CONCEPTUAL FLOOD CONTROL WALL DESIGN AND CONSTRUCTION NOTES

The following notes are intended as general recommendations for the design and construction of a flood control wall using Redi-Rock's Hollow-Core Freestanding block, also referred to as Magic block™. These comments and recommendations are based on the design, construction, and testing of a prototype wall at Redi-Rock's headquarters in Charlevoix, Michigan. A view of the test wall is shown in **Figure 1**. The objective of this project was to come up with efficient methods to construct a flood control wall and test its watertightness.

Figure 1: *4.5 ft high prototype wall with a reinforced concrete footing 1 ft high and 5 ft wide. Design features include two types of vertical control joints, 90 degree corners, and an abutment to an existing cast-in-place wall.*

The results from the tests show that watertightness depends, to a large extent, on best construction practices and careful attention to detail. Based on our experiments, slight seepage through joints can be expected using standard construction practices.

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After initial construction, the test wall exhibited an average seepage rate of 0.04 gpm/ft. This seepage rate was calculated over the total wall length of 50 feet. However, seepage was not uniform. During the tests, some sections of the wall were completely watertight, while others had visible seepage as shown in **Figure 2**.

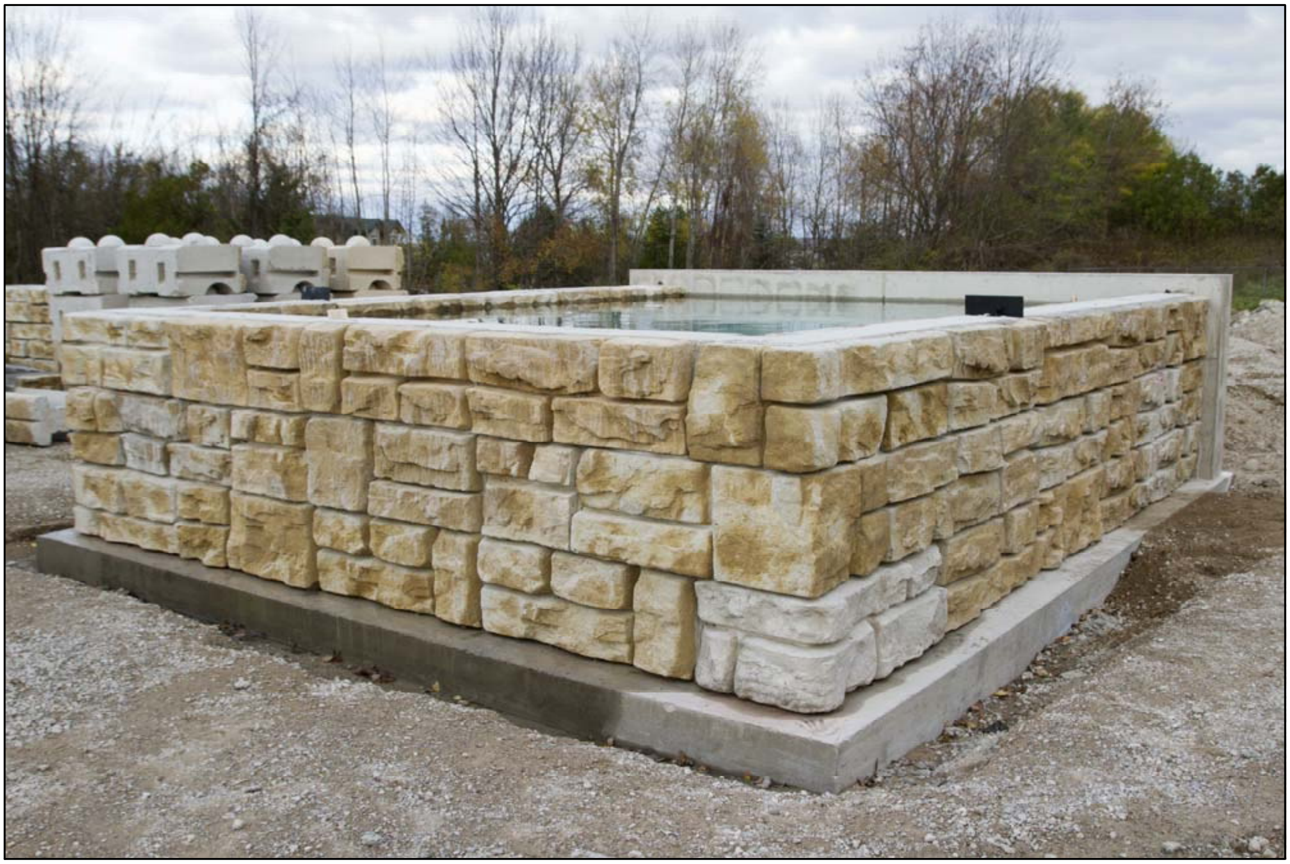

Figure 2: *Observed seepage rates varied along the length of the wall, and increased proportionally as the water elevation increased.*

Following initial construction and testing watertightness, secondary improvements were added to the inside portion of the test wall. All horizontal and vertical joints were sealed with a non-shrink cement grout and a 6 inch by 6 inch concrete curb was constructed at the location of the wall-footing joint.

