G)


REDI-ROCK
REDI-ROCK
REDI-ROCK
REDI-ROCK
Click to Play

Stability Analysis

- Allowable Stress Design and Load and Resistance Factor Design
  - When performing a stability analysis, the wall designer must establish criteria to determine if the proposed wall is acceptable to resist the forces that will be acting on it and estimate the reliability of the analysis. The two methods used are
    - Allowable Stress Design (ASD)
    - Load and Resistance Factor Design (LRFD).
  - Nominal loads and forces, such as the weight of the PMB units and earth pressure force acting on the wall, are calculated for both cases. The difference between ASD and LRFD is what the designer does with the nominal loads.

Stability Analysis

- Allowable Stress Design and Load and Resistance Factor Design
    - In **Allowable Stress Design**, nominal values of the stabilizing forces or moments are divided by nominal values of destabilizing forces or moments to determine a Factor of Safety (FS). If the calculated FS is greater than a minimum value, the wall is considered acceptable to resist that particular failure mode.
    - Commonly accepted factors of safety for gravity walls has been established and is listed in Table 4.1 in the PMB Manual.

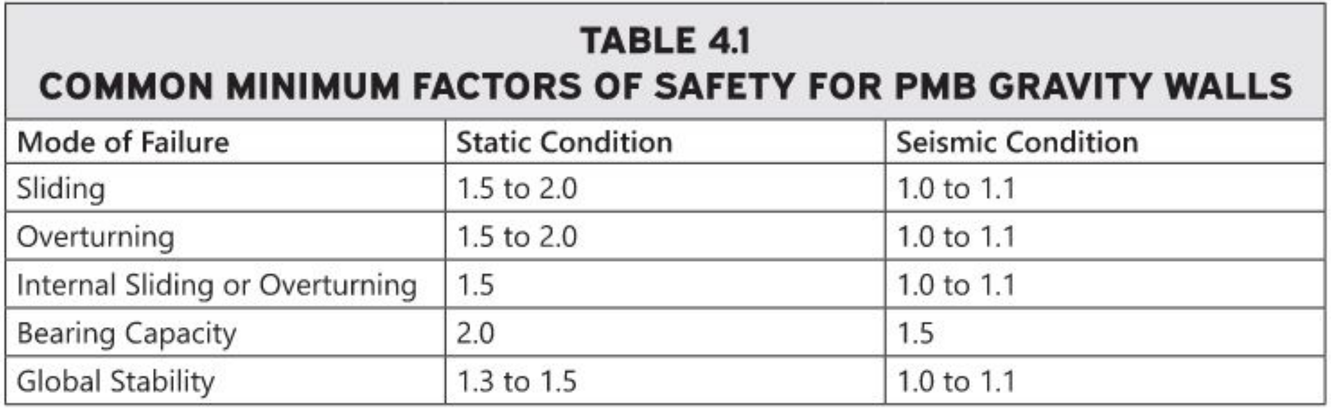


TABLE 4.1
COMMON MINIMUM FACTORS OF SAFETY FOR PMB GRAVITY WALLS

Mode of Failure	Static Condition	Seismic Condition
Sliding	1.5 to 2.0	1.0 to 1.1
Overturning	1.5 to 2.0	1.0 to 1.1
Internal Sliding or Overturning	1.5	1.0 to 1.1
Bearing Capacity	2.0	1.5
Global Stability	1.3 to 1.5	1.0 to 1.1

Stability Analysis

- Allowable Stress Design and Load and Resistance Factor Design
  - In **Load and Resistance Factor Design**, statistically-derived factors are used to both increase the loads acting on a wall and reduce the resistance provided by the wall.
  - Factored loads are divided by factored resistances to determine a Capacity Demand Ratio (CDR). If the CDR is greater than one, the wall is considered acceptable to resist that particular failure mode.
  - In wall design, LRFD is further complicated by the fact that select load factors have maximum and minimum values. This requires that stability analyses be conducted for all possible combinations of load factors.

Stability Analysis

- Allowable Stress Design and Load and Resistance Factor Design
    - **LRFD** - Load and resistance factors are available in AASHTO (2020) and FHWA (2009). Example load combinations are provided in Table 4.2 in the PMB Manual.

