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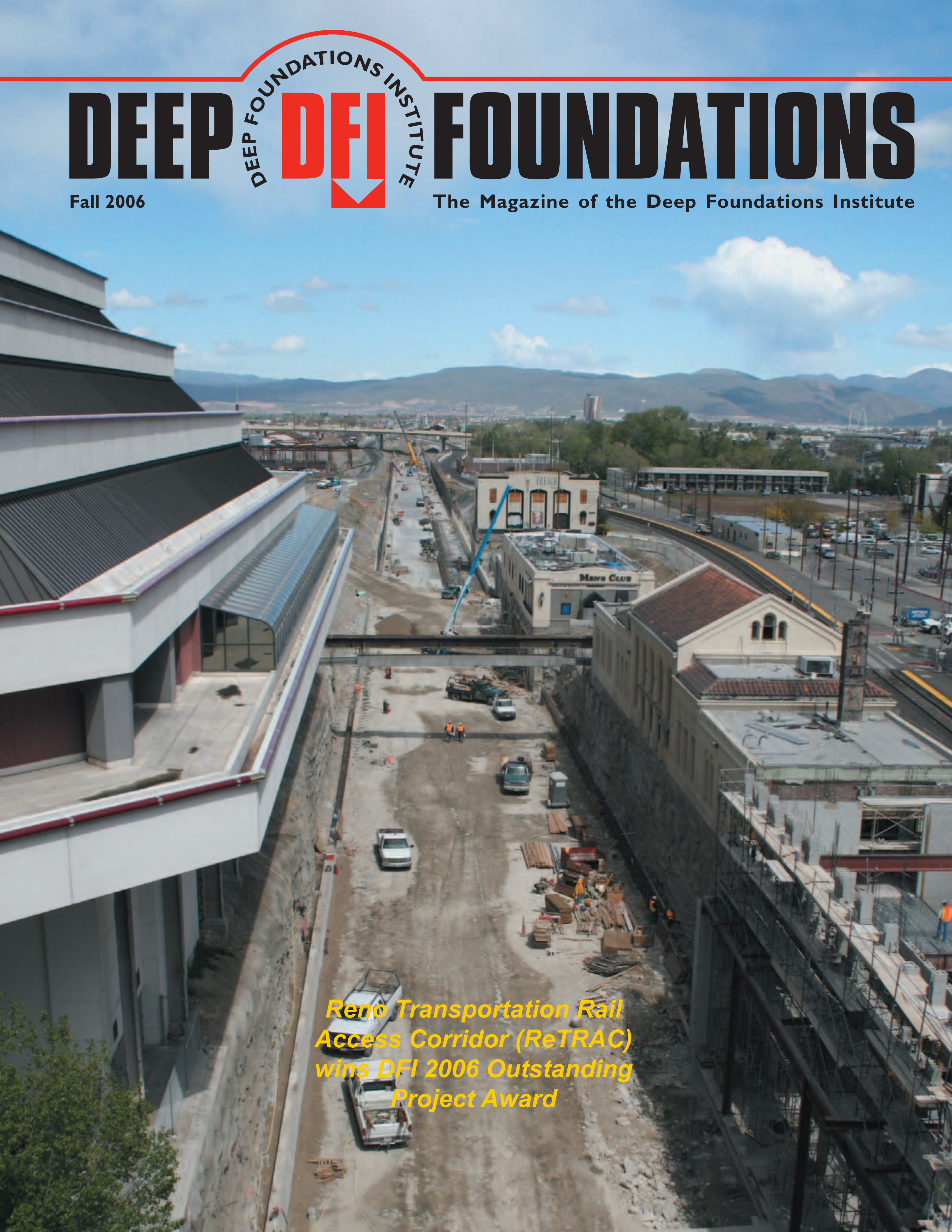

Underpinning and Temporary Earth Retention for the ReTRAC Trench in Reno

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In the spring of 2005 **Schnabel Foundation Company** completed a $15.2 million Design/Build subcontract to underpin 11 structures, and provide 202,800 square feet of earth retention for the Reno Transportation Rail Access Corridor (ReTRAC) project in Reno, Nevada. Schnabel's work was part of a Design/Build contract to depress a railroad alignment through downtown Reno. The depressed section was 2.2 miles long, 54 ft wide, and up to 35 ft deep (3.5 km long, 16.5m wide and up to 10.7m deep). The trench structure was required to be watertight.

