



Sliding and Tipping Analysis of Four Foot Containment System on Dirt / Gravel

Based on Empirical Friction Data

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Overview



- This document provides a report level overview of the analysis and testing performed for the 4 foot wall system utilized in a containment application.
- Sliding and tipping are the primary failure modes addressed in this document.



Assumptions

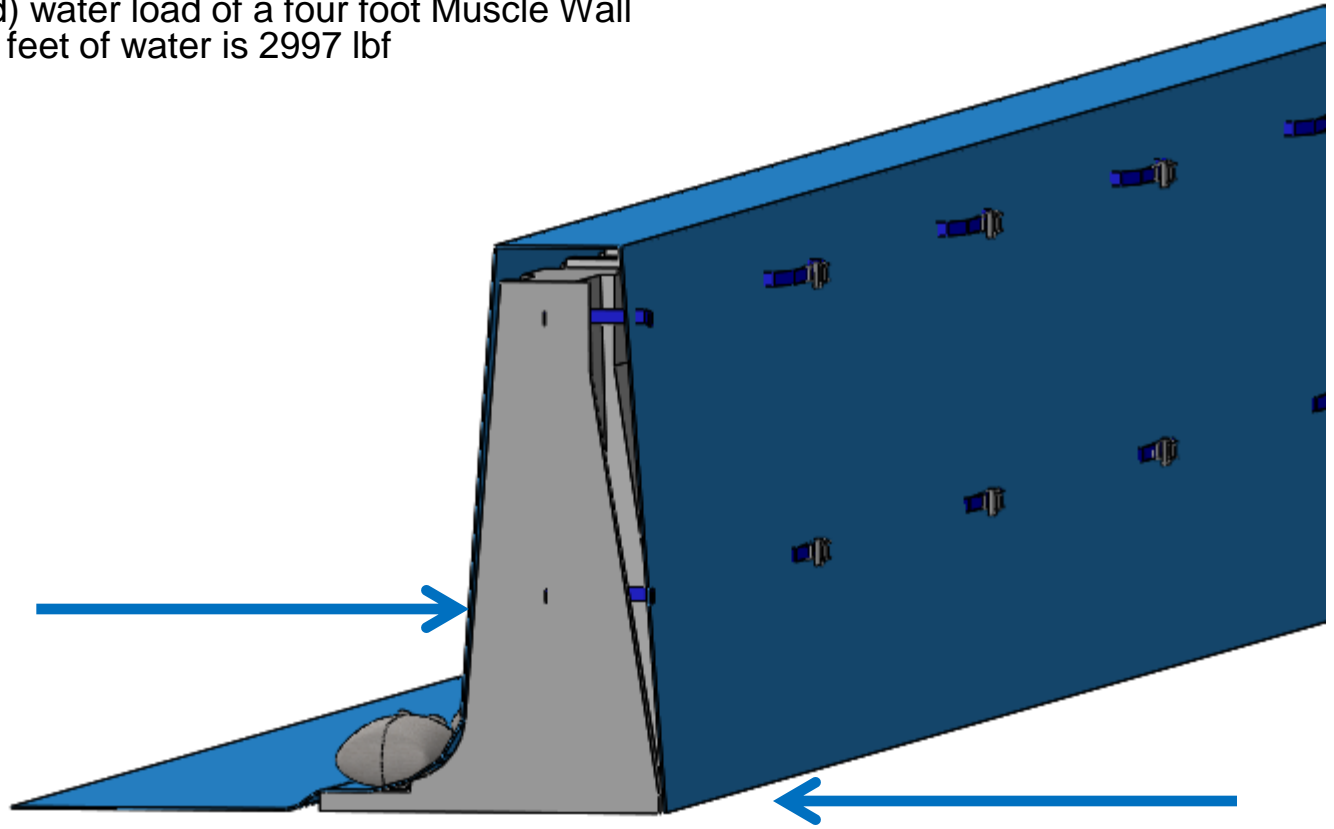


- The following assumptions apply to this analysis:
 - Product: 4 Foot Straight Wall (MW-106)
 - Wall Fill: Water
 - Contained Fluid: Water
 - Maximum Containment Water Depth: 48 inches
 - Set-up service: Dirt / gravel, assumed dry at setup.
 - Grade: Level
 - Liner: 30 mil PE
 - Liner Seal: NA
 - Liner attachment: Lower straps threaded through
 - Back Brace: None
 - Sliding anchors / aids: None

