Mega Wall Block Welded Wire Mesh Connection

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MEGA WALL BLOCK
WELDED WIRE MESH CONNECTION

By

Tyler B. Loertscher

Plan B Report submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Civil and Environmental Engineering

Approved:

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ABSTRACT

Mega Wall Block
Welded Wire Mesh Connection

By

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Utah State University, 2015

Major Professor: James A. Bay

Department: Civil and Environmental Engineering

Mechanically Stabilized Earth (MSE) walls restrain hillslopes to unnatural gradients using reinforced soil. Traditional MSE walls are constructed of large reinforced concrete panels bolted to steel strips for soil reinforcement. Segmented Retaining Walls (SRWs) are a form of MSE walls composed of precast concrete modular blocks that incorporate geosynthetic soil reinforcement. In comparison, traditional MSE walls have faster construction times and are typically stronger, but SRWs have increased in popularity because they are much cheaper to build.

There are many precast companies that produce different SRW block designs, these blocks have facing areas that range from 1 to 13.75 sq. ft. and can weigh approximately 90 to 2,000 lbs. There are advantages to both block types that must be addressed during design. Typically construction costs are lower for small blocks because they can be placed by hand rather than using equipment. Large blocks require less construction time but are usually more expensive to fabricate.
Oldcastle is a precast company that has several modular block designs. The newest model called the Mega Wall block is 5.5 feet wide, 2.5 feet tall and weighs approximately 2,000 lbs. The block is designed to accommodate both welded wire mesh and geosynthetics soil reinforcement. Prior to being released to the market design strengths must be determined through laboratory testing.

This report presents the results of the Mega Wall block welded wire mesh connection capacity. Three tests were performed by pulling the welded wire mesh to failure under simulated overburden pressures. Results of the testing show that welds in the wire mesh failed well below the yield strength of the steel. As the wires were pulled, the mesh applied stress concentrations to edges of the concrete grooves. Conical concrete failures were observed in the concrete after each test. After the concrete failed, the mesh was allowed to bend considerably, which began to apply a bending to the welds already experiencing shear stress. This excessive bending deformation caused premature failure in the welds during testing.

In order to achieve higher connection capacities, several modifications to the Mega Wall block design were presented to Oldcastle. These suggestions were acknowledged but not implemented. Oldcastle was not interested in testing modifications to the block and testing was terminated. It is assumed that the Mega Wall block design will not be modified and that Oldcastle will not recommend using the welded wire mesh connection.
Chapter 1

LITERATURE REVIEW

Introduction and History

Advances in reinforced earth technology have allowed previously unusable or undesirable land to be developed. Retaining walls are a form of reinforced earth that can restrain soil to unnatural slopes. This allows for more efficient use of land without the need for long laterally extending hillslopes. Early retaining walls were mainly constructed of cast-in-place gravity or cantilever walls. In the 1960’s French engineer Henri Vidal conducted research that led to the first methods of soil reinforced retaining walls. These reinforced soil retaining walls or Mechanically Stabilized Earth (MSE) walls were first constructed in the U.S. in the early 1970’s. These walls were constructed using reinforced concrete panels bolted to steel strips for soil reinforcement. During the 1980’s retained earth technology took another step forward with Segmented Retaining Walls (SRW’s). These walls are constructed using precast modular blocks that use geosynthetic materials for soil reinforcement rather than steel. These SRW’s were more economical to produce than traditional MSE walls and quickly grew in popularity.

Steel reinforcement for MSE walls can consist of steels straps or welded wired mesh. Steel is considered to be inextensible meaning that the entire reinforcement engages soon after an active zone develops. Geosynthetic materials are considered extensible and progressively engage backwards as the wall face moves due to the active zone. Since a geosynthetic mat does not engage at once like steel SRW’s a geosynthetic design must include a smaller reinforced zone as shown in Figure 1.
Precast companies have created dozens of different modular block types. Each SRW block has its own advantages that require different construction and design techniques. These blocks can have different sizes with most being small enough to place by hand with no construction equipment, though some blocks can weigh as much as 2,000 lbs.

