Abstract

Micropiles have been used recently for a variety of foundation applications on railway structures and foundations throughout the country. The high capacities achievable with the use of micropiles, combined with specialty rigs for easy installation without track downtime in low headroom and difficult access areas makes them a good choice for situations often encountered on railway projects. Whether retrofitting bridge piers, re-supporting snowshed structures, or constructing new bridges, micropiles have proven to be a viable option for many projects. In this paper the authors will discuss three recent projects in which micropiles were designed and installed on railway projects. Design, construction, and quality assurance issues will be covered, with the inclusion of supporting figures.

Projects covered include: The installation of 150-kip micropiles for foundation upgrades along a mainline snowshed in Montana where access was limited to the roof of the snow shed. On another project, near St. Louis, micropiles were successfully designed and installed to retrofit an existing pier on a twelve span mainline structure. On the final project discussed in this paper, micropiles were used as the foundation for a bridge in Minneapolis where there was limited construction access due to a city street located beneath the existing structure.

BNSF Bridge 12.5 Foundation Retrofit
St. Louis, Missouri

Background

Bridge 12.5 is mainline railroad bridge over Gravois Creek and a St. Louis county Bicycle Path, Grant’s Trail, located south of the St. Louis City. In 1957, heavy flows in Gravois Creek washed out pier 8, which was rebuilt as a bent with double rows of exposed H-pile. Over the years, the bent in the soft overburden soils and relatively high rock began to exhibit lateral movement under load. In 2006, the owner requested that the geotechnical contractor provide a design-build solution for retrofitting the existing foundation to stabilize it against further movement.

The general soil stratigraphy of the site consists of:
0 to 25 ft: Very soft silt
25 ft to 32 ft: Silty gravel with some cobbles
32 ft to 35 ft: Weathered Rock
Competent Limestone was encountered at approximately 33 – 35 ft
Micropile Design

The owner provided the design service loads at the location of the proposed micropile-supported concrete pile collar.

The geotechnical contractor’s design (Figures 1 & 2) included installation of (8) micropiles at bent 8. The micropiles were designed for both tension and compression capacity, with vertical design loads being 100 kips per pile.

The micropile casing consisted of Grade 80 pipe, with a 5.5-inch outside diameter and 0.415 inch wall thickness. Central reinforcing steel consisted of a 1.375-inch diameter, Grade 150 threadbar, was extended full length in the micropiles to resist the tensile design load. The micropiles were tremie filled with neat cement grout $f'c = 5000$ psi.

The micropile casing was drilled approximately 25 feet below grade. The bond zone then extended from the bottom of the casing to 10 feet into competent rock.

Figure 1. Plan view of micropiles installed at bent #8.
Production Work

The geotechnical contractor provided layout of the micropiles and concrete pile cap. Once layout was complete shear connections, shown in Figure 2, were attached to the existing piles. The micropiles were drilled adjacent to the existing end bearing H-pile foundations. Because the bridge remained in service during installation of the micropiles, the micropile contractor selected a non-vibratory, non-displacement drill procedure so as not to jeopardize the load carrying capacity of the existing foundation elements. All drilling on site was completed with water flush. The rock sockets were drilled by duplex methods, with water flush. All of the work completed for installation and attachment of the micropiles to the existing structure was completed without track down time. After the micropiles were cut to the appropriate elevation, the concrete pile cap was poured. High early strength concrete was used to minimize down time required to allow proper curing of the concrete pile cap.

Bent 8 was located on adjacent to the bank of the channel, requiring some earthwork to allow access for micropile installation. An extended reach, track mounted drill rig, similar to an excavator, was utilized to reduce the amount of benching required to permit access. The work was performed under approximately 18 feet of headroom.

The following steps were used for installation of the micropiles: The drill rig was set up in place at each micropile location, the micropile drill string was then advanced through cobbles and clay, to approximate depths of 30 feet to the top competent rock. The geotechnical contractor then tremie-filled the bond zone and casing with neat cement grout mixed on site with a colloidal
mixer. Grouting continued until clean grout flowed out of the top of the casing. The internal threadbar was then placed in each micropile.

![Image](image_url)

**Figure 3.** Top, Completed micropiles at bent #8, completion of tension and compression connection detail. Bottom Tension/Compression Connection

Following completion of micropile construction, the geotechnical contractor excavated for the new pile cap to a depth of 4 feet below grade. The pile cap was then formed and poured. Pouring and curing of the pile cap required four hours of track down time, but the track was able to remain in operation during micropile drilling and installation.
Quality Control

The installation crews logged all installation details in a drill log for each pile. Proper micropile position and alignment was ensured by the use of layout of each pile by a surveyor and the use of an angle indicator monitored during installation of all piles.