After these secondary design elements were constructed, the structure was filled with water and seepage rates were measured again. The improvements resulted in reduced seepage rates of 0.005 gpm/ft for retained water heights of up to 24 inches and 0.016 gpm/ft for retained water heights of up to 48 inches. As before, the seepage rates were an average over the entire wall length. There continued to be areas that appeared completely watertight, while others had visible seepage, as shown in **Figure 3**.

Figure 3: *Observed seepage areas.*

GETTING STARTED

Redi-Rock Magic Blocks™ are hollow core freestanding blocks. Straight blocks have finish texture on two sides and corner blocks have finish texture on three sides. The main texture panels in a Magic Block™ are connected by structural ribs, leaving the center core of the block hollow. The blocks include precast grooves for easy installation of horizontal and vertical reinforcing steel. Cast-in-place concrete can used to fill the center core, creating a monolithic wall. Due to the continuous nature of the cast-in-place center concrete core, the Magic Block™ is well suited for projects like flood control structures. Views of the Magic Block™ are shown in **Figure 4**.

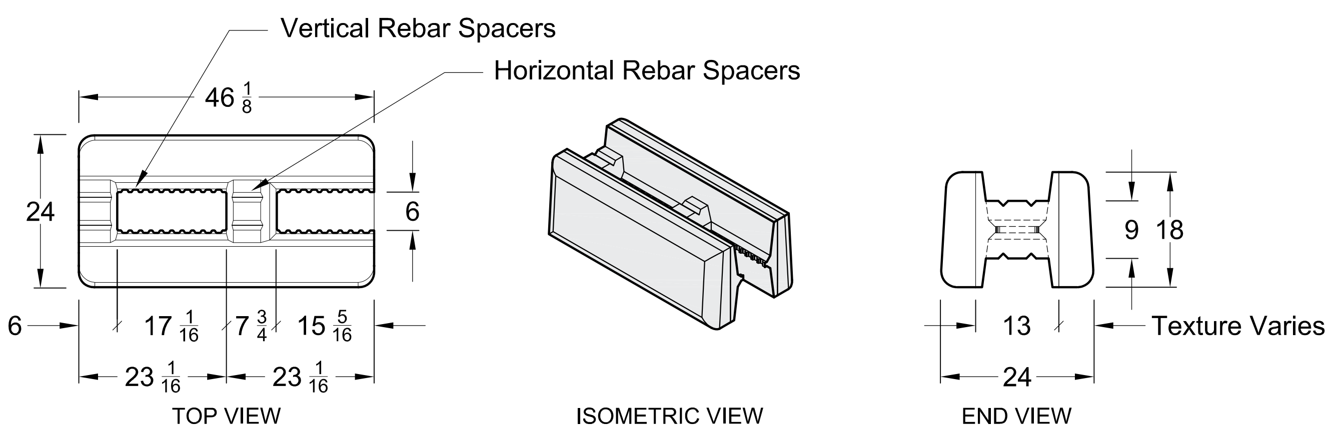

Figure 4: *Magic Block™ Details*

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WALL DESIGN

Magic Block™ walls that are constructed on a concrete footing and filled with reinforcing steel and concrete are essentially traditional cantilever walls. The Magic Blocks™ act like decorative formwork for a cast-in-place concrete wall.

- Design the wall footing following, reinforcing steel, and concrete strength using standard reinforced concrete design methods.
- Remember to include the impact of uplift, buoyancy, and hydraulic flow beneath the footing for structures that retain water.

PLANNING BLOCK LAYOUT

Design of Magic Block™ walls should consider the block layout in addition to the structural design of the wall. The most important aspect to consider is how to fit the blocks around the rebar ties that extend from the concrete footing up into the center core of the Magic Block™ wall. A detailed plan view drawing showing block layout greatly helps in constructibility of the wall.

- Magic Blocks™ are designed to be placed end to end with the open end of one block immediately abuting the structural rib of the next block. When the blocks are placed this way, the open space for vertical rebar installation is maximized. In addition, when the next course of blocks is placed in a running bond configuration (where one block equally straddles the two blocks below), the structural ribs align, keeping the open space consistent from row to row.
- In the case where blocks cannot be installed end to end as described above and are placed so that two end structural ribs abut each other, carefully cut one of these ribs. It is important to have poured concrete around the rib to avoid a gap that would allow water flow along a cold joint between ribs in adjacent blocks.
- During construction, pay close attention to the spacing of the vertical rebar in the footing, as this is critical to avoid conflicts between the rebar, structural rib locations, and equipment used to set the blocks.
- To set the first row of blocks, snap a line on the footing and use this to align the inside of the blocks. The parting line between the finished face texture and smooth form surfaces in the blocks can be used for proper alignment.
- Blocks in our test facility were set with a 16 inch wide clamp. A clear spacing of 17 inch between every other rebar allowed blocks to be set with minimal interference as shown in **Figure 5**.