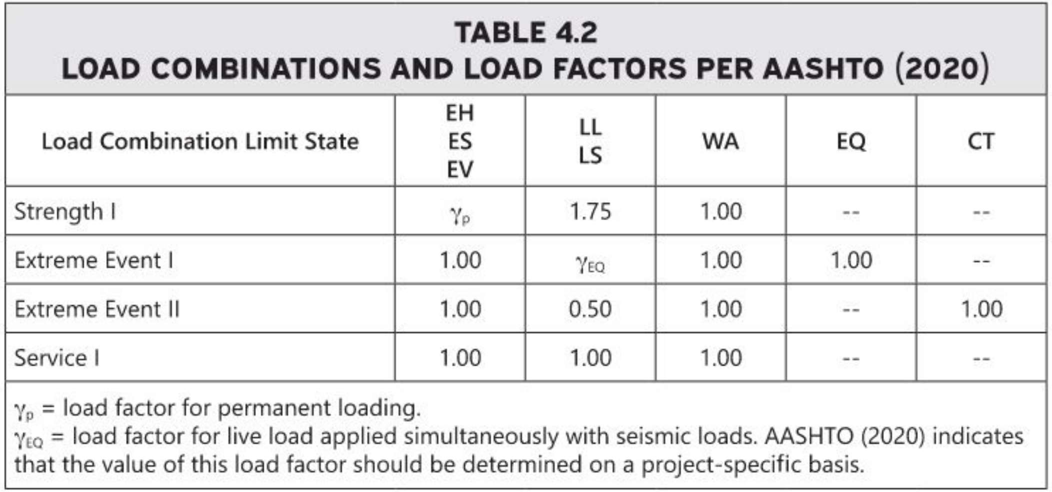
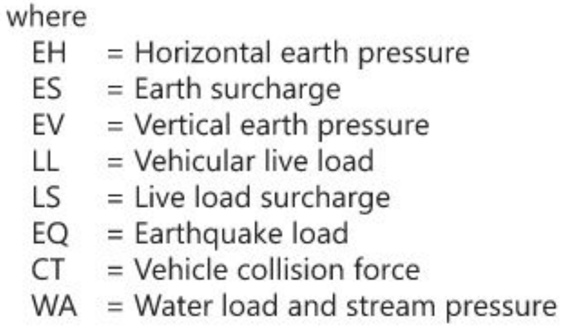


TABLE 4.2
LOAD COMBINATIONS AND LOAD FACTORS PER AASHTO (2020)

Load Combination Limit State	EH ES EV	LL LS	WA	EQ	CT
Strength I	γ_p	1.75	1.00	--	--
Extreme Event I	1.00	γ_{EQ}	1.00	1.00	--
Extreme Event II	1.00	0.50	1.00	--	1.00
Service I	1.00	1.00	1.00	--	--

γ_p = load factor for permanent loading.
γ_{EQ} = load factor for live load applied simultaneously with seismic loads. AASHTO (2020) indicates that the value of this load factor should be determined on a project-specific basis.



where
EH = Horizontal earth pressure
ES = Earth surcharge
EV = Vertical earth pressure
LL = Vehicular live load
LS = Live load surcharge
EQ = Earthquake load
CT = Vehicle collision force
WA = Water load and stream pressure

Stability Analysis

- Allowable Stress Design and Load and Resistance Factor Design
    - **LRFD** - Load factors are provided in Table 4.3 of the PMB Manual.

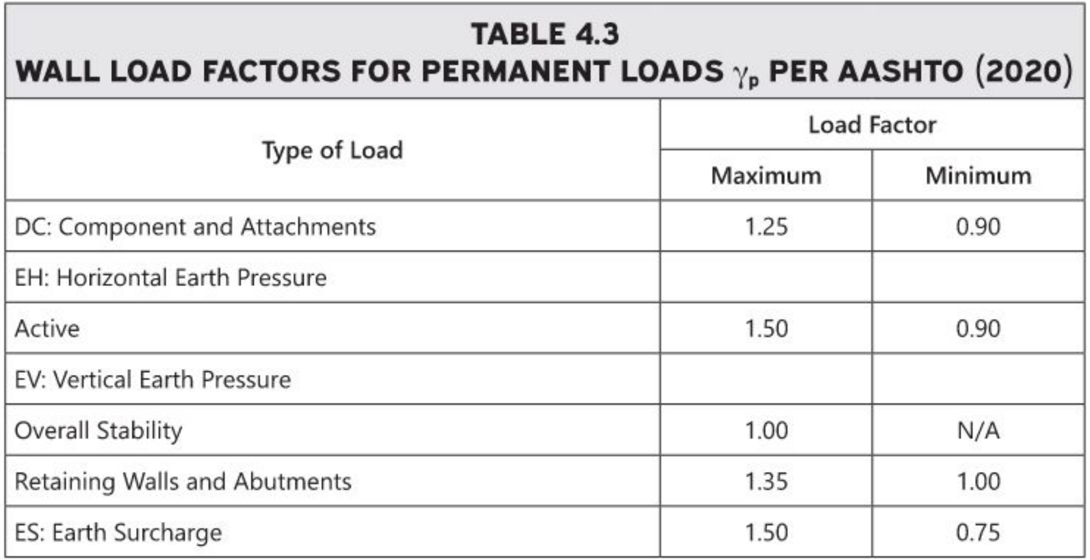


TABLE 4.3
WALL LOAD FACTORS FOR PERMANENT LOADS γ_p PER AASHTO (2020)

Type of Load	Load Factor	
	Maximum	Minimum
DC: Component and Attachments	1.25	0.90
EH: Horizontal Earth Pressure		
Active	1.50	0.90
EV: Vertical Earth Pressure		
Overall Stability	1.00	N/A
Retaining Walls and Abutments	1.35	1.00
ES: Earth Surcharge	1.50	0.75

Stability Analysis

- Allowable Stress Design and Load and Resistance Factor Design
    - **LRFD** - Resistance factors are provided in Table 4.4 of the PMB Manual.

