



BIG-R-BRIDGE SUPER-COR BURIED METAL STRUCTURAL PLATE ARCH AND VIST-A-WALL MECHANICALLY STABILIZED EARTH RETAINING SYSTEM: CONSTRUCTION AND SETTLEMENT REPORT

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Abstract

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Table of Contents

1. Introduction	7
2. Super-Cor Arch	7
2.1. Site Preparation	7
2.2. Arch Construction	9
2.3. Construction Challenges	13
3. Vist-A-Wall	15
3.1. Site Conditions	15
3.2. Wall Details	15
3.3. Reinforcing Strips	16
3.4. Wall Units	17
3.5. Construction	18
3.6. Geotechnical Instrumentation	20
3.7. Groundwater Monitoring	20
3.8. Settlement Platforms	22
3.9. Observations	24
4. Recommendations	25

Table of Figures

Figure 1: Excavating for the Arch Foundation.....	8
Figure 2: Arch Foundation Elements Ready for the Closure Pour	9
Figure 3: Curing the Closure Pour	9
Figure 4: Constructing the first ring section.....	10
Figure 5: Raising the first ring section.....	11
Figure 6: Expansion of the arch by adding additional sections.....	11
Figure 7: Contractors connecting panels with torqued arch bolts	12
Figure 8: Fully assembled Arch	13
Figure 9: Arch Collar Formwork in Construction.....	14
Figure 10: Example wall panel being placed on leveling pad	15
Figure 11: Steel reinforcing strips placed in backfill behind the metal arch.....	16
Figure 12: Reinforcing strips connected to the wall panels.....	17
Figure 13: Typical reinforcement layout pattern	17
Figure 14: Northern wingwalls elevation view	18
Figure 15: Typical cross section of Vist-A-Wall and reinforcement	19
Figure 16: Geotechnical instrumentation layout	20
Figure 17: Monitoring well data.....	21
Figure 18: Piezometer data	22
Figure 19: Type I settlement platform data	23
Figure 20: Type IV settlement platform data.....	24
Figure 21: Completed Vist-A-Wall abutments and bridge	25
Figure 22: Completed Structure over the trail.....	26

1. Introduction

During the summer of 2017 the Vermont Agency of Transportation (VTrans) constructed a Super-Cor arch bridge, four Vist-A-Wall mechanically stabilized earth (MSE) wingwalls, and an independent retaining wall as part of the St. Johnsbury BF 7000(20) bridge replacement project. The Super-Cor arch was built with Vist-A-Wall wingwalls to replace the existing bridge spanning the Lamoille Valley Rail Trail and the retaining wall was built to provide support to Route 2B adjacent to a driveway.

Big R Bridge, who owns the proprietary wall system called Vist-A-Wall and Super-Cor arch, provided the shop drawings for the project, based upon design criteria provided by VTrans. Since this was the State of Vermont's first time using this particular type of Arch and MSE system on a federal aid project, it was designated an Experimental Feature Research Project.

The Super-Cor Arch and Vist-A-Wall MSE Structural Wall System was thought to be beneficial for several reasons.

- Complete details of the arch and wall system would be solicited in advance and incorporated into the contract documents. This would allow contractors in this area not familiar with this type of construction to become better acquainted with the construction requirements.
- The design could be reviewed in advance by the Agency of Transportation. This would allow the Agency to resolve any problems it had with computations, allowable stresses, design loads, construction details, and specifications, before bid letting.
- The anticipated settlement of the foundations was expected to be between 2 and 3 inches. The Vist-A-Wall MSE Earth Structural Wall System and Super-Cor buried corrugated steel arch can accommodate approximately 6 inches of settlement over a 50-foot span.
- In accordance with the Agency's "Policy on Earth Retaining Structures" dated November 1995, successful completion and satisfactory performance of this wall in the field would allow the addition of another retaining wall system to the Agency's Earth Retaining System Selection Chart for Mechanically Stabilized Earth walls and more competitive bidding of future projects.
- The Vist-A-Wall MSE wingwalls would be more tolerant to differential settlement than a conventional reinforced concrete wall.

This report documents our observations during and post construction, the results from the geotechnical instrumentation, and provides a summary of our recommendations.

2. Super-Cor Arch

2.1. Site Preparation

Several engineers from VTrans Structures spent May 16th – 19th, 2017 observing the construction of a 47 feet wide galvanized steel structural plate arch on VT Route 2B in St. Johnsbury VT. The structure is an open-bottom arch (OBA) spanning a heavily used recreational trail, the Lamoille Valley Rail Trail (LVRT). The arch was required to be at least 25'-1"

tall to allow for possible railroad re-use in the future. The construction sequence and important notes regarding construction of the arch are discussed in the following paragraphs:

After demolition of the previous bridge at the site and removal of old foundations initial excavation could proceed. Site conditions were wet due to heavy rains and moisture seeping from a significant clay layer, (primarily on the west side of the site, see geotechnical section for more information).

Arch component construction began by placing small, efficient foundation elements. Each footing was split into five precast concrete sections and joined with structural closure pours. Each section was small (approx. 6' wide x 2' thick x 6'-long) and light enough to be lifted with a wheel loader, instead of a crane. There was a 4" deep recess in the top of each precast block to receive the leg of the arch. Foundation elements were set directly on 12" of select granular backfill for structures. After adjoining abutment elements were aligned, closure pours were performed using high-performance rapid-set concrete. Per the contract documents, rapid-set concrete was required to cure to 4000 PSI before any construction loading. The cure period took approximately a day and a half to reach the required strength. Figures 1-3 depict foundation excavation and closure pour curing.



