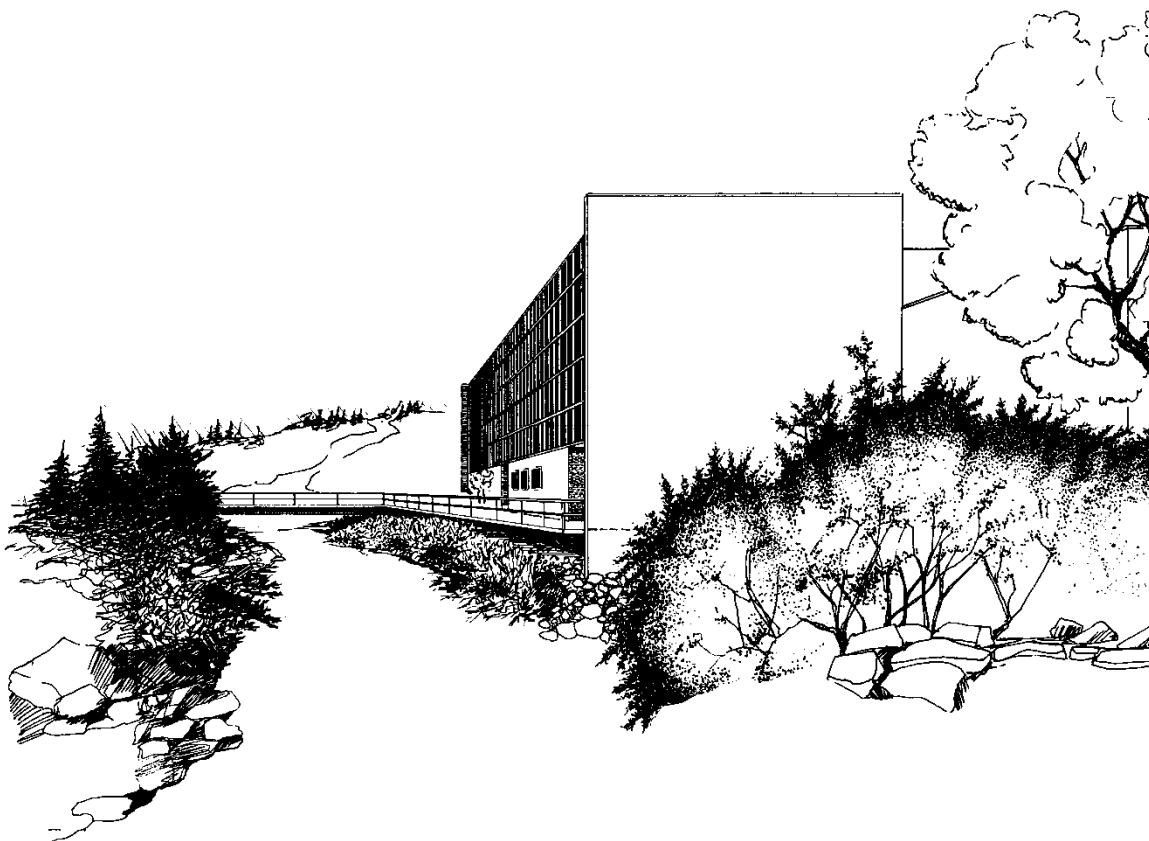


# **PERFORMANCE TESTING OF THE MUSCLE WALL**

Prepared for

Muscle Wall, LLC

March 2010



**UTAH WATER RESEARCH LABORATORY**

**Utah State University  
Logan, Utah**

**Report No. 2167**

# PERFORMANCE TESTING OF THE MUSCLE WALL

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## **INTRODUCTION**

Utah State University was contracted by Muscle Wall LLC to performance test their Muscle Wall Flood Barricade. The purpose of the testing was principally to determine the following characteristics:

1. Seepage rate
2. Overflow performance
3. Wave performance
4. Impact performance
5. Sliding performance

The aforementioned tests were performed in two separate locations with one test occurring at the hydraulics modeling building at the Utah Water Research Laboratory (UWRL) and the second set of tests were conducted at the Logan City firefighter training facility.

## **DESCRIPTION**

The Muscle Wall system consists of lightweight hollow barricades that are designed to be interconnecting. The connection is effectively a hinge that allows adjoining barricades to pivot which enables the wall to make sweeping bends. In addition, corner pieces are used to allow 90-degree bends. Figures 1 and 2 show the Muscle Wall and the hinged connection.