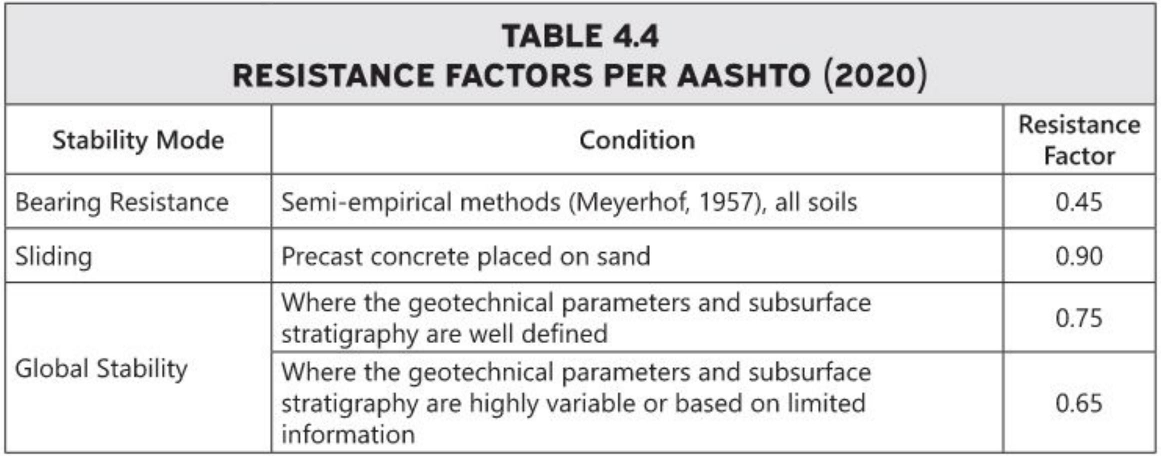


TABLE 4.4
RESISTANCE FACTORS PER AASHTO (2020)

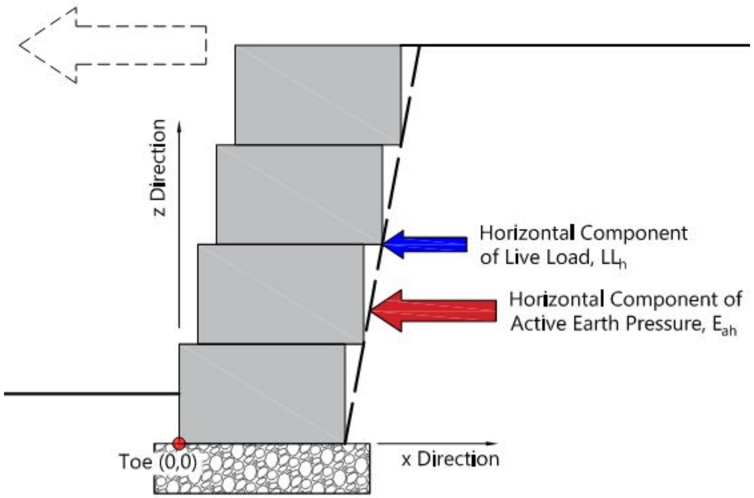
Stability Mode	Condition	Resistance Factor
Bearing Resistance	Semi-empirical methods (Meyerhof, 1957), all soils	0.45
Sliding	Precast concrete placed on sand	0.90
Global Stability	Where the geotechnical parameters and subsurface stratigraphy are well defined	0.75
	Where the geotechnical parameters and subsurface stratigraphy are highly variable or based on limited information	0.65

Stability Analysis

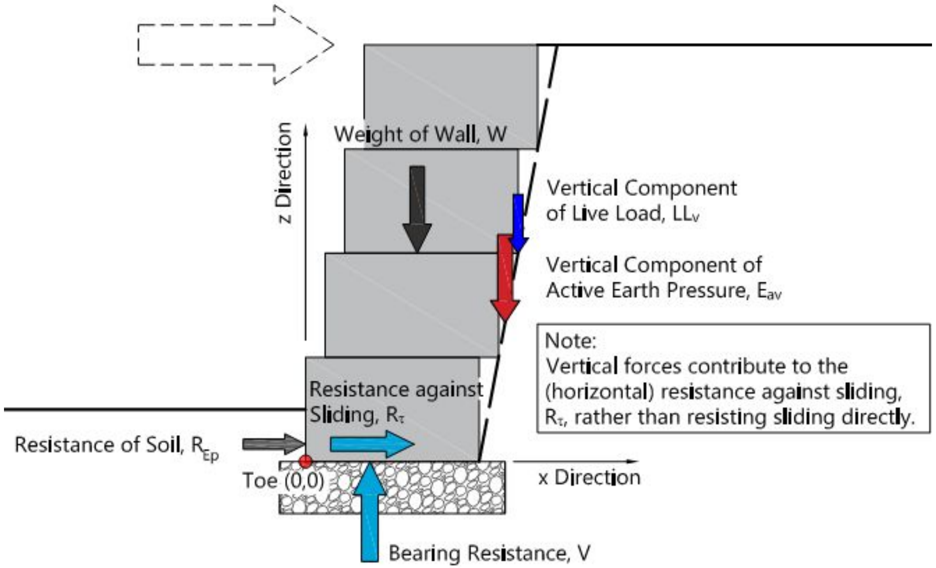
- External Sliding Stability
  - External sliding stability calculations are performed to ensure the wall is substantial enough to keep from being moved by the supported soil and any other applied loads.
  - Driving forces that would cause sliding typically include
    - The horizontal component of the earth pressure force
    - The horizontal component of the force from supported surcharge loads.
    - Other less common driving forces may include
      - water pressure
      - pedestrian loading on handrails
      - Impact forces from vehicle barriers
      - Earthquake loads.
  - Sliding is resisted by
    - Friction
    - Shear strength of the foundation soils

Stability Analysis

- External Sliding Stability
    - Example wall



Forces that produce sliding



Note:
Vertical forces contribute to the (horizontal) resistance against sliding, R_τ, rather than resisting sliding directly.