**Design Properties**

SRW’s retain the active portion of a hillslope by developing passive resistance using soil reinforcement. This passive resistance is quantified using the pullout capacity of the reinforcing material. Designing SRW’s requires an extensive look at several possible failure modes, by determining the engineering properties of the retaining wall system. These failure modes are separated into three different categories known as global, external and internal stability.
Global Stability

A global stability analysis is typically performed on larger walls where slip surfaces may exist outside of the reinforced soil zone. This is essentially a slope stability analysis to determine potential failure modes either through the reinforced soil zone or around the entire SRW structure. These slip planes are known as internal and external global sliding surfaces respectively.

External Stability

External stability addresses failure modes associated with sliding and overturning of the SRW block units and bearing capacity of the soil. These failures are associated directly with the soil properties and SRW blocks resistance against lateral earth pressures.

Internal Stability

Reinforced SRW’s require a reinforcing material that holds a shear stress that can adequately resist the lateral earth pressures acting upon the wall. Potential failure modes associated with internal stability are associated with the reinforcing material strengths such as pullout, tensile overstress and connection capacity.

Connection Capacity

When using these reinforcement methods it is important to be able to quantify the connection strength between the reinforcing material and the SRW blocks. Connection capacity should be greater than the applied shear stress on the reinforcing material. This is important for design and cost, if the reinforcement has a strong connection to the wall then the designed loads that a specific reinforcement can support will get closer to the actual yield strength of the material.
Oldcastle Mega Wall block

In construction, cost seems to be the most important limiting factor. This is the main reason that SRW’s have become more popular than traditional MSE walls. However, in large projects with greater wall heights, MSE walls are still preferred because inextensible steel reinforcement is trusted more than extensible geosynthetics.

Oldcastle is a precast company that sells several modular block designs. The newest model called the Mega Wall block is 5.5 feet wide, 2.5 feet tall, has a facing area of 13.75 sq. ft. and weighs approximately 2,000 lbs. as shown in Figure 2. The block is designed to accommodate both welded wire mesh and geosynthetic soil reinforcement. This design flexibility should make Mega Wall block popular as it can be built economically enough to be competitive with other SRW’s blocks as well as strong enough to be considered for larger projects.

Figure 2: Oldcastle Mega Wall block

This is not the first time steel reinforcement has been used in an SRW block. Keystone blocks are very popular and are typically associated with geosynthetic reinforcement. A new model called Keysteel incorporates a pinned connection with welded wire mesh shown in Figure 3. The
Mega Wall will be different from the Keysteel concept because there will be no pinned connection. The welded wire mesh will sit inside of the grooves on top of the block shown in Figure 2.

![Tri-Plane and Straight Split](image)

**Figure 3: SRW Pinned Connection with Welded Wire Mesh**

**Geotextiles**

The Mega Wall has a deep groove near the back edge of the block shown in Figure 4. A specially designed wedge connector is placed through the geosynthetic reinforcement and then hammered into the groove. Edges along the side of the connector lock the reinforcement into place. According to Old Castle, testing has previously been completed on the connection capacity between the geosynthetic reinforcement and the Mega Wall block.
Typically, welded wire mesh has only been used with reinforced panels containing steel connectors cast in place as shown in Figure 5. Depending on the connector, which is often proprietary, the mesh can be bolted or hooked to the panel. The Mega Wall blocks unique design
allows the welded wire mesh to be placed into grooves with no bolted connection. Connection capacity then relies entirely on the strength of the concrete and the weight of the blocks stacked on top of the welded wire mesh.