Figure 1. Muscle wall sections.



Figure 2. Muscle wall hinged connection.

## **INSTALLATIONS**

The first installation of the Muscle Wall was done at the Utah Water Research Laboratory's Hydraulics Modeling Building (Figure 3.). The barricades were installed on an extremely smooth concrete floor and the standard reinforced plastic was placed on the inside of barricaded area. Sandbags were used to keep the reinforced plastic in place while filling. This installation represents the most adverse of installations that may be possible. The Muscle Wall hinged connections were the only mechanism of restraint to prevent wall movement. The Muscle Wall is designed so that stakes can be used to restrain the wall from sliding when used on soil or asphalt.

The second installation of the Muscle Wall was done at the Logan City Fireman Training facility. Again this testing was completed on concrete; however nylon straps were used to tie each barricade together to prevent barricade separation at the joint. Plastic with a thickness of ten mils was used on the inside of the barricades. Figure 4 shows the installation for this series of tests. Figure 5 shows the straps used to tie adjacent walls together and keep them from sliding on concrete.



Figure 3. Muscle wall installation at UWRL.



Figure 4. Muscle wall at Logan City's firefighter training facility.



Figure 5. Strap used to secure walls together.

## **TEST RESULTS**

### Seepage

Seepage tests were conducted at both installations and seepage was determined by filling the pool created by the Muscle Wall barrier and timing the rate at which the water surface dropped. In both cases the concrete was saw cut and the joints were not completely sealed. To quantify the seepage, it must be related to the length of Muscle Wall installed. The rate was obtained by dividing the change in water elevation by the elapsed time and the length of Muscle Wall installed.

The testing at the UWRL yielded a seepage rate of 0.002 inches/foot/minute with a water depth of 36 inches. The seepage rate at the Logan facility was 0.0013 inches/foot/minute with a water depth of 48 inches. The differences in the two tests are attributed to the placement of the plastic liner. It is likely that with more care, the seepage rate could be significantly less.

### Wave and Overtopping Tests

Waves were generated in both facilities by raising and lowering a steel plate with a crane or forklift. The Muscle Wall barricade showed no problems with waves at the Logan facility when connected together with straps. At the UWRL, the testing was done at a depth of about 36 inches and showed no problems. Figure 6 shows the Muscle Wall with considerable wave interaction.

The Muscle Wall was tested with water running over the top of the barricade. This test showed that overtopping had no detrimental effects on the Muscle Wall.

### Impact Test

A 6-inch x 6-inch x 144-inch timber was used to impact the Muscle Wall. The timber was accelerated to approximately 5 feet per second and slammed into the wall. The result was simply a small puncture in the plastic liner. The timber rebounded and the wall was not displaced. Figure 7 shows the timber impacting the wall.



Figure 6. Muscle Wall wave test.



Figure 7. Impact test.

### Sliding Test

The testing at the UWRL was done with the Muscle Wall system unrestrained and placed on exceptionally smooth concrete. The Muscle wall restrained the water to a depth of 40 inches at which time it slid causing separation at the joint. While this installation was extreme and not prescribed, it showed at what condition failure due to movement on slick concrete occurs. In a normal installation, the Muscle Wall would be anchored to the ground or strapped together. In that case, the Muscle Wall easily withstood 48 inches of depth and a resulting force on each barricade of approximately 3,000 lbs. Each barricade when filled with water weighs about 1,680 lbs and the additional force of water on the toe adds 1,830 lbs. To prevent sliding, the static coefficient of friction must be greater than 0.85 or the Muscle Wall must be restrained. Normal values of static friction coefficients are in the 0.3 range.

### Stability Calculations

Calculations were completed to determine the stability of the Muscle Wall restraining a depth of water of 4 feet. The unit weight of water used was  $62.4 \text{ lbs/ft}^3$  and it was assumed that the outside surface of the Muscle Wall profile was used to determine the volume of the barricade.

The analysis was completed to show if the Muscle Wall would overturn without end restraints. Figure 8 shows the free-body diagram with the representative weight forces, and pressure forces that act horizontally (FH) and vertically (FV) on the Muscle Wall. The forces shown are located at the centroids of the Muscle Wall and running through the centroid of water over the toe and at the location where the horizontal hydrostatic force would be located.