Figure 1: Excavating for the Arch Foundation



Figure 2: Arch Foundation Elements Ready for the Closure Pour



Figure 3: Curing the Closure Pour

2.2. Arch Construction

After curing rapid-set concrete on both strip footings to the required strength, arch construction could commence. Big-R bridges dispatched two technicians/engineers to be on-site during arch construction. This proved to be an invaluable resource for the contractor, as the construction of the arch can be confusing to a contractor who is inexperienced in

structural plate assembly. Big-R representatives provided the contractor with a color-coded diagram to aid in assembly. From the factory, the structural pieces of the arch are provided as individual labelled plates (called “leaves”).

The plates bolt together in a specific order to form four-foot wide cross-sections of the arch. These are referred to as “rings”. Construction was performed by first constructing the first ring on the ground. This ring was then raised with two excavators to rest atop the foundation. The contractor used wooden blocks on the pivoting edge of the ring to protect the edges from damage. The ring was supported while workers began bolting additional leaves to the base of the raised ring using a man lift. Once the arch had been assembled to the point of bearing on two leaves at the base, the excavators were disconnected from the raised structure as it could support itself safely. One excavator was used to raise additional half rings that were constructed on the ground while leaves were attached to the base. Construction of the arch can be seen in Figures 4-6.



Figure 4: Constructing the first ring section



Figure 5: Raising the first ring section



Figure 6: Expansion of the arch by adding additional sections

The contractor completed arch assembly in an efficient manner. One crew worked on prebuilding half leaf sections on the ground, while another crew worked on installing the base leaves on the standing structure. While assembling the leaf on the ground, bolts were tightened with an electric impact wrench, but not torqued to specification. Bolts were torqued only after the leaves were lifted and assembled on the standing structure. Inspection staff noted that the contractor must be vigilant about protecting the galvanized coating when lifting stacks of individual structural plates for assembly. The

stacks were very heavy (5,000 – 10,000 lbs.) and the galvanized finish was damaged by rubbing against a chain while lifting. Doubling the lifting points (using two chains), using a coated chain or nylon strap to lift, using a spreader bar, or employing a combination of these methods eliminated damage to the galvanizing. A cold-galvanizing touch-up product was used to recoat small sections of the arch that were damaged during lifting.

The contractor was supplied with 2" and 3" length bolts for assembly. However, in some connections where four plates were stacked, the contractor realized that 4" bolts would be necessary for assembly. Otherwise, there was not sufficient thread projecting through the multiple plate stack to attach the nut. The heads of the connection bolts were consistently placed on the outside face of the arch, although this was not a design specification. Bolt tensioning was performed from below for the sake of assembly convenience. The contractor decided to face the bolt threads inward, because they found it easier to tension from below. Figures 7 and 8 show the workers torquing arch bolts and the arch fully assembled.



Figure 7: Contractors connecting panels with torqued arch bolts



Figure 8: Fully assembled Arch

2.3. Construction Challenges

VTrans has experienced a mixed history of results involving galvanized pipe material and durability. Conditions in Vermont are usually harsh due to frequent and heavy application of roadway deicing salts. The designers took several measures to guard against future durability issues. First, the contract required arch components to be galvanized to VTrans' material specification 726.08. This specification requires galvanization to meet the requirements of AASHTO M 111. This is standard practice for any galvanized parts/components utilized in VTrans projects. Second, a special electrochemical specification was included in select backfill specification for fill around the arch. The specifications called for backfill to meet the following requirements: Resistivity: 3000 ohm-cm, pH: 5-10, Sulfates: 200 ppm max, Chlorides: 100 ppm max, and Organic Content < 1%

The contractor had some difficulty finding backfill that met these requirements. However, a supplier was eventually located who could meet the specification. Contractors should be aware that electrochemical tests take approximately two weeks per test and should be prepared to schedule accordingly. Third, the structural steel components specified an engineered thickness of 0.218" (5 ga). This was recommended by Big R Bridge to meet the required 75-year design-life. Lastly, the designers specified a geomembrane liner and drain system to be placed over and through the select backfill. This membrane protects the backfill from corrosive sulfates leaching into the material.

The contractor experienced several issues during construction that may be rectified in future designs. The first involved expected arch deformation. First, due to existing roadway elevations the arch design allowed for little cover (only about two feet) between the arch peak and final grade, for placing dense graded crushed stone. The designers expected some settlement that did not occur. In addition, the arch shape may have been very slightly distorted due to a slight imbalance in the backfill and compaction operations on opposite legs. This distortion is normal for these structures. Contractors

should take care to keep fill levels as balanced as possible on each side of the arch during backfilling. This project specified a maximum backfill differential of 12". After speaking with Joel Hahm of Big R Bridges, VTrans determined that some minor arch distortion is both normal and difficult to predict when constructing structures like this, especially of this size. The lack of space for cover over the arch required field staff to raise the finish grade approximately five inches. Future designers should note that grades are somewhat difficult to control with structures of this nature due to deflection, backfill effects and settlement uncertainties. If possible, additional tolerance should be planned for in the dimensions between the peak of the structure and roadway elevation.

The second construction challenge was the specification of an architectural cast-in-place collar to cover the entrance and exit edges of the plate arch. The north and south face collars were slightly different. The north collar was connected to the MSE wall cap on the center portion of the north face. However, the south collar was independent of the wall cap at the middle of the arch, as the geometry allowed this simplification. Figure 9 shows the construction of the architectural collar.



Figure 9: Arch Collar Formwork in Construction

The field construction of the architectural collar proved to be time-consuming and challenging to form, pour, and cure. The complex curve and skew of the arches complicated this issue, which is why they were not considered for precasting. The contractor did not meet the first of their two contractual re-opening dates (for the LVRT), partially due to issues constructing these collars. The original design did not specify pouring the collars in three sections (two legs and a center arch). This modification was approved in the field, but affected scheduling.