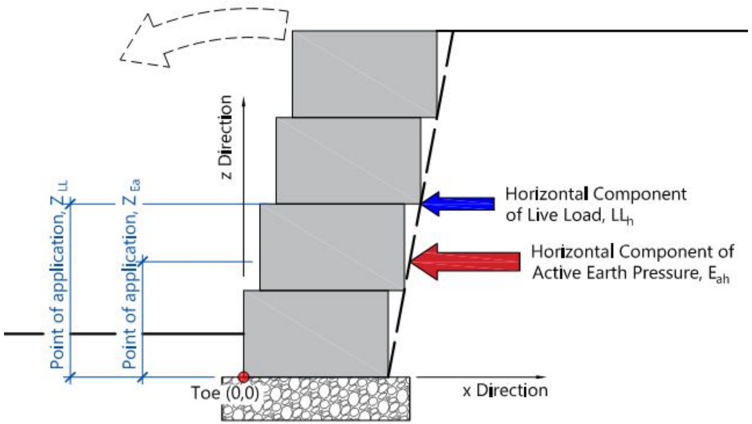
Forces that resist sliding

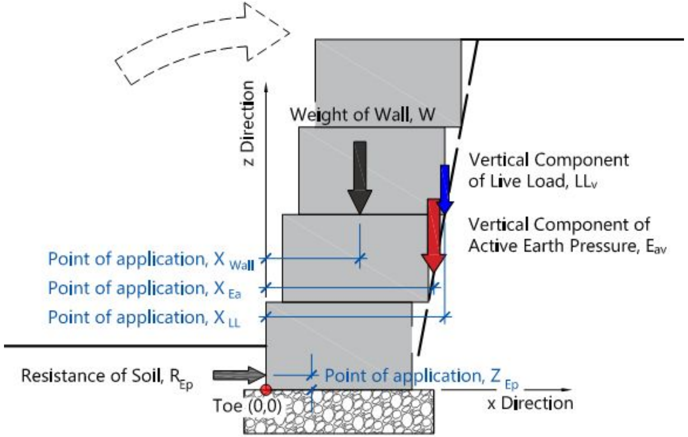
Stability Analysis

- External Sliding Stability
    - The PMB Manual goes into more detail on external sliding considering the following conditions.
        - Resistance Against Sliding for Cohesionless Soils
        - Resistance Against Sliding for Soils with Cohesion
        - Resistance of the Soil in Front of the PMB Wall

Stability Analysis

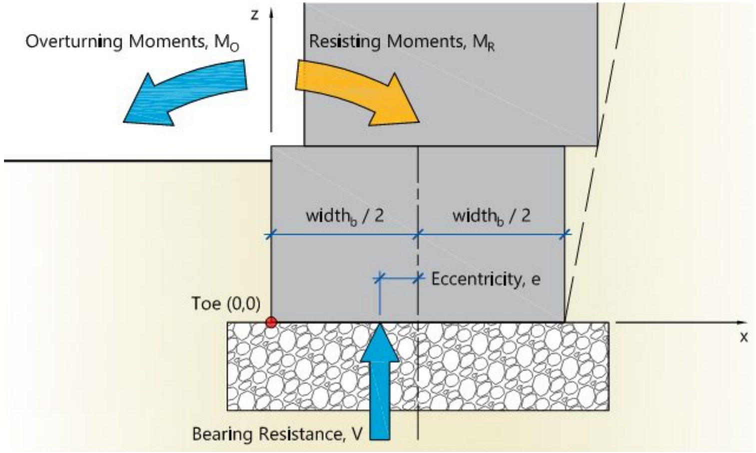
- External Overturning Stability
  - External overturning stability calculations are performed to ensure the wall is big enough to keep from being tipped over by the supported soil and any other applied loads.
  - In overturning calculations, we determine overturning and resisting moments separately. Standard practice in wall design is to ignore bearing resistance forces acting on the wall from the supporting soils when performing the external overturning stability analysis.





Stability Analysis

- Eccentricity
  - Eccentricity and overturning are related concepts. For a wall to keep from moving, the vertical loads are resisted by an equal and opposite force provided by the foundation soils.
  - If we include bearing resistance of the foundation soils in addition to overturning and resisting moments, we can determine the distance from the center of the wall that the bearing resistance force has to act for the sum of moments to be zero and prevent the wall from rotating.
  - This distance from the center the wall to the bearing resistance force is called eccentricity.
  - Some wall designers will use an eccentricity limit instead of overturning to evaluate stability. AASHTO (2020) requires the resultant bearing resistance force to be located within the middle two-thirds of the base width



Stability Analysis

- Bearing Capacity
  - Bearing capacity checks to determine whether or not the foundation soils will adequately support the wall.
  - Analysis of footings subject to both vertical load and moments. Pressure distribution under the footing is trapezoidal in shape, with the overturning moment producing higher pressures on one end of the footing.
  - Some analyses will simplify this by approximating the pressure as a rectangular shape and applying it over a reduced portion of the footing. The reduced width or effective footing width at the bottom of the retaining wall is calculated with the following equation.