**Chapter 1 Summary**

The ability to retain hillslopes to unnatural gradients allows for the development of uneven terrain. MSE walls and particularly SRWs are growing in popularity due to flexible designs that are relatively cheap compared to traditional MSE walls. Connection capacity between the SRW block and reinforcement is an important engineering design parameter. The Mega Wall block is a new SRW design from Oldcastle that incorporates advantages of traditional MSE walls. Typically SRWs use geosynthetic reinforcement and traditional MSE walls use welded wire mesh, the Mega Wall design can connect with both types of reinforcement. The Mega Wall is a new design and engineering parameters such as connection capacity with welded wire mesh reinforcement have not yet been determined.
Chapter 2

TEST SETUP

Apparatus

The apparatus consists of five Mega Wall blocks stacked two courses high, in an alternating or “bonded” pattern, with three blocks on the bottom and two blocks staggered on top. Four 14-inch thick reinforced concrete bulkheads were used to contain the reinforced soil zone behind the Mega Wall blocks (two sides, one back and one on top). The back bulkhead contained seven 2-inch holes that would feed the longitudinal lengths of the welded wire mesh outside of the apparatus. The top bulkhead was used to evenly distribute loads simulating overburden pressure. Figures 6 and 7 show the testing apparatus before and after setup. This testing will determine the connection capacity of the Mega Wall with the welded wire mesh reinforcement.

Figure 6: Apparatus Initial Setup

Figure 7: Apparatus Final Setup
To simulate a 40 ft. tall wall the soil and blocks were loaded vertical using hydraulic cylinders. The added vertical stress on the soil would increase the lateral forces exerted on both of the side bulkheads. To prevent sliding and overturning of the two side bulkheads a steel casing was used to connect the top and bottom of each bulkhead to the other as shown in Figure 8. When simulating a 40 ft. wall the lateral earth pressure at rest was calculated to be 2,200 psf. Each side bulkhead was 5 ft. tall and 2.5 ft. wide, which results in an equivalent lateral force of 27 kips on each bulkhead. The steel needed to withstand tensile stresses of the lateral forces acting on both bulkheads (28 kips). Each steel casing consisted of two 0.5 in. by 3 in. rectangular straps that extended the distance between the bulkheads. With a yield strength of 50 ksi the total capacity of the steel straps was calculated to be 300 kips. The two straps were welded to 0.5 in. steel angle that wrapped around the corner of the bulkhead holding the casing in place. Calculations for the lateral earth pressures and steel capacity are shown in Appendix A.

Figure 8: Top Steel Casing
Process

Preparing the apparatus for each test took approximately eight hours for tear down and reassembly. A procedure for assembling the testing apparatus is numbered in sequential steps. The actual order of steps can be changed slightly, however, following these steps seemed to correlate to faster assembly. If facing the back bulkhead longitudinal wires were numbered 5 to 1.

1. Align 3 Mega Wall Blocks with middle block centered with and touching reaction column base plate. (if the uneven, textured, block facade is not flush with base place wood in between to prevent stress concentrations)
2. Center back bulkhead holes with grooves in middle block, set 30 inches apart.
3. Lay down steel casing for side bulkheads between blocks and back bulkhead
4. Set side bulkheads inside of steel casing against angle. (use plywood and 2x4s to cover up any gaps between bulkheads and blocks to keep soil inside apparatus)
5. Set top steel reinforcement on top of side bulkheads to prevent any overturning while placing gravel.
6. Set rock chute over bulkheads and begin adding gravel as shown in Figure 9.
7. After gravel layer is at the middle of the first course of blocks, compact using small vibratory plate compactor.
8. Fill gravel to top of first course of blocks and compact again.
9. Slide longitudinal wires through holes in back bulkhead and set wire mesh into grooves on top of middle block with transverse wires facing down.
10. Add top two Mega Wall blocks set staggered on top of bottom course. (add wood between gaps as needed and between block facade and I-beam bolted to reaction column)
11. Add gravel to middle of top block course and compact
12. Fill gravel to top of top block course and compact.