3. Vist-A-Wall

3.1. Site Conditions

The Super-Cor arch is supported by four Vist-A-Wall MSE wingwalls as well as an independent retaining wall supporting an elevated section for the roadway. The four wingwalls ranged from 44.3 feet to 55.8 feet in length and 30.6 feet to 34.1 feet in height. Three borings: B-101, B-103, and B-104 were drilled by the Agency in June of 2014 and indicated the in-situ soil profile to be comprised of loose to very loose silty sand/sandy silt over a layer of very soft clay and soft silty clay. The layer of soft clay ranged between 12 and 20 feet in thickness and overlaid a layer of very dense sandy silt to bedrock. Laboratory triaxial and consolidation testing was conducted on the clay and silty clay material and although encountered in the field as soft, the material was found to be over-consolidated. An additional subsurface investigation was conducted for the separate retaining wall in September of 2014. Two additional borings: B-201 and B-202 were drilled by the Agency in the location of the retaining wall. These borings indicated a mixture of sand and silt overlying silt to the depth of the borings.

3.2. Wall Details

The retaining wall system supplied by Big R Bridge was produced through Old Castle Precast, in Rehoboth, MA. The wall system achieves its structural integrity through the use of steel reinforcing strips, placed within layers of compacted fill material, which are attached to vertical concrete wall panels to form a reinforced earth mass behind the wall. The precast wall panels are placed on a concrete leveling pad and stabilized, then the reinforcing strips are buried in backfill in staggered lifts. The placement of the panels can be seen in Figure 10 and the reinforcing strips can be seen in Figure 11.



Figure 10: Example wall panel being placed on leveling pad

3.3. Reinforcing Strips

The reinforcing strips used for this project were galvanized steel meeting ASTM A 572 grade 450. The strips were 2 inches wide with 3-inch ribs spaced at 12-inch intervals along the strip. For the wingwalls, the length of the reinforcement varied from 21 feet to 23 feet in length. For the retaining wall, the strips ranged from 9 to 13 feet in length. The strips were connected to the wall panels with vertical bolts. The strips and connections can be seen in Figure 12.

The wingwalls were built opposite one another and the reinforcing strips were placed in the backfill between the walls. Due to the length of the strips, the reinforcement overlaps in some places in the backfill. Where the strips overlap, a minimum of 3 inches of soil was placed in between the strips. A plan view of the MSE reinforcement can be seen in Figure 13.



Figure 11: Steel reinforcing strips placed in backfill behind the metal arch



Figure 12: Reinforcing strips connected to the wall panels

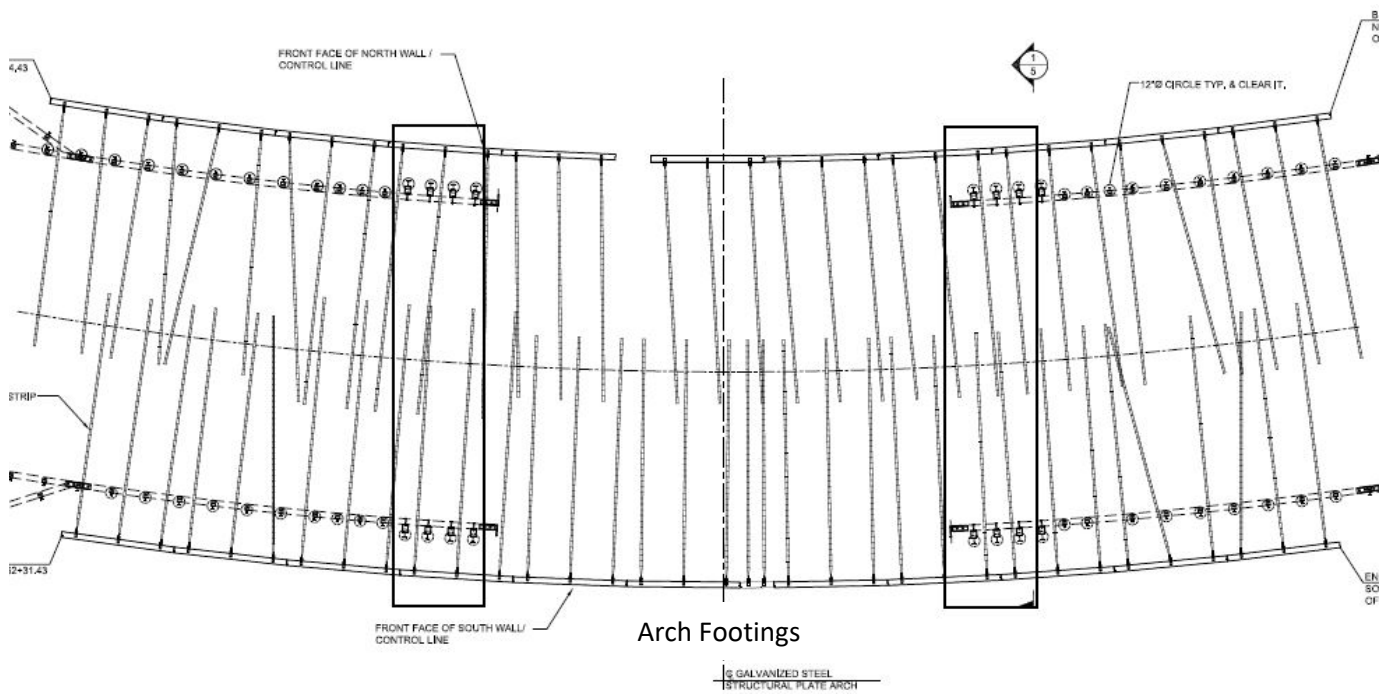


Figure 13: Typical reinforcement layout pattern

3.4. Wall Units

For this project, various precast panel types were used to form up the wall around the arch structure. Typically, the panels were rectangular in shape with 10-foot lengths and varied heights from 2 feet to 7.5 feet. Smaller, more irregularly shaped panels were located adjacent to the metal arch. Panels also varied in the number of reinforcing strips attached to each one. In general, panels at the base of the wall had the most reinforcement with fewer strips on the top panels. The panels

were capped with cast-in-place blocks that were 2 feet tall and 10 feet long. The caps act as support and provide an aesthetic look to the top of the wall. Figure 14 shows an elevation view of the northern wingwalls showing some of the different wall panels used.