Hydrostatic Water Load



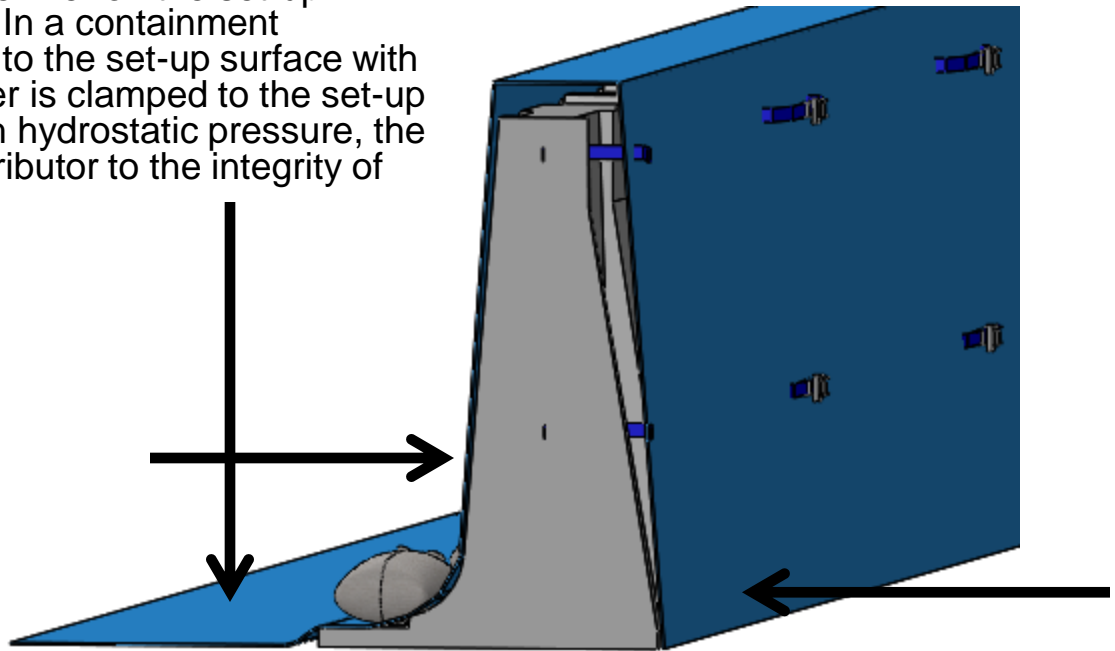
- The horizontal (outward) water load of a four foot Muscle Wall segment filled with four feet of water is 2997 lbf



Friction Components



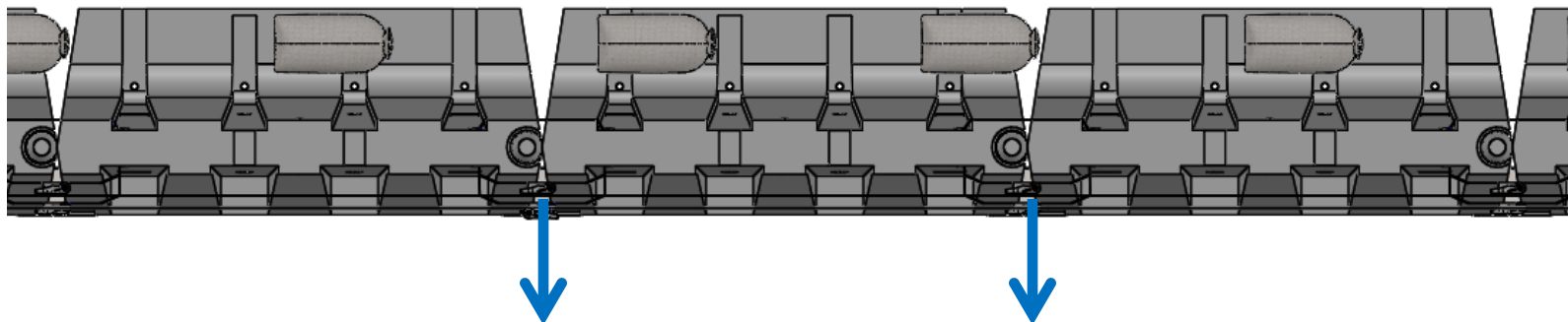
- **Resisting Friction:** Several components work together to resist the lateral force component due to the hydrostatic pressure of the water.
 - Wall Friction- The friction of the filled MuscleWall on the set-up surface is significant.
 - Liner Tension- As the water pressure force loads the Muscle Wall, the liner becomes a tension member. Its ability to carry load is limited by the material properties of the liner and by the friction of the liner on the set-up surface and on the MuscleWall. In a containment application, the liner is clamped to the set-up surface with very large forces. When the liner is clamped to the set-up surface and the MuscleWall with hydrostatic pressure, the liner becomes a significant contributor to the integrity of the system.



Empirical Friction Data



- Empirical testing was done by applying a measure pull-out force to the outside of the walls of a filled containment to determine the point of slipping.
- Slipping was defined as movement of the Muscle Wall by 0.5 inches or more. In no case during the testing was a containment failure experienced. In no case did the wall slip abruptly. Sliding was graceful and in no case was the wall, liner or liner seal compromised.
- **Conservative Loading Assumption:** The load was applied evenly to both ends of a wall segment. Because movement of the wall segment necessitates partial movement of the neighboring walls, measured load was divided by 2 assuming that 50% resistance to movement was based on the loaded wall and 50% of movement was based on the resistance of the neighbors with 25% allocated to each neighboring wall.