13. Place top bulkhead between reinforcing straps on top of soil. (use loose soil to fill in gaps until top bulkhead is level)

14. Place table underneath longitudinal wires extending out of the back bulkhead.

15. Slide 1” steel plates over each wire set against back bulkhead.

16. Slide hollow stem hydraulic cylinders over the wires against 1” steel plates

17. Slide ½” steel plates over each wire against the hydraulic cylinders

18. Slide all five ring load cells over the wires (make sure wire numbers and load cell numbers are matched up)

19. Slide an additional ½” steel plate over each wire sandwiching the load cells.

20. Secure everything in place by using chucks on each longitudinal wire

Figure 9: Rock Chute (left)
If adding overburden pressure greater than 2.5’ follow steps (21 to 23)

21. Place four 1” steel plates centered on each of the top two Mega Wall blocks. Place I-beam across these two stacks (make sure I-beam only sits on steel plates and not concrete nubs)
22. Center vertical hydraulic cylinders above I-beam and above top bulkhead.
23. Place load cells below hydraulic cylinders (use steel plates to decrease distance between load cells and hydraulic cylinders as needed)

**Data Acquisition**

Wire loads were measured using ring load cells manufactured by Omega shown in Figure 10. Figure 11 shows the typical setup for the ring load cells. Two 1 in. thick steel plates were used to sandwich the load cells and ensure even loading and were held in place against the cylinders using wire chucks. The ring load cells were used to measure the force applied to the wires and have a loading capacity of 30 kips with an accuracy of ±3.5%.

![Figure 10: Ring Load Cell](image-url)
Large diameter load cells, manufactured by Geokon and oriented vertically, were used to measure the force applied to the top soil plate to simulate the overburden and the blocks to simulate additional courses of blocks. The vertical load cells had much higher capacities, around 300 kips, with an accuracy of ±0.5%, to accommodate the large loads necessary to simulate an MSE wall up to 40 feet tall.

During testing data was recorded using the Vishay System: Model 5100B computer data acquisition system. This system recorded 100 measurements per second of the amount of force upon each horizontal wire and the vertical forces applied to the blocks and soil. Shown in Figure 12 are all of the load cells hooked up to the Vishay System.
Hydraulics

Three hydraulic pumps and seven hydraulic cylinders were used to perform this test. Five hollow core single acting cylinders were placed horizontally behind the back bulkhead over each of the protruding longitudinal wires. Two larger cylinders were attached to the reaction beam above the apparatus. A double acting cylinder was used to load the mega wall blocks, through a spreader beam, and a single acting cylinder was used to load the soil. Figure 13 shows the entire hydraulic system fully assembled. Each of the five horizontal cylinders had a capacity of 60 tons (120 kips), the two vertical cylinders had capacities of 250 tons (500 kips). The five horizontal cylinders and the block cylinder were loaded using two separate electric powered hydraulic pumps. The soil cylinder was loaded slowly using a hand powered hydraulic pump to allow for a controlled application of the load on the soil.
Equal pressure was provided to each of the five horizontal cylinders using a ten port manifold. Pressure was applied to the manifold which was then equally distributed to each of the cylinders. A pressure gauge was attached to one of the ports to ensure that pressure in the manifold did not exceed the 10,000 psi limit of the hydraulic lines.

**Testing Protocol**

Once the load cells are connected to the Vishay System and the hydraulic cylinders are hooked up to the appropriate hydraulic pumps (as described in previous sections) the apparatus will be completely assembled and is ready for testing. The testing protocol is outlined in the following steps.

1. Open Vishay Software and confirm that all load cells are reading loads properly by manually applying a small load with a hand.