SUBCONTRACT WORK OVERVIEW

Eleven buildings along the track alignment required underpinning. Three types of underpinning were used, designated Type 1, Type 2 and Type 3.

At four buildings the trench retaining walls were to be located directly under the exterior footings. This alignment eliminated traditional underpinning and cut-off wall techniques that could normally be used to support structures. Type 1 underpinning was used at these buildings. This underpinning system consisted of a combination of permeation grouting, hand-dug piers, and permanent tiebacks. This underpinning system became the new watertight trench walls.

Five buildings were located a few feet behind the trench walls, and their exterior walls were supported by continuous footings. Type 2 micropile/pile cap underpinning (patent pending) was used to support these buildings.

The remaining two buildings were also located a few feet behind the trench walls, but they had column footings along the exterior walls. At these structures traditional micropile underpinning was provided through the existing footings. This is described as Type 3 underpinning.

Temporary earth retention was required on both sides of the trench along most of the alignment. This shoring supported frontage roads, private property and surcharge from the temporary railroad shoofly running parallel to one side of the trench.

SUBSURFACE CONDITIONS

The soil along the trench alignment consisted of river outwash deposits. The top 2 to 18 feet (0.6m to 5.5m) generally consisted of flood plain silt and sand deposits, or fine-grained fills. These fine-grained soils are underlain by the Tahoe Outwash Formation which consists of interbedded layers of sand; sand and gravel; and sand, gravel, cobbles and boulders. Some of these layers encountered during construction consisted of 30 to 50 percent cobbles and boulders, with some boulders up to eight feet in diameter.

A major challenge to the design and construction of the trench structures and the underpinning was the ground water table which was 10 feet (3m) above subgrade in the deepest portions of the trench. Based on specification restrictions, temporary and permanent dewatering was not feasible. As a result, the selected design and construction methods had to consider three water conditions: the anticipated groundwater level during construction (CGW), the groundwater level for permanent design (DGW), and an additional special design condition with water at street grade.

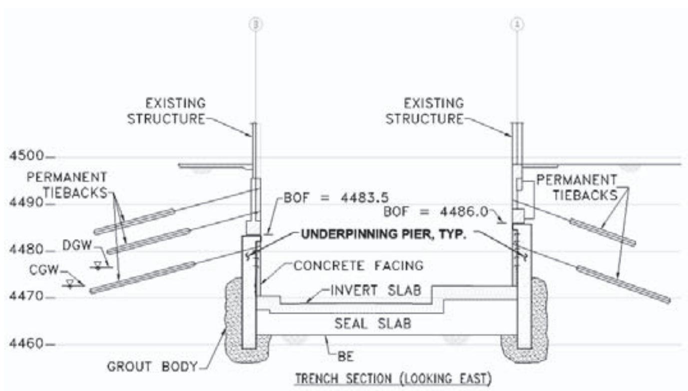

Figure 1. Underpinning Retaining Walls: Cross-section at Fitzgerald's Garage.

TYPE 1 UNDERPINNING

Overview

Type 1 underpinning was used where the trench walls needed to be built directly beneath the existing footings. This was the most difficult and expensive underpinning method and the only type of underpinning that became permanent trench retaining walls. The completed Type 1 underpinning at Fitzgerald's garage is shown in Figure 1.

Fitzgerald's Parking Garage

Fitzgerald's Garage was 300 feet long and the heaviest structure underpinned on the project.

The precast concrete garage has seven levels, and four of them span over the railroad tracks, Figure 2. The new trench walls were required to be directly below the column lines that straddle the trench. Each column line had 19 columns. Twelve to 24 inch (300mm to 600mm) thick shear walls extended 10 to 16 feet (3m to 5.5m) below existing grade. Precast columns rested on top of the shear walls. The existing footings were three feet thick. The footing width was three feet on the north side of the trench and two feet six inches on the south side. Footing loads along the two column lines varied from 18 to 41 kips per linear foot (262kN to 598 kN per meter).