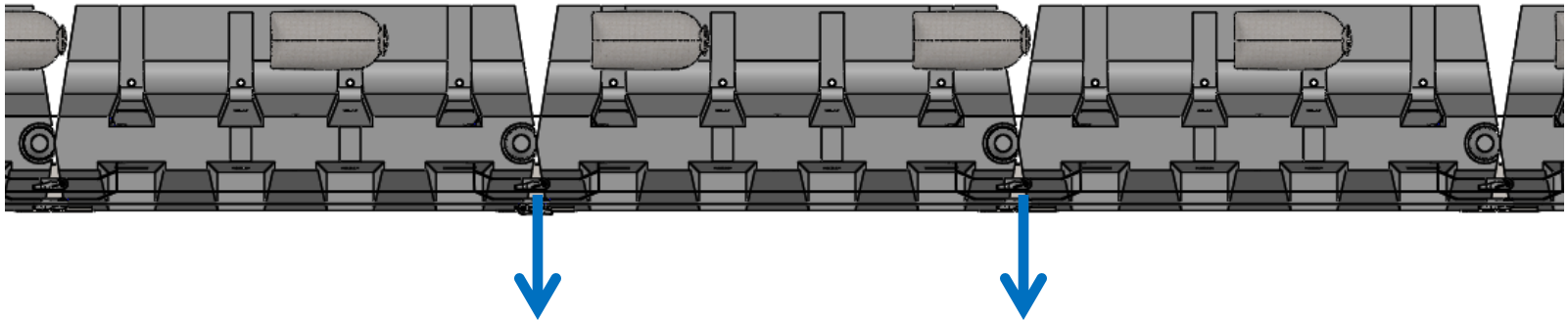
Sliding Friction Factor of Safety



- The pull-out force to achieve sliding on dry soil is 2614 lbf
 - This equates to a net force per wall of 1307 lbf
 - Note that this force acts in the same direction as the water pressure so that it is a direct measurement of the margin as testing was done with a full containment.
 - The factor of safety for a fully loaded four foot Muscle Wall segment on dry soil is therefore:

$$FS_1 = \frac{2997\text{-lbf} + 1307\text{-lbf}}{2997\text{-lbf}}$$

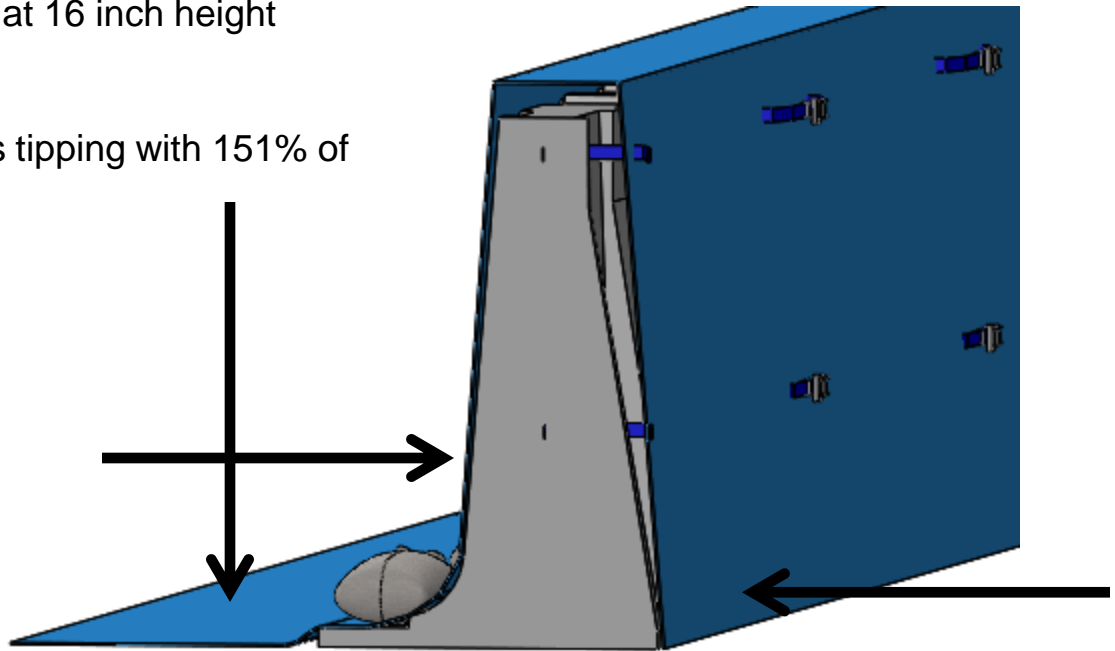
- This results in a 44% margin. The wall can handle 144% of intended load based on static water pressure.



Tip Over Analysis



- The horizontal component of the hydrostatic force for a 6 foot wide, 4 foot high wall segment filled with stationary water is 2997 lbf.
- Sum of moments about tipping point shows 1.51 factory of safety with the following assumptions:
 - Wall filled with water weighs 1400 lbf
 - 4 inches of water column off front edge of toe included
 - Liner must remain intact
 - 2997 lbf water pressure applied at 16 inch height
- **Tipping moment:** 47,945 in*lbf
- **Stabilizing moment:** 72,498 in*lbf
- **Factory of safety:** 1.5, system resists tipping with 151% of intended load.





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