2. Once all load cells are reading loads properly begin recording data on the Vishay Software.
3. Apply the simulated load to the Mega Wall blocks.
4. Begin applying the simulated load to the Soil.
5. While applying load to the soil if the measured load on the blocks drops below the desired simulated load then stop loading soil and reapply load to blocks before continuing to load the soil.
6. Once the simulated loads have been applied to the blocks and soil begin slowly loading the horizontal wires.
7. Continue to load the horizontal wires until failure occurs.
8. Once failure has occurred in the wires, release loads on the wires, soil and blocks in that order.
9. Stop recording data and begin tear down of testing apparatus

Chapter 2 Summary

This testing was meant to determine the connection capacity between the Mega Wall block and the welded wire mesh reinforcement. The testing was performed using a testing apparatus with the ability to simulate a 40 ft. tall wall. Simulated loads were applied using three hydraulic pumps and seven hydraulic cylinders. The applied loads were measure and recorded using the Vishay System: 5100B.
Chapter 3

TESTING

Results

Testing of the Mega Wall Welded Wire Mesh reinforcement connection consisted of three tests that occurred between April 9 and April 28, 2015 the results of these tests are discussed in more detail in subsequent sections. These tests were meant to simulate actual field situations that would be expected in building an MSE wall with these blocks and reinforcement. Each test showed very similar failures in the mesh welds between the transverse and longitudinal wires.

Test #1: Simulated 6 ft. wall with W7 wire

The first test was performed using the W7 wire with an overburden of 2.5 feet. The top bulkhead was positioned on the soil but no vertical loads were applied to the soil or blocks. The wire mesh was placed in the center of the bottom block as shown in Figure 14
Horizontal loading of the wires began and increased slowly until a pop was heard, after no observable damage, the loading resumed until a second pop was heard. Again, no damage was observed and testing resumed until a louder pop was heard and the number 5 ram extended fully. Figure 15 shows these periods of loading and waiting separated by changes in load on the wires. As loading was applied a third time the data shows a decrease in load to wires 4 and 5 after the loud pop was heard. A maximum load of approximately 650 lbs. was measured in wire 2 prior to the first wire failure, however, loads never equalized among all wires.

![Test #1 Plot of Wire Load versus Time](image)

**Figure 15: Test #1 Plot of Wire Load versus Time**

After testing was completed the apparatus was taken apart and the results were documented. The weld between the wire 5 and the front transverse wire had failed. This failure likely allowed for further deformation to occur in wire 4 which would explain the decrease in
measured load after the break. The failure appeared to have initiated in the middle wire where deformation was the greatest. All longitudinal and transverse wires had slipped out of the grooves on top of the block shown in Figure 16. The block was cleaned up and conical failures were observed in the concrete at each of the locations where the longitudinal and transverse wires were welded together.

![Figure 16: Test #1 Wire Failure](image)

**Test #2: Simulated 6 ft. wall with W20 wire**

The smallest wire size available (W7) was used for Test #1 and after seeing how easily it slipped out of the grooves the largest wire size (W20) was chosen for Test #2. The Mega Wall blocks had grooves for a welded wire mesh that was seven sections wide. All of the mesh sizes available for testing were only five sections wide, so in order to test the edges of the block the
W20 wire was not placed directly in the center of the block but staggered off to the side by one section as shown in Figure 17.

Figure 17: Test #2 Welded Wire Mesh Setup

Similar to Test #1 the top bulkhead was placed on top of the soil but no vertical loads were applied simulating 2.5 feet of overburden. The wires were then loaded, several pops were heard before momentarily stopping the test to see if any observable damage had occurred. After no damage was observed the wires were loaded again, several more pops were heard followed by a loud bang and Cylinder 5 extending fully, indicating a wire break after which testing stopped. Figure 18 shows data for Test #2, it was observed that wire 5, in green,

lost a significant amount load after the fracturing sound was heard. A maximum load of approximately 1800 lbs. was measured in wire 2 prior to the first wire failure.
The apparatus was deconstructed and a weld break between Wire 5 and the front transverse wire as shown in Figures 19 and 20 was documented. Figure 20 also shows a conical failure in the concrete that was typical across the block. It appears that this failure initiated on the outside wire where the weld ruptured. At the point of rupture, there was very little support for the mesh from the concrete, due to the shape of the block. The weld between Wire 5 and the front transverse wire was just outside of the concrete block and the weld with the back transverse wire as shown in Figure 19 was not retained by concrete and was just sitting on the soil.
Figure 19: Test #2 Results Mesh Deformation

Figure 20: Test #2 Results Weld Break and Conical Concrete Failure
Test #3 Simulated 40 ft. wall with W20 wire

For Test #3 W20 wire mesh was centered on the block with the outside longitudinal wires on the outside of the male keys on top of the block as shown in Figure 21.