3.5. Construction

The Vist-A-Wall MSE walls were assembled by JP Sicard, Inc. Figure 15 illustrates a typical cross section for this project. The first stage of construction required the excavation and benching of the in-situ soil and the construction of the one foot by six inch unreinforced, cast in place, leveling pads. The first row of panels was then placed on the leveling pad and shored using temporary wooden supports. The joints between the panels were covered with geotextile fabric to prevent fines from migrating through the gaps. When the walls were set, the backfill was placed in six-inch lifts and compacted up to the first layer of reinforcing strips. The reinforcing strips were then connected to the panels with bolts. Once the strips were attached, backfill material was placed on top of the reinforcement in six-inch lifts and compacted using a vibratory drum roller except within 3 feet of the arch and the walls, where a hand compactor was used. Due to the nature of the arch structure, the backfill needed to be placed and compacted evenly on both sides. The height of the backfill was supposed to be maintained within a maximum difference of 12 inches across the arch, however, during construction the height difference was greater than 12 inches at times due to the accelerated nature of the project.

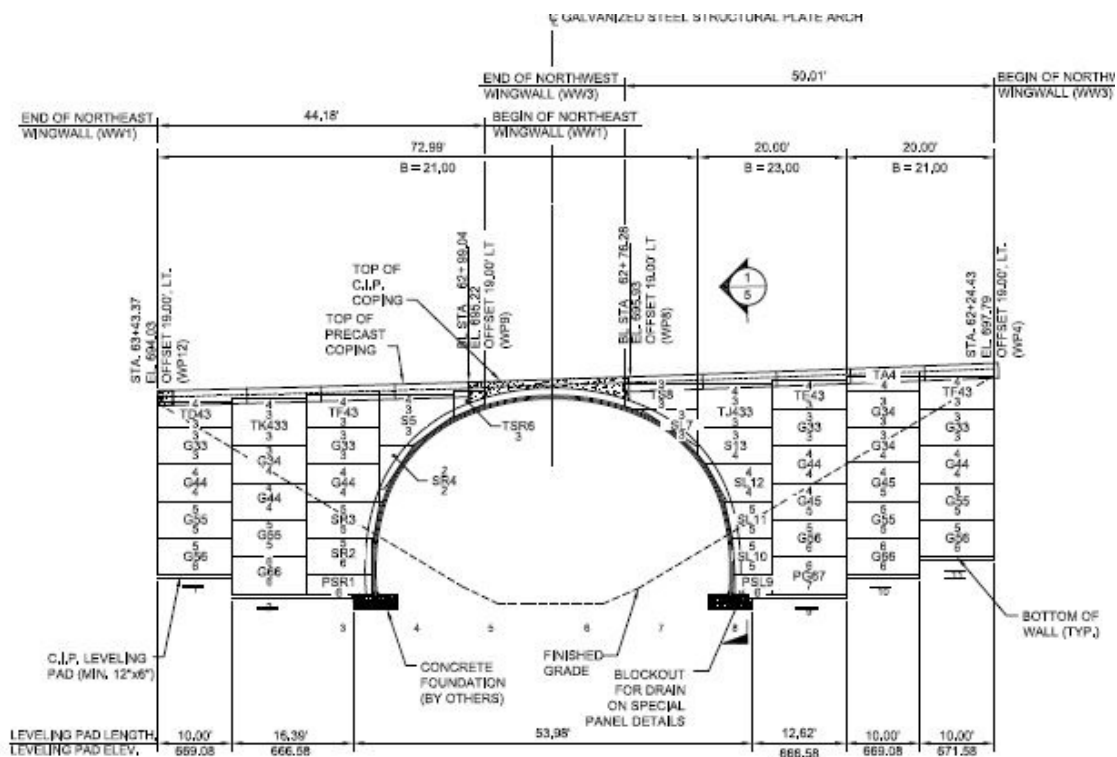


Figure 14: Northern wingwalls elevation view

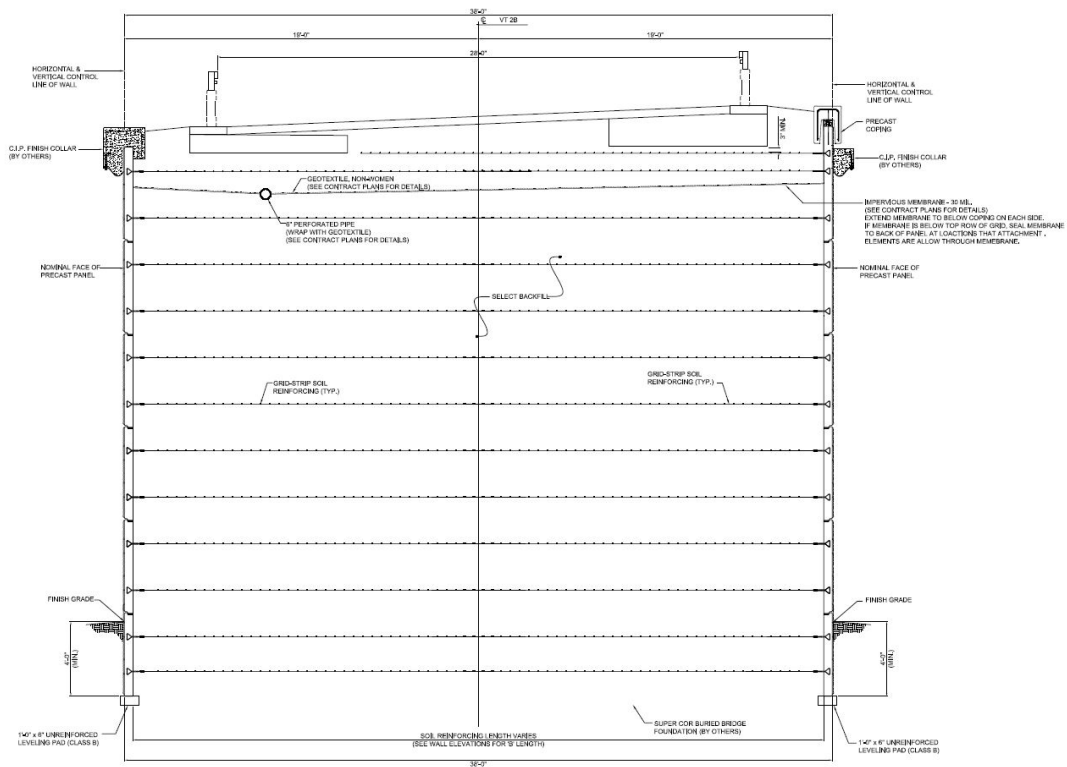


Figure 15: Typical cross section of Vist-A-Wall and reinforcement

Once all the layers of reinforcement and wall panels were in place, forms were erected for the cast-in-place concrete wall caps and arch collar. During the placement of the backfill, Sonotubes were placed in the locations of the bridge rail posts. This was one of the few issues the contractor had while constructing the wingwalls. The locations of the actual bridge rails differed slightly from the Sonotube locations, likely due to the curve of the bridge, so posts had to be installed in the fill and not within the Sonotubes in some places. Fortunately, the final locations of the posts did not coincide with any of the reinforcement locations. For future projects, designers, contractors, and inspectors should be aware of this issue and ensure the locations of bridge rail posts are accurately located. Another challenge during construction was getting proper compaction near the wall panels, especially where the reinforcing strips attached to the panels. Compaction within 3 feet of the panels required additional hand compaction by the contractor to ensure proper compaction of the backfill. The Special Provisions for this project did not require soil density tests in this area. In future projects, the compaction within 3 feet of the panels should be at a minimum spot-checked during installation.