$$B' = B - 2e$$

where

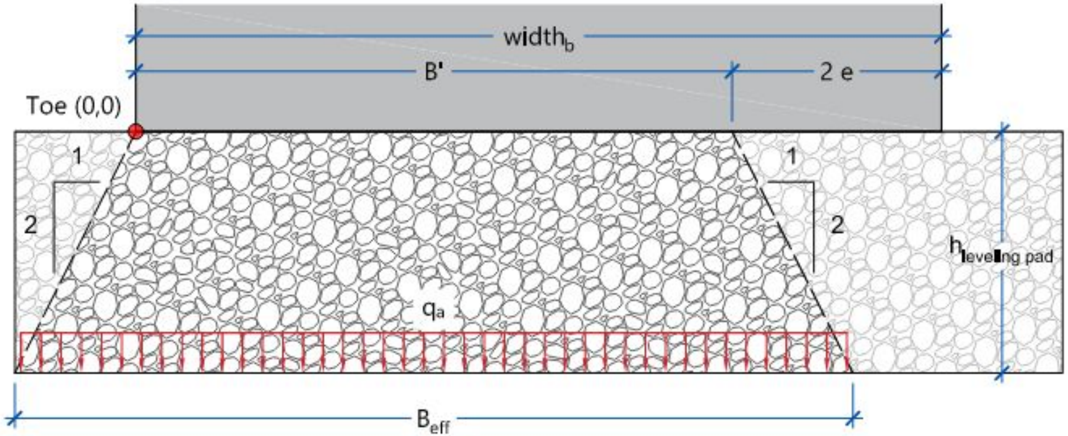
B' = effective footing width at the bottom of the bottom PMB unit (ft) or (m)

B = width of the bottom PMB unit (ft) or (m)

e = eccentricity of the bearing resistance loads (ft) or (m)

Stability Analysis

- Bearing Capacity
  - The total vertical loads on the wall are applied over the reduced footing width to calculate a uniformly distributed vertical stress at the bottom of the PMB units.
  - The vertical stress at the bottom of the units (σ_V) is transferred through the granular leveling pad and acts on the foundation soils. It is commonly assumed that the stress spreads through the stone at an angle of 1 horizontal to 2 vertical.



Stability Analysis

- Bearing Capacity
  - Equations to calculate bearing capacity of foundation soils have been developed by Terzaghi, Meyerhof, and others. The basic form of the equation is below.

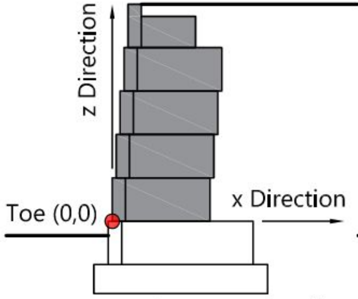
$$q_{ultimate} = c\, N_c\, s_c + q\, N_q\, s_q + 0.5\, \gamma\, B\, N_\gamma\, s_\gamma$$

  - Wall designers often make the following assumptions:
    - The wall acts like a strip footing and the resulting shape factors are 1.0.
    - The impact of inclined loads has little effect on the bearing capacity and is ignored.
    - The water table is not located in close proximity to the wall.
  - For walls that do not have a toe slope below the bottom of the wall, no reduction in bearing capacity due to proximity to a slope is made. As a result, the above equation can be simplified and the bearing capacity of the foundation soils can be calculated as follows:

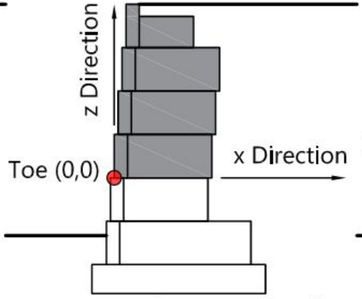
$$q_{ultimate} = c\, N_c + D_{footing}\, \gamma_q\, N_q + 0.5\, \gamma_f\, B_{eff}\, N_\gamma$$

Stability Analysis

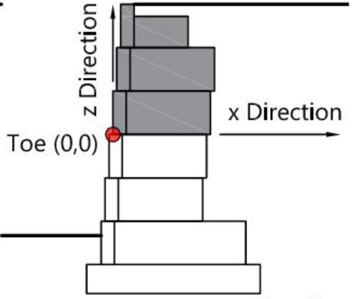
- Settlement
  - PMB walls that are built upon well compacted, coarse grained soils are typically not subject to significant settlement and their modular nature generally allows them to tolerate modest amounts of displacement.
  - As such, settlement calculations are not often performed for PMB walls. Should concerns persist, I would refer you to a geotechnical engineer for settlement analysis.
- Internal Stability
  - Internal stability calculations are similar to external stability calculations; however, instead of starting at the bottom front corner of the lowest PMB unit, calculations start at the bottom front corner of the remaining PMB units from row 2 to the top of the wall.