Figure 21: Test #3 Welded Wire Setup

Both Test #1 and #2 were performed with a simulated overburden load of 2.5 feet. The test apparatus was designed to simulate up to 40 feet of overburden. Oldcastle wanted to know how the blocks and wires would behave at this maximum simulated test. After the wire mesh was in place, the apparatus was prepared much like the previous tests except that two vertical cylinders were positioned above the apparatus, one above the top bulkhead and the other above an I-beam on top of the blocks. These rams were mounted on a reaction frame above the apparatus. The blocks were loaded with 60 kips of force (30 kips on each of the top two blocks to simulate 15 blocks above) and the soil was loaded with 76 kips to simulate 37.5 feet of soil (2.5 of soil was already in place above wires).
Figures 21 and 22 plot load versus time for the wire load cells and the vertical load cells, respectively. The blocks were loaded first to ensure they would not deform from the lateral forces of the soil. The soil was then loaded slowly with a hand pump. The hand pump had a relatively large reservoir of hydraulic fluid, but the hydraulic ram needed to extend a fairly large distance before contacting the top bulkhead. While in the process of loading, the reservoir was emptied and was refilled. Figures 22 and 23 show the load drop off significantly while the reservoir was refilled. After refilling, loading on the soil resumed slowly with the hand pump. As the applied load on the soil increased the load on the blocks decreased and the load on the wires increased. As the vertical load on the soil increased the lateral forces increased causing the back bulkhead to tilt slightly and increase the measured load on the wires. This deformation caused a slight decrease in the lateral forces acting on the blocks as the area of the soil increased. To maintain an approximate vertical load of 60 kips on the blocks the load was periodically increased as needed.

Once the desired vertical load on the soil and blocks were achieved, the longitudinal wires were loaded. Several pops were heard with a single loud fracture sound, followed by the number 3 cylinder extending fully, indicating a failure in the middle wire. The wires were continually loaded until another loud bang was heard and the number 2 cylinder next to the middle wire extended fully. The wires were continually loaded until a third bang was heard and the #1 ram extended fully. A maximum load approximately 3600 lbs. was measured in Wire 4 prior to the first wire failure. Figures 24 and 25 shows the wire loads along with soil and block loads respectively during testing.
Figure 22: Test #3 Wire Load versus Time

Figure 23: Test #3 Soil and Block Load versus Time
Figure 24: Test #3 Loading data (Wires), following active wire loading

Figure 25: Test #3 Loading data (Soil and Blocks), following active wire loading
The first failure occurred in Wire 3 indicating that the wire mesh failure initiated in the middle wire and extended to one side as more deformation was achieved. After deconstruction of the apparatus, conical concrete failures were observed in all junctions of the welds between the transverse and longitudinal wires shown in Figure 26. The junction between middle longitudinal wire and the back transverse wire is shown in Figure 27. The middle longitudinal wire seemed to have slipped out of the groove before causing a concrete failure. Many welds were ruptured and the three longitudinal wires that failed prior to ending the test were completely separated from the transverse wires.

Figure 26: Test #3 Conical Failure in Concrete
Chapter 3 Summary

Three tests were performed with varying wire sizes and simulated wall heights. As shown in Figure 28 all wire failures occurred at loads well below the yield strength of the steel. Calculations of yield loads in the wires are shown in Appendix A. All of the failures observed

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<th>Calculated Yield Load in Wire (lbs.)</th>
<th>Measured Load in Wire at Failure (lbs.)</th>
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<td>6ft</td>
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<tr>
<td>Test #2</td>
<td>W20</td>
<td>6ft</td>
<td>15,960</td>
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<tr>
<td>Test #3</td>
<td>W20</td>
<td>40ft</td>
<td>15,960</td>
<td>3,600</td>
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Figure 27: Test #3 No Conical Failure in Middle Groove