The design of the project required that a drainage pipe be installed on the back side of the wall. The drainage pipes were constructed with a perforated pipe that was buried in crushed stone and wrapped in geotextile. The MSE backfill specifications specified a free draining backfill that along with the drainage pipes, installed on both sides of the arch, help prevent excessive hydrostatic pressures from developing during and after construction.

The final step in constructing the bridge was placing the prefabricated concrete rail support slabs and dense graded crushed stone and paving the roadway. During the construction of the bridge, the arch shape was slightly distorted which

is not uncommon in these types of structures. For this reason, in order to maintain the cover between the arch and roadway, the grade of the road had to be altered slightly in construction from the original design.

3.6. Geotechnical Instrumentation

Concerns of differential settlement and excessive total settlement of the structure, very wet conditions on the western side of the bridge, and a desire to monitor the performance of the wall as an Experimental Feature resulted in the use of the following types of geotechnical instrumentation:

- Monitoring wells on both sides of the arch to monitor the effectiveness of the free draining backfill in the reinforced soil mass located near the face of the walls.
- Vibrating wire piezometers buried directly behind the arch footings to monitor the hydrostatic levels of the reinforced soil mass.
- Two types of settlement platforms to monitor the differential and total settlements across the arch, along the northwestern wingwall (Wingwall 1), and across the western footing.

The instrumentation was monitored by the contractor during construction and was monitored by VTrans personnel for six months after the completion of construction. The locations of all the instrumentation in the area of the MSE walls is shown in Figure 16.

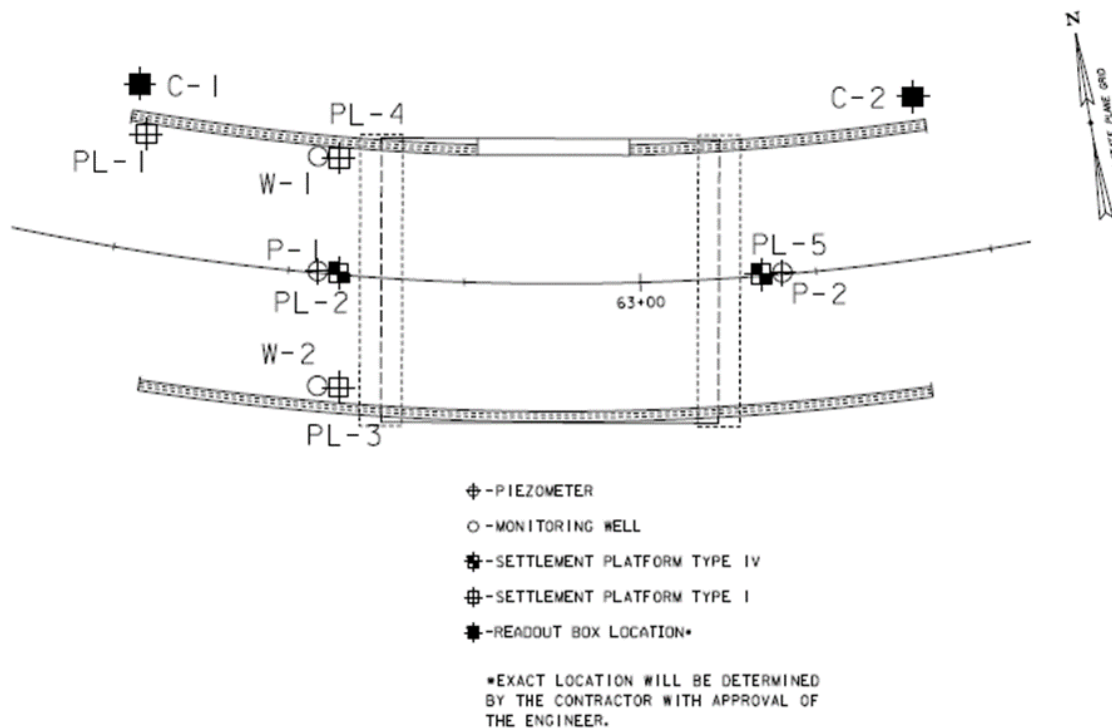


Figure 16: Geotechnical instrumentation layout

3.7. Groundwater Monitoring

During the design phase for this project, it was noticed that the site had a significant amount of water. While on site, surface water was observed, and groundwater was encountered at approximately 5.4 feet below the ground surface in