Figure 2. Preconstruction Condition Looking West

The underpinning piers were designed to be nominally five feet (measured parallel to trench alignment) by three feet in plan. This dimension was large enough to meet the structural design requirements and allow a man standing in the excavated pit enough space to work. It was also small enough to not excessively undermine the existing structure. The piers were installed in a checkerboard pattern in order to limit settlement. The bottom of the piers were about 40 feet (12m) below existing grade, which was approximately 13 feet (4m) below the CGW level.

Added Degree of Difficulty

Four factors increased the level of pier underpinning difficulty:

Soil Conditions: Removal of boulders up to eight feet (2.5m) in diameter was challenging due to the five by three feet (1.5m by 0.9m) pit dimensions. A significant part of a boulder had to be exposed to determine how much of it was inside and outside the pier dimensions. Some boulders were broken up in the pit and removed in pieces while others were removed in one piece. As would be expected, removal of some large boulders required many days. Figure 3 demonstrates a pitman uncovering a boulder. Figure 4 shows a boulder that was removed from an underpinning pit in one piece.

Figure 3. Boulder in pit

Figure 4. Boulder removed from pit

High Groundwater: Up to 13 feet (4m) of pier excavation was done below the CGW level. The solution to this challenge was to permeation grout the water zone where the pit was to be excavated. The grouted soil had to be impermeable enough to prevent water flow, weak enough to allow hand excavation, and of sufficient size to allow a worker to safely hand excavate below the ground water table without cracking or punching through the grout body. The grouting program successfully met these criteria.

Corbel: To provide the railroad with its minimum horizontal clearance, the piers were set back 10 inches (254mm) behind the front face of the existing footing. This allowed a thin facing to be installed to provide a uniform finish and to cover the tieback anchor heads. However, because the footings were so narrow the pier needed to have full contact with it. To meet this need, a corbel was designed integral with the pier that extended 10 inches to the front face of the existing footing. This condition made access to construct the pier more difficult because the pier became recessed farther back beneath the existing footing. The load on the corbel also added bending moment to the pier which had to be accounted for in the design of the piers and tiebacks.

Size of the job: During portions of the underpinning up to 20 Type 1 piers were being worked on simultaneously. At Fitzgerald's alone the underpinning crew consisted of more than 50 people. The majority of this work was done during a very cold winter in Reno. As a result, finding a sufficient number of personnel and training crews that would work effectively and safely on this very specialized and difficult work was a formidable challenge.

Design

The underpinning had to extend deep enough to accommodate the excavation for a seal slab. This resulted in a temporary design height of up to 37 feet (11.3m). For the permanent condition, the design height was reduced by the combined thickness of the seal slab and invert slab to a maximum value of 29 feet (8.8m).

For the temporary and permanent condition, the design lateral pressures had to include; earth pressure, water pressure from the CGW level, and surcharge pressure from an adjacent stair/elevator structure and Cooper E80 train loading from the shoofly.

In addition, the permanent condition design lateral pressures had to include:

- Water pressure from the DGW level
- Seismic loading corresponding to a Contingency Level Earthquake (CLE) defined as an event with a 1,000 year return period but with an acceleration level not less than the Maximum Credible Earthquake (MCE) (this translated to a rather large uniform seismic pressure increment of 34H psf with H being the design height for the permanent condition in feet) or 5.34 kN/m2 with H expressed in meters
- Special condition using reduced load factors where the water level was assumed to be at street grade.

Permanent tiebacks were designed to resist all lateral pressures. Tieback design loads were up to 162 kips (720 kN).

The reinforced concrete design was in accordance with the AREMA (American Railway Engineering and Maintenance-of-Way Association) design specifications

Construction

The sequence of construction to create the completed permanent underpinning cut-off wall shown on Figure 1 was as follows:

1. Perform permeation grouting work from existing grade.
2. Install tiebacks through the existing shear walls.
3. Excavate to the top of footing elevation, set up all safety systems and air quality monitoring, and install the underpinning piers.
4. After all piers were complete, excavate and install remaining tiebacks.
5. Excavate to bottom of seal slab, install seal slab, dewater, install the invert slab, and 10 inch (254mm) pier facing.