Figure 5: *16 inch clamp requires 17 inch minimum spacing between every other rebar to avoid any conflicts while the blocks are set.*

INTEGRATING 90° CORNERS

Corners can be integrated into the wall by using hollow-core corner blocks. Modifications to the corner block are needed to provide the continuous reinforcement and concrete-filled center core needed for water control projects. Careful consideration also needs to be given to the footing rebar tie locations in the corner.

- If the design requires continuous rebar, corner blocks require cutting a small section out of the side near the end. The location of this cut section is where this block abuts the wall perpendicular to it. The cut should be wide enough (approximately 9 inches wide) for the horizontal rebar to wrap around the corner with sufficient concrete cover, as shown in **Figure 6**.

- Some textures, such as the Redi-Rock Ledgestone texture, have significant relief and might require trimming to minimize gaps in the vertical joint between the corner block and the block perpendicular to it. For these cases the depth of the texture can be trimmed on the corner block by 2 - 3 inches so the abutting block fits tight against the corner block.

Figure 6: *Modified Corner block for continuous reinforcement and concrete-filled center core.*

Figure 7: *Continuous horizontal rebar through a corner using bars bent 90°. Make sure to follow design standards for minimum development lengths on the bent bars.*

WATERSTOP INSTALLATION NOTES

Common options for waterstops include flexible bentonite/butyl rubber expandable strips and PVC ribbed center bulb strips. Both types were integrated into our test wall to test for watertightness. It is importatnt to carefully follow the waterstop manufacturer's installation guidelines. **Optimal performance of the waterstop depends largely on installation procedures.**

INSTALLING HORIZONTAL WATERSTOPS BETWEEN BLOCKS AND FOOTING

- Following the waterstop manufacturer's recommendations, the waterstop should be installed between the footing and the bottom of the wall. It should be installed close to the center of the block, at a location where it doesn't interfere with the vertical rebar.

- When using a ribbed center bulb strip, it should be installed prior to pouring the footing. Half of the strip should be embedded in the footing. A common installation practice includes drilling small holes on the outer edges of the waterstop and attaching it to the rebar using rebar wire ties.

- A bentonite/butyl rubber expandable waterstop strip can be installed on top of the footing prior to installing the first row of blocks as shown in **Figure 8**. It is important to keep the waterstop protected and clean of debris for optimal performance.

- Some designs may include forming a keyway on the footing and installing the waterstop in the keyway.

Figure 8: *Installing a bentonite/butyl rubber expandable waterstop strip on top of the footing.*

INSTALLING CONTROL JOINTS AND VERTICAL WATERSTOPS

If the design of the hollow-core wall requires vertical control/expansion joints, start by constructing the wall in sections. The length of each section can be determined by the distance between control joints. Each section should be built to its full height, or for taller walls, each section should be built with the blocks to the height of the first concrete pour. Two different types of vertical waterstops were tested. They are shown in **Figures 9** and **10**.

- Once all the blocks have been stacked for one wall section, proceed to install the materials to create the control joint.

- To create a control joint, install a thin and rigid material wide enough to act as a bond break and ensure future cracks form in that location. For the purposes of this test, sheets of ABS plastic were used. The thickness of the plastic depends on the rigidity required to sustain the fluid pressure of the concrete.

- When using a bentonite/ butyl rubber flexible expanding strip waterstop, install the waterstop on both sides of the bond break material following manufacturer's directions.

- If the design requires continuous horizontal rebar through the control joint, measure and drill holes in the bond break material to accommodate the rebar.

- Attach the bond break material to the open ends of the blocks on the built wall section with outdoor construction adhesive. Proceed to stack the blocks for the next wall section.

Figure 9: *Control joint using ABS plastic along with a PVC ribbed center bulb waterstop secured with wire ties.*

Figure 10: *Control joint using ABS plastic along with bentonite/butyl expandable waterstop strip (installed on each side of the ABS plastic sheet).*

FILLING THE CENTER CORE

Prior to in-filling the wall with concrete, it is recommended to grout the joints between the blocks with non-shrink standard grout. This helps prevent leakage during the infill and vibration process, it also provides an added aesthetic element to the wall.

- It is recommended to place concrete evenly on both sides of the control joints when in-filling the wall, to avoid blowing out the bond break material due to the excessive fluid pressure.

- While the wall is being in-filled, use an internal concrete vibrator to vibrate the concrete to ensure consolidation and eliminate voids as shown in **Figure 11**.

Figure 11: *Infilling and vibrating concrete inside the hollow-core wall.*

ADDITIONAL MEASURES

The test performed at the facility in Charlevoix only achieved 100% watertight joints in some locations and not throughout the entire wall. If extremely high or completely watertight structures are needed, specialized measures are likely required. These may include using a self-conolidating concrete mix to keep any air voids formed during pouring and vibrating the concrete to an absolute minimum. Additionally, advanced chemicals like integral crystalline waterproofing admixtures may be used (such as Penetron or Xypex). Foundation wall waterproofing experts should be consulted to select and assist with the installation of any performance improvement measures.