boring B-101 during drilling. The soils present at the western abutment location appeared significantly wetter than the eastern abutment. For this reason, a pair of two-inch diameter PVC groundwater observation wells and a pair of vibrating wire piezometers supplied by Geokon Inc. were installed to measure the groundwater levels. The purpose of the wells was to measure the effectiveness of the select backfill and drainage pipe in draining water during and after the end of construction in the fill behind the western abutment. The piezometers were installed at locations where monitoring wells would have interfered with traffic behind both abutments and were used to determine the effectiveness of the select backfill and drainage system on either side of the bridge. Once the final fill elevation was achieved, the water level decreased from the highest elevation by 5.6 feet and after approximately 5 months of observation, had decreased by an average of 4.5 feet. Results from the monitoring wells and piezometers can be seen in Figure 17 and Figure 18, respectively.

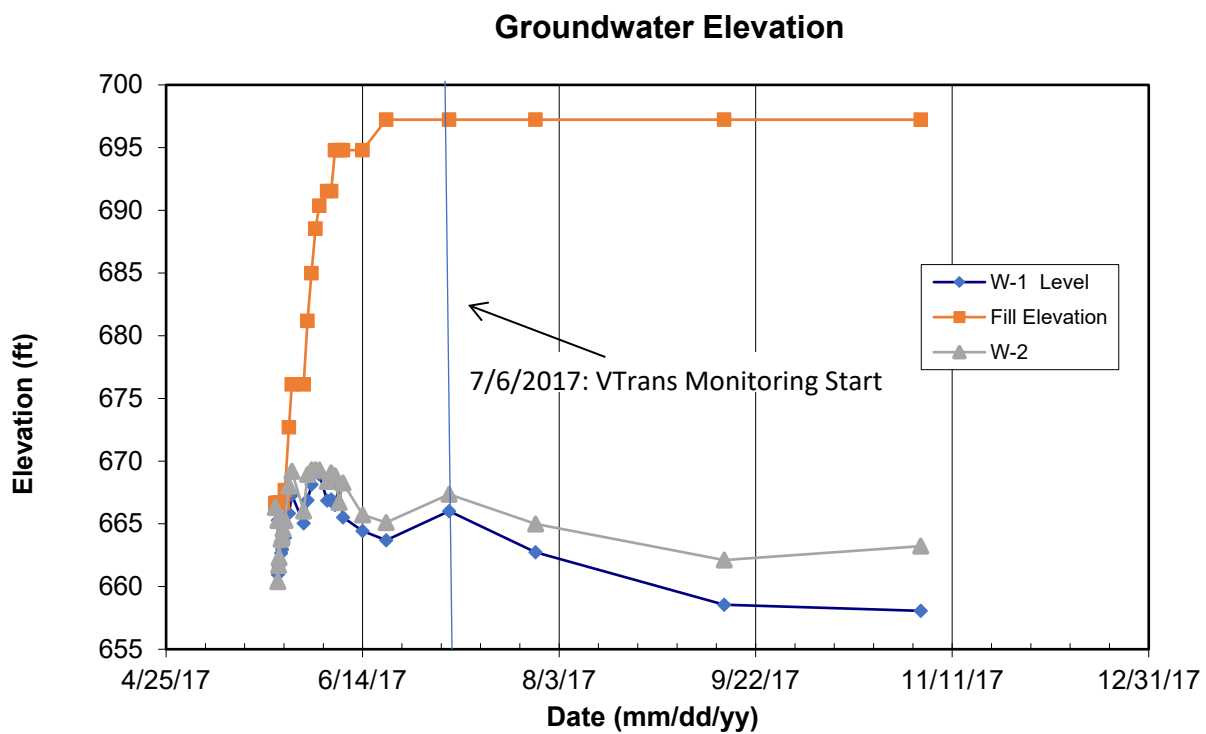


Figure 17: Monitoring well data

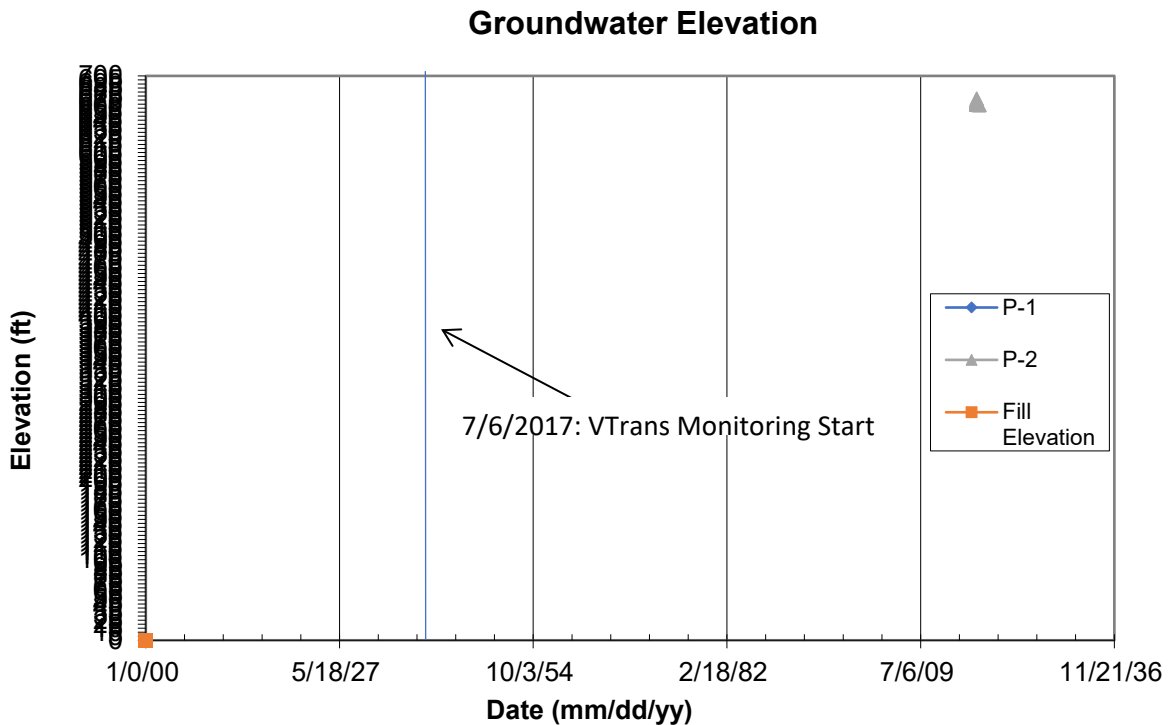


Figure 18: Piezometer data

3.8. Settlement Platforms

Two types of settlement platforms were used to monitor the vertical displacements anticipated due to the addition of the MSE walls and arch footings. The in-situ cohesive soil was found to be over-consolidated, therefore the settlement expected was within the loose cohesionless soil layers and expected to occur during construction of the fill for the most part. Three Type I standpipe settlement platforms and two Type IV vibrating wire settlement platforms were placed in the locations shown in Figure 16. Type I platforms consisting of 3-inch diameter galvanized steel standpipes attached to four foot by four-foot sheets of pressure treated plywood were placed on the existing ground prior to fill placement. As the MSE abutments and wall sections were constructed, additional riser pipe sections were added, and the elevation changes were recorded using traditional survey equipment. The results from the Type I settlement platforms can be seen in Figure 19.