PMB Row 2 to Top of Wall



PMB Row 3 to Top of Wall



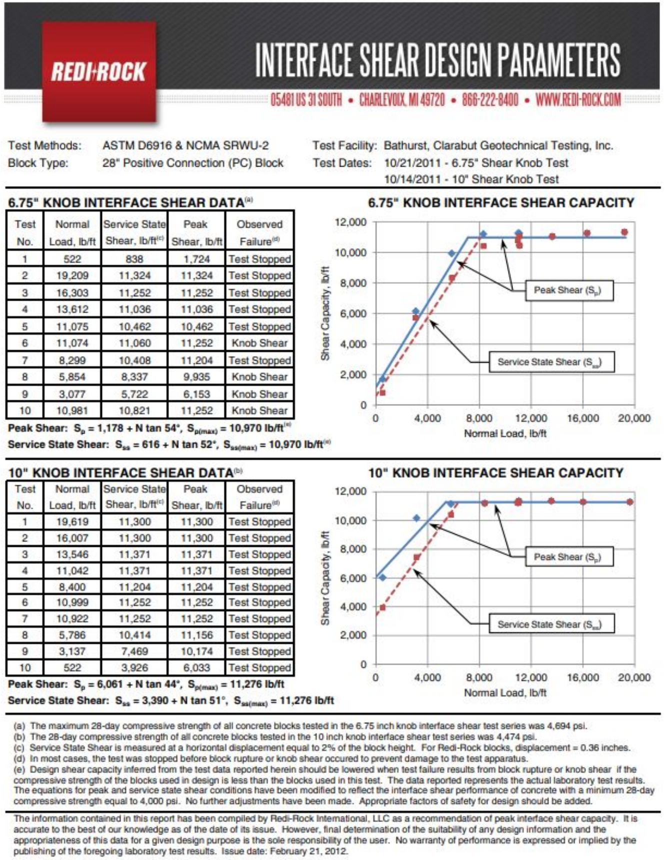
PMB Row 4 to Top of Wall

Stability Analysis

- Sliding
  - Driving and resisting forces are only calculated for the portion of the wall under evaluation in the particular internal stability check. Any pressure below the bottom row of PMB units being considered is neglected.
  - Resistance to sliding is produced by block-to-block interface shear.
  - Depending on the PMB unit, resistance may be generated from
    - Interlocking features
    - Friction between PMB units
    - Resistance to shear in granular core fill material.
  - Design values of interface shear to resist sliding between units are obtained from full scale lab testing of the units. ASTM D6916 *Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)* is followed in most PMB block-to-block interface shear testing.

Stability Analysis

- Sliding
  - Here is an example of a PMB manufacturers published results of block-to-block interface shear testing.



REDI-ROCK

INTERFACE SHEAR DESIGN PARAMETERS

05481 US 31 SOUTH • CHARLEVOIX, MI 49720 • 866-222-8400 • WWW.REDI-ROCK.COM

Test Methods: ASTM D6916 & NCMA SRWU-2
Block Type: 28" Positive Connection (PC) Block
Test Facility: Bathurst, Clarabut Geotechnical Testing, Inc.
Test Dates: 10/21/2011 - 6.75" Shear Knob Test
10/14/2011 - 10" Shear Knob Test

6.75" KNOB INTERFACE SHEAR DATA[a]

Test No.	Normal Load, lb/ft	Service State Shear, lb/ft[c]	Peak Shear, lb/ft	Observed Failure[d]
1	522	838	1,724	Test Stopped
2	19,209	11,324	11,324	Test Stopped
3	16,303	11,252	11,252	Test Stopped
4	13,612	11,036	11,036	Test Stopped
5	11,075	10,462	10,462	Test Stopped
6	11,074	11,060	11,252	Knob Shear
7	8,299	10,408	11,204	Test Stopped
8	5,854	8,337	9,935	Knob Shear
9	3,077	5,722	6,153	Knob Shear
10	10,981	10,821	11,252	Knob Shear

Peak Shear: $S_p = 1{,}178 + N \tan 54°$, $S_{p(max)} = 10{,}970$ lb/ft[e]

Service State Shear: $S_{ss} = 616 + N \tan 52°$, $S_{ss(max)} = 10{,}970$ lb/ft[e]

6.75" KNOB INTERFACE SHEAR CAPACITY

10" KNOB INTERFACE SHEAR DATA[b]

Test No.	Normal Load, lb/ft	Service State Shear, lb/ft[c]	Peak Shear, lb/ft	Observed Failure[d]
1	19,619	11,300	11,300	Test Stopped
2	16,007	11,300	11,300	Test Stopped
3	13,546	11,371	11,371	Test Stopped
4	11,042	11,371	11,371	Test Stopped
5	8,400	11,204	11,204	Test Stopped
6	10,999	11,252	11,252	Test Stopped
7	10,922	11,252	11,252	Test Stopped
8	5,786	10,414	11,156	Test Stopped
9	3,137	7,469	10,174	Test Stopped
10	522	3,926	6,033	Test Stopped

Peak Shear: $S_p = 6{,}061 + N \tan 44°$, $S_{p(max)} = 11{,}276$ lb/ft

Service State Shear: $S_{ss} = 3{,}390 + N \tan 51°$, $S_{ss(max)} = 11{,}276$ lb/ft