Figure 28: Calculated Wire Yield Loads verse Maximum Measured Load
were a combination of conical concrete failures in the grooves on the blocks and weld breaks in
the wire mesh. As stated previously, the wire mesh began to have large deformations in the middle wire. Figure 29 shows that due to the shape of the blocks there is nothing holding the middle wire in the grooves other than the weight of the soil. As force is applied equally to all the wires the middle wire likely met resistance laterally but almost no resistance vertically, slipped out of the angled groove and began deforming the back transverse wire. This deformation then spread to the front transverse wire and spread out affecting the other longitudinal wires. The wires slipped out of the grooves as much as possible but met resistance from the blocks above. The wires would then be slightly out of the grooves and applying very large stress concentrations to the edges of the concrete grooves. This was most noticeable at the welds of the longitudinal and transverse wires. As the longitudinal wires were loaded and the transverse wires became more deformed, the welds would have experienced shear stress from the axial load in the longitudinal wires as well as a bending/prying action from the transverse wires. This additional
stress on the welds caused the premature failure in the welds prior to reaching the yield stress of the wires.

In order to achieve higher connection capacities, several modifications to the Mega Wall block design were presented to Oldcastle.

- Making the grooves deeper so that the wires would be less likely to slip out
- Placing inserts cast into the concrete that would prevent conical failures
- Placing grout over the wire mesh once it is in the grooves to prevent the wires from slipping out

These suggestions were acknowledged but not implemented. Oldcastle was not interested in testing modifications to the block and testing was terminated. It is assumed that the Mega Wall block design will not be modified and that Oldcastle will not recommend using the welded wire mesh connection.

Referring to the wire load vs time plots for each of the three tests, it was observed that measured wire loads were not equal across the entire mesh during loading. As stated in the data acquisition section, the 30 kip capacity ring load cells can be inaccurate by up to ±3.5%. This means 3.5% equates to ±1,050 lbs meaning one load cell could read up to 2,100 lbs more or less than another. All of the recorded data falls well within these limits. A potential check for future researchers could be to place the ring load cells in series and load them with the same hydraulic cylinder. This could help identify if the there was an issue with the way the load cells were used, or if the unequal loading was due to the measurement error.
Chapter 4

RECOMMENDATIONS, CONCLUSIONS

All tests of the Mega Wall block ended in combined wire slip, conical concrete failures which resulted in wire weld rupture from large deformations/prying action. Test #1 simulated a 6ft wall using W7 wire, the largest applied load was about 650 lbs., and the wire yield load was calculated to be 5,579 lbs. The failure occurred in the number 5 wire but mesh deformation and wire slip began in the number 3 wire and progressed outward. Test #2 simulated a 6ft wall using W20 wire, the largest applied load was about 1,800 lbs., and the wire yield load was calculated to be 15,960 lbs. This mesh was offset from the center to test the connection of the block edge as shown in Figure 17. The failure occurred and was initiated in the number 5 wire. This is likely due to the lack of resistance from concrete due to the shape of the block. Test #3 simulated a 40ft wall using W20 wire, the largest applied load was about 3,600 lbs., and the wire yield load was calculated to be 15,960 lbs. The failure occurred and was initiated in the number 3 wire, this deformation and wire slip then progressed outward until failures occurred in wire 2 and wire 1 respectively.

In order to achieve higher connection capacities, several modifications to the Mega Wall block design were presented to Oldcastle.

- Making the grooves deeper so that the wires would be less likely to slip out
- Placing inserts cast into the concrete that would prevent conical failures
- Placing grout over the wire mesh once it is in the grooves to prevent the wires from slipping out
These suggestions were acknowledged but not implemented. Oldcastle was not interested in testing modifications to the block and testing was terminated. It is assumed that the Mega Wall block design will not be modified and that Oldcastle will not recommend using the welded wire mesh connection.