The data from the Type I settlement platforms was measured from the same survey point by both the contractor during construction, and VTrans personnel after construction. This data shows total settlement values of between 0.6 inches and 2.3 inches with the majority of the movement happening while the embankment fill was being placed. This amount of settlement was anticipated by the design which predicted settlements of up to 2 to 3 inches expected during construction.

Settlement platform PL-1 experienced the greatest amount of settlement and PL-3 experienced the least amount of settlement. This matches what was expected as PL-3 is located in the area of the previous pier and PL-1 is located in what was the previous embankment. The in-situ material in the location of PL-3 likely experienced greater pressures from the previous structure than PL-1 and more settlement likely occurred long before the settlement platforms were constructed.

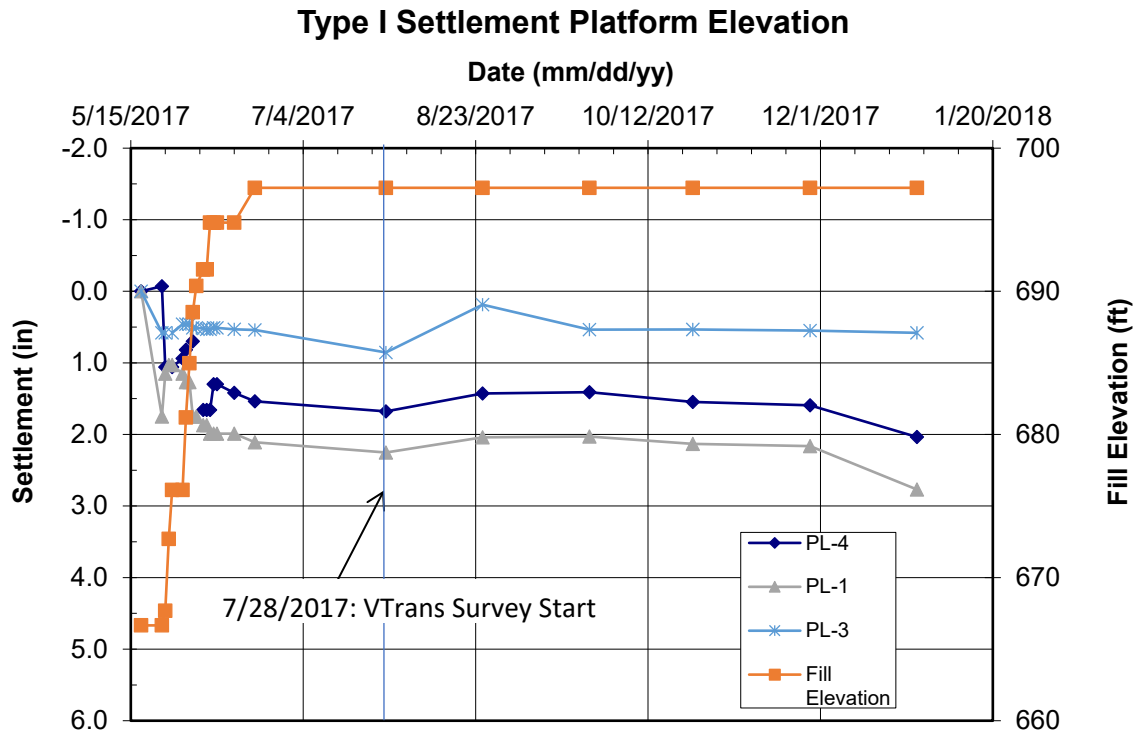


Figure 19: Type I settlement platform data

In areas where standpipes would interfere with traffic, Type IV vibrating wire settlement platforms supplied by Geokon Inc. were installed to monitor the elevation changes remotely. Vibrating wire pressure transducers were attached to reservoirs and settlement plates at the ground surface via fluid filled tubes. As the settlement platforms move with the ground surface, the transducers sense the change in fluid in the tubes and provide a measure of the difference in the elevation between reservoir and the sensor. The vibrating wire settlement platforms were connected to a remote readout location and were monitored with a Model GK-405 Readout Box during construction and for 5 months after construction. The results from the Type IV settlement platforms can be seen in Figure 20.