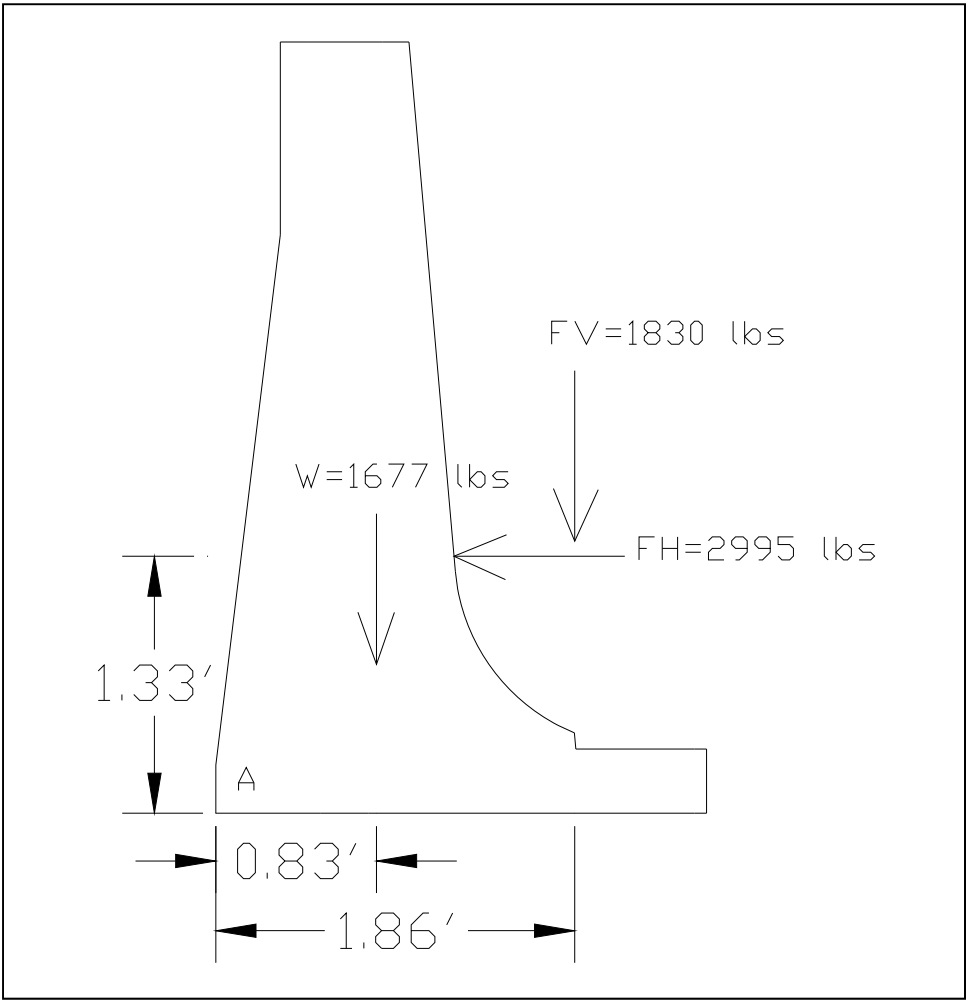


Figure 8. Free-body diagram of the Muscle Wall and resultant forces.

Taking the overturning moment about point A with overturning moments assigned positive values and resisting overturning moments assigned negative values yields:

$$M_A = 2995 * 1.33 - 1677 * 0.83 - 1830 * 1.86 = -812.4 \text{ ft} \cdot \text{lbs}$$

Because the resulting overturning moment is negative the resisting overturning moment is greater than the overturning moment. Therefore, a properly installed Muscle Wall should not overturn if four feet of water is being restrained.

## **SUMMARY**

The Muscle Wall barricade was tested at the Utah Water Research Laboratory and at the Logan City, Utah firefighter training facility. The purpose of the testing was to acquire information pertaining to the Muscle Wall performance capabilities. The testing demonstrated that the lightweight, mobile system was capable of restraining a wall of water that was four feet deep. In addition, the system withstood wave activity, sudden impact, and overtopping. The Muscle Wall barricade without restraining straps slid at a water depth of approximately 40 inches and the seepage rate was measured to be 0.0013 inches/foot/minute. The calculations for overturning showed that the Muscle Wall should not tip over if it is unrestrained. Sliding can occur if the Muscle Wall is unrestrained at water depths of approximately 40 inches and higher. Sliding can be prevented by using stakes or additional barricades behind the Muscle Wall installation.