Figure 5 shows the completed underpinning pier retaining wall with the invert slab completed, but without the facing wall installed. The corbel can be seen at the top of the piers.

The pier underpinning retaining walls for Fitzgerald's and the other three Type 1 underpinned buildings required 6,500 cubic yards (4,970 m^3) of permeation grouting, 4,700 vertical feet (1,433m) of pier excavation, and 10,000 feet (3,050m) of tieback drilling.

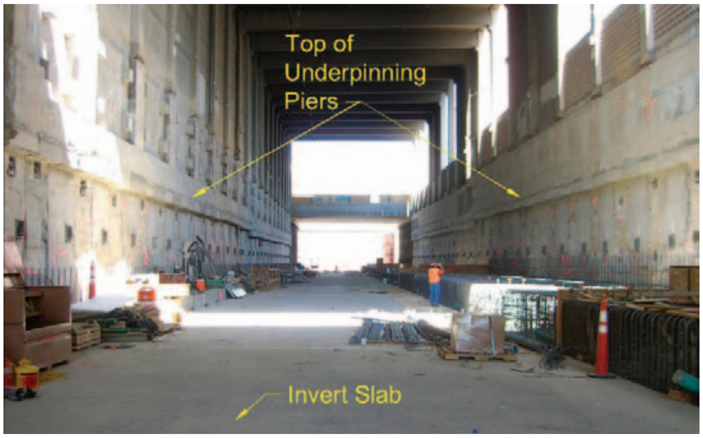

Figure 5. Fitzgerald's Hand-dug pier wall.

TYPE 2 UNDERPINNING

Type 2 micropile/pile cap underpinning (patent pending) was used for the historic Amtrak building (Figure 2) and four other structures. The Amtrak building wall line was nine feet behind the inside face of the new trench wall, and the excavated depth in front of the building was 34 feet

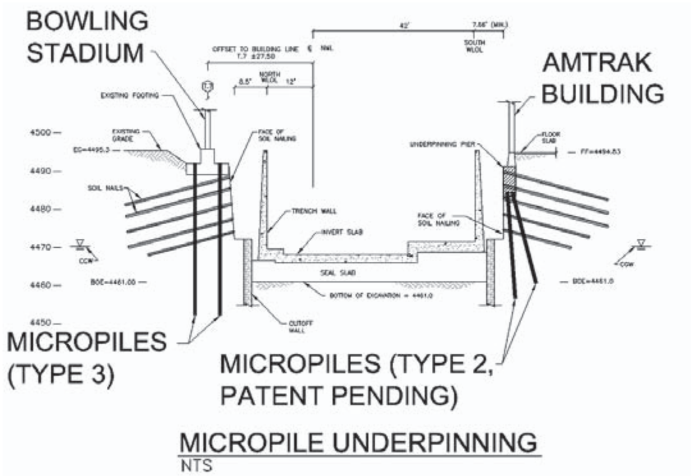

Figure 6. Micropile Underpinning

(19.4m). A cross-section showing the micropiles and hand-excavated pile cap is shown on the right side in Figure 6.

A photo of the completed underpinning with shoring in front of the Amtrak Station is shown in Figure 7. The structure experienced a maximum settlement of 1/4 inch (6.4mm).

Figure 7. Micropile Underpinning of Historic Amtrak Structure

TYPE 3 UNDERPINNING

Type 3 underpinning was used to temporarily underpin spread footings at the National Bowling Stadium (Figure 2) and one other structure. At these buildings, micropiles were installed through core holes drilled through the existing footings, as illustrated on the left side in Figure 6.

The National Bowling Stadium is an enormous bowling venue that contains 78 championship lanes. Limiting settlement of this structure was critical due to bowling lane tolerance requirements. A photo of the completed underpinning and shoring in front of the Bowling Stadium is shown in Figure 8.