Production Proof Test Pile

The geotechnical contractor performed a full-scale, tension load test on a production micropile. The micropile was incrementally loaded to 1.67 times the 100 kip design load. Displacement of the pile head at design load was 1.767 inches, meeting Davisson Failure Criterion for a quick load test. The pile also met the creep test specifications with 0.001 inches of displacement over the 10 minute hold period. Residual pile head movement measured approximately 0.077 inches after the load was removed from the pile. The load test data is shown in Figure 4.

The geotechnical contractor contracted with an independent testing facility to perform compressive strength tests on grout samples taken during installation of the micropiles and pouring of the pile cap. The testing confirmed that the grout exceeded the minimum design strength of 5000 psi. The concrete for the pile cap had a design strength of 2500 psi in 3 hours and in excess of 4000 psi at 28 days.

Figure 4. Load Test Data

BNSF Snowshed Foundation Retrofit MP 1168
Essex, MT

Background and Geotechnical Profile

Snowshed #12 on BNSF Mainline track between East Glacier and West Glacier, Montana was originally constructed in the late 1920’s in order to protect the track from snow avalanches as well as landslides. The snowshed is at Line Segment 36 -- Mile Post 1168.23 Hiline Subdivision, Essex, MT. The Owner desired a retrofit of the down slope foundations in order to re-establish
support of the posts. Due to the large volume of trains through the area and problematic access into and out of the snowshed, it was desirable that track time not be used for this upgrade. In late 2005 it was requested that the geotechnical contractor provide a design/build proposal for the installation of 25 kip and 150 kip micropiles that would support the downhill timber posts of the snowshed structure. In addition, an 8 kip lateral load requirement was included in the specifications for each micropile.

The geology on the project was at best “difficult”, and consisted of highly variable overburden soils including sandy/silty river deposits, landslide debris, cobbles, boulders (up to 4 ft in diameter) and possibly bedrock (approx 30 -55 ft deep) at some of the micropile locations.

The geotechnical contractor designed a micropile system which could be installed from the roof of the snowshed, thereby not utilizing track time, providing a safer work environment for the crew, and increasing productivity and reducing schedule duration.

**Design Methodology**

The micropiles were designed to be 8 inches nominal diameter, 55 ft total length, have a cased length of 15 ft, and a bond length of 40 ft. The casing consisted of 7 5/8-inch OD, 0.500-inch wall, Grade N80 pipe and was installed in the top 15 ft to provide the required lateral load capacity to each pile. A center 1.75-inch, Grade 150 threadbar was installed the entire length of the hole, and the micropile was grouted using neat cement grout with a compressive strength of 3500 psi at 28 days.

**Installation Method**

In order to meet the owner’s desire of not utilizing track time, the geotechnical contractor selected a scheme whereby the micropiles were installed from the edge of the snowshed roof, 25 ft off the ground. The piles were slightly battered into the hillside in order to center the pile under the beam. Initially a safety railing was installed along the edge of the roof for safety purposes. Custom-made man baskets were designed to attach to the bottom of the drill mast and to hang over the side of the snowshed roof and provide access to the drill crew. The railing was designed to slide away at each micropile location once the drill moved onto that pile and then reattach once the drill moved to the next location. Six-inch laminated crane mats were used to distribute the load of the drill onto the pile roof, and meet the Owner’s requirement of no more than 600 psf equipment load.

**Test Pile**

As part of the project, a test micropile was required in order to confirm parameters and geology used in the design (Figure 5). The pile was installed as close to the shed as practically possible along the tracks. Four reaction anchors were drilled, and the system was loaded to 200% of the 150 kip design load. At 300 kips, a total displacement of approximately 0.500 inches was observed. Pile performance from the load tests was then evaluated. Generally, pile failure can be defined as:

1) More than 0.5 inch total vertical movement at 100% of design load.
2) Movement during the creep test exceeding 0.04 inches / log cycle time (1 to 10 minutes) or 0.08 inches / log cycle time (6 to 60 minutes).
3) If total net settlement, after deducting rebound, exceeds 0.01 inch per ton of test load.
4) Slope of the load vs deflection curve should be less than 0.025-inch per kip at 2.0DL.
Total pile displacement at 100% design load was 0.128 inches and at 200% (300 kips) design load was 0.506 inches. During the 10 minute (1 log cycle) creep test at 130% DL, total pile creep was 0.028 inches, well below the 0.040 inch maximum. At 200% DL, the pile was held for an additional 10 minutes and experienced a creep of 0.038 inches, also below the 0.040 inch maximum (Figure 6).

Total net settlement for the pile was approximately 0.118 inches. This approximates to 0.0008 inches of movement per ton of load, well below the failure criterion of 0.01 inches per ton of load as outlined above.