The readout box used to obtain the settlement measurements for the Type IV platforms as well as the fluid filled tubes were moved during construction multiple times. The tubes were protected from construction activity and covered with burlap fabric to reduce the effect of weather on them. However, as can be seen in the data, the readings fluctuate until the final fill height is established. At this point, the tubes were buried and the readout box location was moved for the last time. Although the data was calibrated, the final values show a negative settlement which is likely inaccurate. Looking at the trend of the data obtained, it shows that the majority of the movement occurred during construction and has leveled out afterward, which correlates to the data obtained from the Type I platforms. The data from the Type I platforms should be used to evaluate the performance of the wall system as it is likely more accurate.

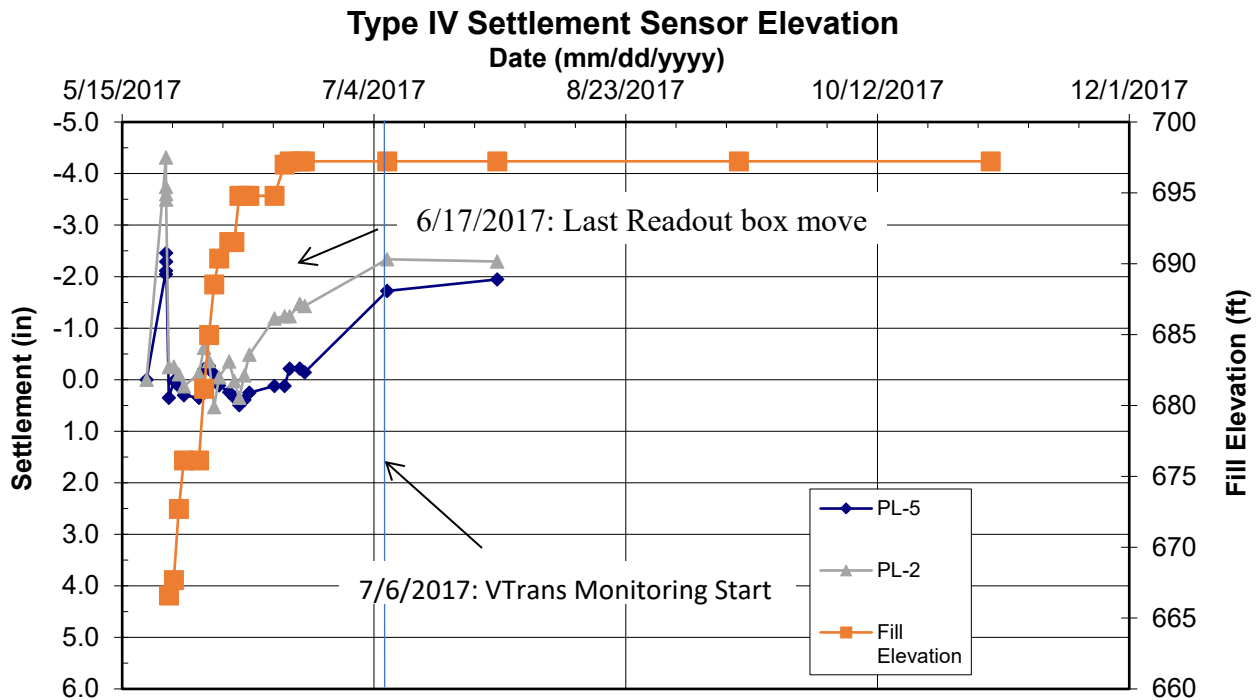


Figure 20: Type IV settlement platform data

3.9. Observations

Overall, the construction of the Vist-A-Wall went smoothly. The biggest challenge with the installation of the wall sections was accessing the site with larger equipment that needed to track on soft and wet in-situ soils. The bearing material consisted of a clay material with a high-water table during the start of construction. After some difficulties, the contractor decided to slightly over-excavate the native material and place some of the select backfill to have a better working platform for equipment and personnel.

The largest challenge encountered during construction was the placement of the readout locations for the instrumentation. The readout locations were chosen prior to construction to stay within the state right-of-way. However, during construction it became evident that the pre-selected locations would not work. Because of the necessary excavation of the existing embankments, the readout locations were placed in temporary construction easements. Once the abutments and embankments were completed, the readout locations were moved back into the right-of-way. The electrical and fluid filled lines running from the instrumentation to the readout boxes were also moved during construction as the embankments were constructed. Precautions were taken to ensure that the instrumentation was not damaged during construction, however all of the relocating and movement may have impacted the data in the early phases of the project as explained above. The long-term monitoring shows that the wall systems appear to be performing as designed.

4. Recommendations

The wall system discussed in this report incorporated the use of galvanized steel strips as soil reinforcement. This wall system proved to be an acceptable Mechanically Stabilized Earth Wall on this project. In the future, the Vist-A-Wall retaining wall system will need to be designed on a project specific basis to consider variations in wall heights, reinforcement lengths, soil conditions, and external loads acting on the retaining wall.

Issues with the Super-Cor arch included lower than acceptable cover depth, resulting from less deflections than expected, and deformations from uneven backfilling. If possible, additional tolerance should be planned for in the dimension between the peak of the structure and roadway elevation.

It is also recommended that this project be monitored into the future for any adverse changes and the changes be reported in future updates. If excessive water at the site or settlement of the structure are observed, the in-place vibrating wire piezometers and settlement platforms can be used to quantify the changes and determine what corrected measures should be taken.

As a result of the performance documented in this report, the Vist-A-Wall retaining wall system has been added to the Vermont Agency of Transportation Earth Retaining System Selection Chart for Mechanically Stabilized Earth walls. Figure 21 and 22 below shows the completed structure.



Figure 21: Completed Vist-A-Wall abutments and bridge



Figure 22: Completed Structure over the trail