The maximum depth of excavation in front of this building was 34 feet (10.4m). The existing footings were up to 11 feet by 11 feet (3.35m x 3.35m), with estimated column loads up to 484 kips (2,153 kN). Core holes were drilled through the existing footing, and up to seven micropiles installed to support each footing. Load transfer from the footings to the micropiles was provided by a grouted connection in the cored hole. The existing structure experienced a maximum settlement of 1/16 inch, (1.6mm) well within the tolerance required.

Micropile installation for the Type 2 and Type 3 underpinning required 13,500 linear feet (4,015m) of drilling.

Figure 8. Micropile Underpinning of Bowling Stadium (left side)

TEMPORARY EARTH RETENTION

The subsurface conditions presented severe challenges to traditional Earth Retention systems due to the cohesionless soils and numerous large boulders. To meet these challenges off-line battered soil nailing was selected as the most versatile, cost effective and quickly installed earth retention system, Figure 9. A nominal 1:6 batter was used, which allowed the granular soils in each lift to stand-up just long enough to get shotcrete placed over the exposed face before it began to ravel. The off-line batter also allowed the numerous boulders that were encountered to remain in the ground and protrude into the nominal batter, eliminating costly filling of voids with shotcrete. At locations where the water table extended above subgrade, a cutoff wall was constructed from the bottom of the soil nail wall to subgrade. The cutoff wall was typically 2 to 12 feet deep (0.6m to 3.6m), and was designed and constructed by another subcontractor.

Figure 9. Soil nail shoring to protect railroad shoofly

Soil nailing for the trench required 10,000 feet (3,050m) of soil nail wall, 192,000 square feet (17,840 m^2) of shotcrete face, and 141,000 feet (43,000m) of soil nail drilling.

There were a few locations where utility conflicts precluded the use of soil nailing. At those locations 10,800 square feet (1,000 m^2) of soldier beam and tieback walls were installed. The total surface area of earth retention installed on the project was 202,800 square feet (18,840 m^2).

MONITORING

Wireless tiltmeters were used to monitor underpinned structures (Ludwig, et. al., 2005). The maximum settlement readings for the exterior columns and walls ranged from 1/16 to 1/2 inch (1.6mm to 12.7mm), all within acceptable limits. Extensive monitoring of horizontal and vertical deformation of the shoring walls also showed those movements to be within acceptable industry standards.

SUMMARY AND CONCLUSIONS

The project's Design/Build performance specification allowed the Owner to benefit from the subcontractors experience in designing and installing underpinning and shoring. It did this by giving the sub-contractor the flexibility to determine the best solutions to deal with the unusually difficult geotechnical and alignment challenges presented by this project.

By combining hand-dug pier, permeation grouting and permanent tieback technology, permanent trench walls were successfully constructed directly below existing footings.

New (patent pending) and existing micropile techniques provided cost effective solutions for support of seven structures.

Adapting soil nailing techniques for use in cohesionless sands, gravels, cobbles and boulders provided a versatile, cost effective, and quickly installed shoring system.

The extensive monitoring of the existing structures and shoring verified that movements were well within acceptable limits.

Schnabel Foundation Company's underpinning and shoring work was completed without a single general liability claim for damage to existing structures or utilities.

REFERENCES

Claus Ludwig and Etienne Constable, 2005. Wireless Tiltmeters Monitor Stability during Trench Excavation for Reno Transportation Rail Access Corridor, Geotechnical News, December.

Schnabel Foundation Company has a patent pending application filed with the US Patent and Trademarks Office for certain aspects of the work described in the paper.

SCHNABEL FOUNDATION COMPANY

is to receive the

DFI 2006 OUTSTANDING PROJECT AWARD FOR THEIR RENO NV RETRAC PROJECT

"Everyone has the obligation to ponder well his own specific traits of character. He must also regulate them adequately and not wonder whether someone else's traits might suit him better. The more definitely his own a man's character is, the better it fits him."

Cicero (106 BC - 43 BC)

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View of ReTRAC Trench spanned by temporary bridges, showing soil nail and shotcrete retaining wall subjected to Cooper E-80 train loading from shoofly