Slope of the load vs. deflection curve at 2.0*DL was approximately .006” per kip, again, well below the 0.025” per kip of load criterion as outlined above.

![Figure 5. Test Pile Setup.](image1)

![Figure 6. Load test data confirming design load.](image2)
Production Work/Conclusion

Once the test pile was completed and the design parameters were verified, production commenced from atop of the snowshed. The geotechnical contractor’s work stopped at the top of the finished micropiles and the owner completed the structural steel work and carpentry above. The project proceeded flawlessly, the required schedule duration was met, train traffic was not impacted, and the project was completed in a safe and efficient manner.

Figure 7. Side and end section views of the snowshed and new micropile foundations.
Figure 8. Crew utilizing a custom basket to access the drill.

Figure 9. Aerial view of micropiles being drilled from the snowshed roof.
Bridge 25-8.8 Over Como Avenue  
Minneapolis, MN  

Background  

Bridge 25-8.8 is a mainline two-span railroad bridge, originally constructed in 1910 that stretches over Como Avenue in Minneapolis, MN. In 2006, the railroad completed a project to expand the bridge. The new foundations for the structure were installed with the existing bridge still in service. Due to the subsequent site constraints such as low head room and underground utilities, micropiles were determined to be the best foundation solution for the new bridge piers.

The general soil stratigraphy of the site consists of:

0 to 4 ft: Fill-Sandy Lean Clay  
4 to 16 ft: Lean clay with sand and trace silt  
16 to 30 ft: Fine to Medium Gravel with Sand  
30 to 49 ft: Shale with Gravel  
49 to 55 ft: Shale  
55 to 68 ft: Dolomitic Limestone  

Micropile Design  

Twelve micropiles were planned for both piers. The micropiles were designed to achieve the following load capacities: 430 kips compression; 20 kips tension; and 24 kips lateral. The casing was composed of Grade 80 pipe with a 9.625-inch outside diameter and a 0.545-inch wall thickness. Additional strength was provided by Grade 60, #6 threadbar in the center of the casing with a minimum of 3 feet embedment. The grout had a minimum 28-day unconfined compressive strength of 4000 psi. Micropiles were installed on an 11.5 degree batter to provide the required lateral capacity.

Production Proof Test Pile  

The geotechnical contractor performed a full-scale, compression load test on a test micropile. The micropile was incrementally loaded to 1.67 times the 430 kip compression design load. Displacement of the pile head at design load was 0.637 inches and 1.13 inches at maximum test load, meeting Davisson Failure Criterion for a quick load test. The pile also met the creep test specifications with 0.014 inches of displacement over the 10 minute hold period. Residual pile head movement measured approximately 0.123 inches after the load was removed from the pile (Figure 10).

The owner’s independent lab performed compressive strength tests on grout samples taken during production of the test pile. The testing confirmed that the grout exceeded the minimum design strength of 4000 psi.
Production Work

The geotechnical contractor coordinated with a professional surveyor the exact location of the micropiles. The new footings were excavated to the bottom of footing elevation and drilling was completed from this elevation. The micropile casing was drilled with an overburden drilling system utilizing a 10-3/8" down-the-hole hammer. The casing was drilled through the existing pier and abutment footings, overburden soils, and shale to an average depth of 65 feet, including the 3-foot rock socket into the limestone. All work was performed under 12 feet of headroom with train traffic on the existing structure.

The casing was then tremie-filled with neat cement grout mixed on site with a colloidal mixer. Grouting continued until clean grout flowed out of the top of the casing.

The installation crews logged all installation details in a drill log for each pile. Proper micropile position and alignment was ensured by the use of an angle indicator monitored during installation of all piles.

Within 30 minutes of tremie grouting, the geotechnical contractor connected a pressure cap to the top of the micropiles and then pumped additional grout under pressure (min 150 psi) to fill any existing fissures in the rock and the annular space. Excess grout returned via the annular space. In a few cases, grout did not return to the surface during pressure grouting due to a gravel layer encountered within the shale layers. In those instances, the annular space was tremie grouted until grout returned to the surface.
After grouting, the geotechnical contractor placed #6 threadbar in the micropile to a minimum embedment depth of 3 feet into competent limestone. A 5” x 5” x 0.125” steel (Gr. 50) bearing plate was then installed on the #6 threadbar.

Following completion of micropile construction, the owner’s crews completed construction of the new pile cap and bridge piers. After construction of the bridge piers, the existing spans were removed and replaced. This sequence of work greatly reduced the amount of track down time required for the bridge expansion project.

Figure 11. Left: Micropile casing being advanced under 12 ft of headroom. Right: Finished micropiles before excavation for new pier footings.
Figure 12. Section view of battered micropiles for new BNSF 8.8 bridge piers.