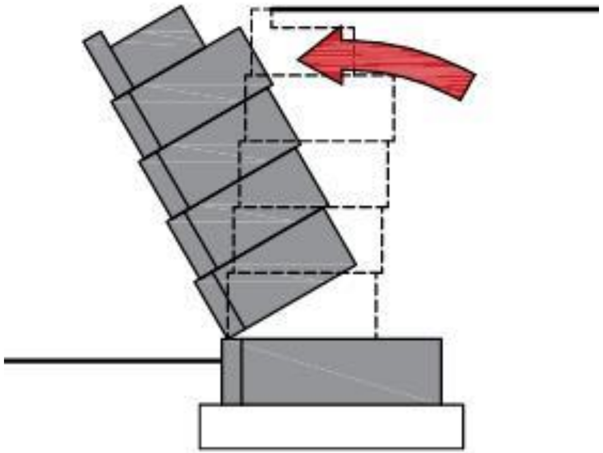
10" KNOB INTERFACE SHEAR CAPACITY

(a) The maximum 28-day compressive strength of all concrete blocks tested in the 6.75 inch knob interface shear test series was 4,694 psi.
(b) The 28-day compressive strength of all concrete blocks tested in the 10 inch knob interface shear test series was 4,474 psi.
(c) Service State Shear is measured at a horizontal displacement equal to 2% of the block height. For Redi-Rock blocks, displacement = 0.36 inches.
(d) In most cases, the test was stopped before block rupture or knob shear occured to prevent damage to the test apparatus.
(e) Design shear capacity inferred from the test data reported herein should be lowered when test failure results from block rupture or knob shear if the compressive strength of the blocks used in design is less than the blocks used in this test. The data reported represents the actual laboratory test results. The equations for peak and service state shear conditions have been modified to reflect the interface shear performance of concrete with a minimum 28-day compressive strength equal to 4,000 psi. No further adjustments have been made. Appropriate factors of safety for design should be added.

The information contained in this report has been compiled by Redi-Rock International, LLC as a recommendation of peak interface shear capacity. It is accurate to the best of our knowledge as of the date of its issue. However, final determination of the suitability of any design information and the appropriateness of this data for a given design purpose is the sole responsibility of the user. No warranty of performance is expressed or implied by the publishing of the foregoing laboratory test results. Issue date: February 21, 2012.

Stability Analysis

- Overturning
    - For internal stability checks, overturning is calculated for each row from that row to the top of the wall.
    - Even if the external stability for overturning is adequate, it is possible that the upper portion of the wall may be unstable or fail to possess the minimum desired level of reliability.



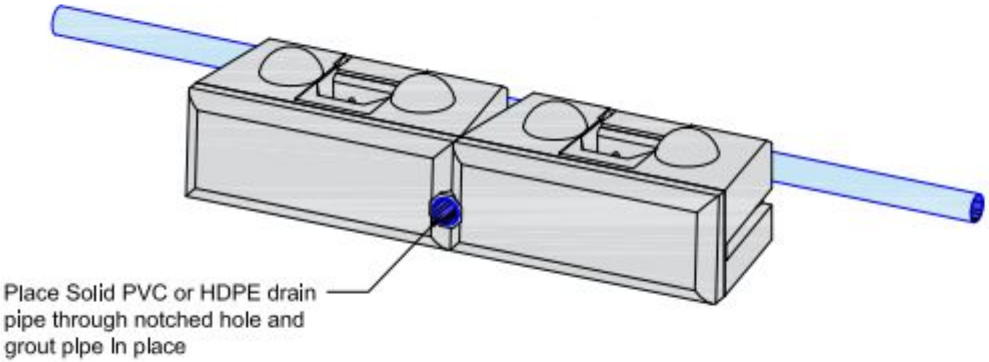
Stability Analysis

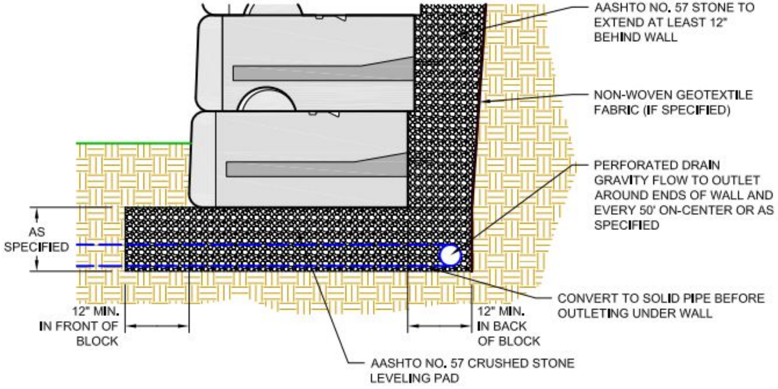
- Global Stability and Internal Compound Stability
    - Overall, or global stability, evaluates the entire slope containing the wall using a limit equilibrium analysis such as Bishop’s method.
    - Global stability calculations evaluate hundreds of potential failure surfaces to determine which produces the minimum factor of safety. Computer programs such as those below are used to perform these evaluations.
        - GEO 5 Slope stability
        - Slide
        - XSTBL
        - Slope/W
    - The design engineer of record for the wall must perform global stability calculations, unless specified otherwise.

Details & Best Practices for Walls

Detailing

- Overview
  - Proper wall design demands more than simply performing stability calculations. Often, it is specific construction details included in the design that will cause a PMB wall project to be successful or not.
  - The following list contains several details that should be included in every design, some that are specific to a particular project, and the list is likely missing specific details that may be required for a very complex project.