The completion of Test #3 proved that the testing apparatus can simulate a 40 ft. tall MSE wall with welded wire mesh reinforcement. The apparatus works well for simulating large block SRWs and might be used to test other MSE walls with a different reinforcement types.

The wire load vs time plots for each of the three tests measured wire loads that were not equal across the entire mesh during loading. As stated in the data acquisition section, the 30 kip capacity ring load cells can be inaccurate by up to ±3.5%. This means 3.5% equates to ±1,050 lbs meaning one load cell could read up to 2,100 lbs more or less than another. All of the recorded data falls well within these limits. A potential check for future researchers could be to place the ring load cells in series and load them with the same hydraulic cylinder. This could help identify if the there was an issue with the way the load cells were used, or if the unequal loading was due to the measurement error.


Wire Loads

Calculated Wire Yield Loads

Test #1
W7 wire

Wire properties

\[ \begin{align*}
D_7 &= 0.298 \text{ in} \\
f_y &= 80000 \frac{\text{lbf}}{\text{in}^2} \\
A_s &= \frac{\pi \cdot D_7^2}{4} \\
A_s &= 0.0697 \text{ in}^2 \\
Q_u &= A_s \cdot f_y \leq \text{Ultimate tensile strength} \\
Q_u &= 5579.7 \text{ lbf}
\end{align*} \]

Test #2 & #3
W20 wire

Wire properties

\[ \begin{align*}
D_{20} &= 0.504 \text{ in} \\
f_y &= 80000 \frac{\text{lbf}}{\text{in}^2} \\
A_{20} &= \frac{\pi \cdot D_{20}^2}{4} \\
A_{20} &= 0.1995 \text{ in}^2 \\
Q_u &= A_{20} \cdot f_y \leq \text{Ultimate tensile strength} \\
Q_u &= 15960.3 \text{ lbf}
\end{align*} \]
Steel Casing

Lateral Earth Pressure

Measured

\( W = 2.71 \text{ ft} \quad \text{Width of side bulkhead} \)
\( H_b = 5 \text{ ft} \quad \text{Height of side bulkhead} \)

Assumed

\( \phi = 34 \)
\( \gamma = 125 \text{ lbf/ft}^3 \)

Calculated

\( K_0 = 1 - \sin \left( \frac{\pi}{180} \right) \)
\( K_0 = 0.4408 \)
\( H_o = 37.5 \text{ ft} \quad \text{Height of simulated overburden} \)

\[ \sigma_v = \gamma \cdot H_o \]
\[ \sigma_v = 4687.5 \frac{\text{lbf}}{\text{ft}^2} \]

\[ \sigma_h = \sigma_v \cdot K_0 \]
\[ \sigma_h = 2065.3 \frac{\text{lbf}}{\text{ft}^2} \]

\[ P_0 = P_1 + P_2 \quad \text{<- Total lateral force applied} \]

\[ P_1 = \sigma_h \cdot K_0 \cdot H_b \cdot W \]
\[ P_1 = 12341.8 \text{ lbf} \]

\[ P_2 = \frac{1}{2} \cdot H_b \cdot K_0 \cdot \gamma \cdot W \]
\[ P_2 = 1866.5 \text{ lbf} \]
\[ P_0 = 14208.3 \text{ lbf} \]

\[ P_o = 28416.6 \text{ lbf} \quad \text{<- Total lateral force applied to both bulkheads} \]

\[ f_y = 50000 \text{ lbf/ft}^2 \]

\[ A_s = \frac{1}{2} \text{ in} \cdot 3 \text{ in} = 1.5 \text{ in}^2 \quad \text{<- Area of each steel strip} \]
\[ n = 4 \quad \text{<- number of steel strips} \]

\[ P_s = n \cdot A_s \cdot f_y \]
\[ P_s = 300000 \text{ lbf} \quad \text{<- Amount of resisting force in steel} \]