Detailing

- Details
  - Running Bond
  - Leveling Pad
    - Aggregate
    - Unreinforced Concrete
  - Drains
  - Slopes
    - Sloping Grade Parallel to the Wall
    - Sloping Grade Perpendicular to the Wall
  - Barriers
    - Rails and Fences
    - Traffic Barriers
      - Post-and-Beam Guardrail
      - Concrete Parapet Wall with Moment Slab
      - Parapet Walls and Moment Slab that Incorporate PMB Units

Detailing

- Details (Continued)
  - Curves and Corners
  - Utilities and Culverts
    - Dry Utilities
    - Wet Utilities
    - Pipes Installed Through the Wall
    - Culvert Headwalls
    - Vertical Slip Joint
  - Ect.

Best Practices

- Topics
    - Geotechnical Site Investigation
    - Design Parameters
    - Site Grading, Alignment, and Utilities
    - Cost Estimating
    - Selecting a Retaining Wall Design Engineer
    - Engineering Design
    - Construction

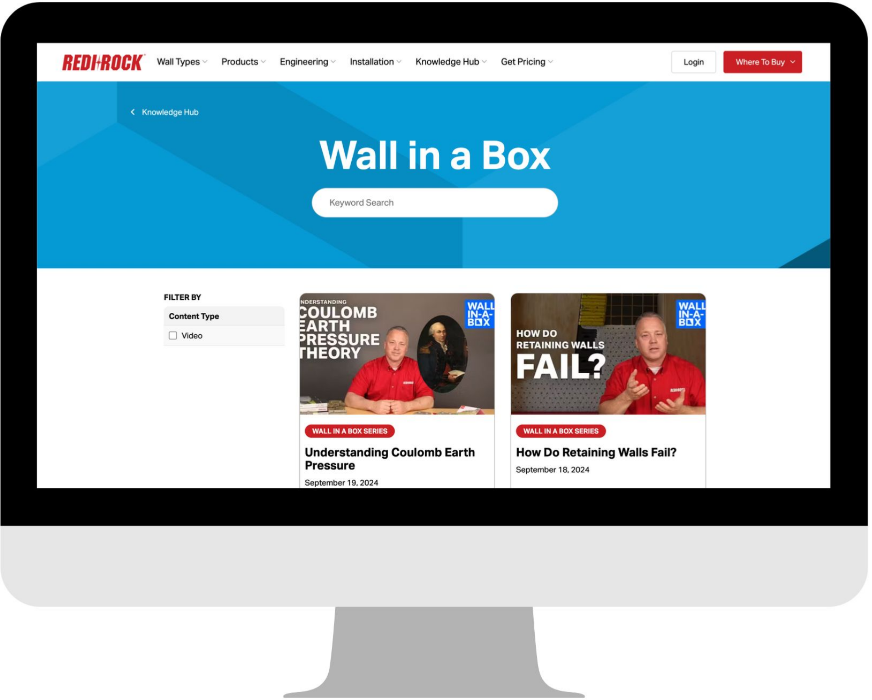
QUESTIONS?

REDI ROCK®

CONTACT US!

engineering@asterbrands.com

NEW!



Wall in a Box

FILTER BY

Content Type

☐ Video

WALL IN A BOX SERIES

Understanding Coulomb Earth Pressure

September 19, 2024

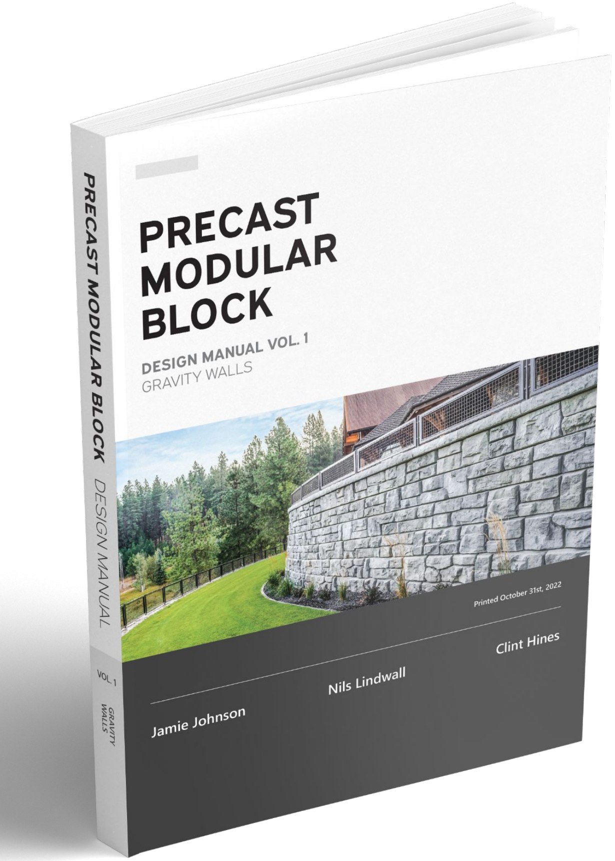
WALL IN A BOX SERIES

How Do Retaining Walls Fail?

September 18, 2024

Scan the QR code for access!

PMB Manual



PRECAST MODULAR BLOCK

DESIGN MANUAL VOL. 1

GRAVITY WALLS

Printed October 31st, 2022

Jamie Johnson

Nils Lindwall

Clint Hines

PRECAST MODULAR BLOCK DESIGN MANUAL

VOL. 1

GRAVITY WALLS

Scan the QR code to download the manual!

REDI ROCK®

Thank you!