FEATURE ARTICLE

Collapsed wall after August 14-15, 2011 storm

# Use of Deep Foundations for Hurricane Damage Repair

The Kerite Corporation, a major manufacturer of industrial power transmission, immediately abuts the Bladens River in Seymour, Conn., with several structure locations within feet of the riverbank. Recent upstream development, steep slopes and dense rocky soils within the river's drainage area result in flash floods. A hurricane on August 14-15, 2011 dumped over 6 in (15 cm) of rain in the Bladens River drainage area within one hour. River height increased approximately 8 ft (2.4 m) above regular levels, and flow rates reached approximately 15 ft per second (4.6 m per second).

## Initial Storm Damage

Prior to the storm, a retaining wall immediately adjacent to Kerite Buildings #21 and #45 was comprised of dry laid stone approximately 10 ft (3 m) high below a 9 ft (2.7 m) high brick and concrete parapet. The wall supported a concrete patio where workers gathered. The upper brick parapet wall belonged to a former 1884 building façade. The wall structure also supported the facility's power and communication utilities.

During the storm, approximately 75 linear ft (23 m) of wall collapsed due to river scour. Subsequent erosion removed approximately 25 cu yds (19 cu m) of material behind the wall, exposing and partially undermining foundations for both buildings. The collapsed wall debris was found deposited some 750 ft (229 m) downstream.

## Temporary Emergency Repairs

GEI was hired by Kerite to design and coordinate site repairs. The first task was to temporarily stabilize the river banks and protect structures prior to the arrival of Hurricane Irene, which was rapidly approaching the area. GEI developed a scheme to place 450 tons (408,233 kg) of individually-packed riprap and boulders within the area. When the hurricane eye passed about 25 mi (40.2 km) west of the site on August 27-28, the riprap and boulders, largely submerged during the hurricane, successfully redirected flow and protected the structures from further damage.

## Permanent Repair Approach

A matrix-based approach was used to evaluate and compare the alternatives for permanently repairing the site. Site-specific considerations included:

- Active and nearby site manufacturing operations
- Downstream structures over the river that limited changes to flow
- Environmental concerns including sensitive wildlife and habitat
- Difficult soil consisting of dense cobble and boulder-laden glacial till

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Input on selection was provided by state and federal permitting agencies, as well as from Kerite and its insurance agency. The selected alternative was a retaining wall in place of the collapsed one. However, the wall needed to be of robust construction to withstand the high water velocity and scour potential.

The design incorporated 24 micropiles spaced at 3 ft (0.9 m) on center. The tight spacing was intended to resist scour, in hopes that the dense soil matrix would provide a possible arching effect between the micropiles. The micropiles themselves consisted of 9.6 in (24.5 cm) diameter casing with 0.5 in (1.4 cm) thick walls, central #11-grade 75 thread bar, and 5,000 psi, (or 34.5 megapascal) grout. The micropiles were designed with a 5 ft (1.5 m) rock socket in bedrock, which lay approximately 15 ft (4.6 m) below riverbed elevation.


Micropile installation

## Retaining Wall Construction

An 18 ft (5.5 m) cast-in-place concrete retaining wall was chosen by the project team for the final wall type, designed with fairly non-typical proportions. The wall has a thick continuous-width 30 in (76 cm) stem to accommodate embedded micropiles, which protruded approximately 5 ft (1.5 m) above riverbed. The heel length was limited to 5 ft (1.5 m) to avoid existing structures behind the wall, and the toe length was limited to 2 ft (0.6 m) to minimize stream encroachment. The base of the wall could not be significantly embedded into the riverbed, since that would require underpinning nearby foundations.

The retaining wall design incorporated deep foundation elements. The project team chose vertical micropiles for a variety of reasons, particularly for supplementing the capacity of the oddly-proportioned wall, ease of drilling through dense glacial till and minimal disturbance to nearby structures.

To provide additional lateral capacity, the general contractor drilled the tiebacks approximately 7 ft (2.1 m) above riverbed elevation. The tiebacks were spaced approximately 9 ft (2.7 m) horizontally, and had to be located carefully to avoid the foundation and other structures behind the wall. The tiebacks consisted of a grout-bonded multiple corrosion protection anchors with an 1.75 in (4.5 cm) all-thread bar and 4,000 psi (27.6 MPa) grout.

The wall backfill consisted of select granular fill, and compacted around site structures with vibratory walk-behind compactors. The final patio area was designed to be concrete with a chain-link fence.

## Retaining Wall Construction

GEI managed the construction of the retaining wall, and based on a competitive bid process, selected Waters Construction of Bridgeport, Conn., to be the project's general contractor. Waters selected Moretrench as its geotechnical consultant for micropile and tieback installation.

The first site operation by the general contractor was to construct a temporary work platform consisting of steel sheet piles driven to shallow depths, and supported laterally by the riprap and boulders used previously. Site workers used a steel plate bridge to access the platform from the other riverbank. Stacked concrete "mafia" blocks were used locally to prevent sloughing of soils beneath building foundations. While mostly providing work access for the drilling equipment, the temporary work platform also contained drill spoils, grout and other construction materials from entering the waterway.

To facilitate construction below the building foundations, the project team decided to use the micropiles to support the soil fill in the work platform down to the top of riverbed. Wooden lagging was placed between the micropiles, and later used as formwork during pouring of the retaining wall concrete.

After the retaining wall concrete was poured, workers installed tieback anchors after partial backfilling with select granular fill. The engineers performed proof tests three days after grout placement, and lock off loads were achieved at 120 kips (534 kN). The pockets for the tieback anchors were then capped with concrete.

Finally, after removing the sheet piles and temporary work platform, the riprap and boulders used for temporary repair were placed at the front of the wall. This not only provided additional scour protection, but also gave an appearance that mimicked the native site landscape.

## Structural Monitoring

Active real-time survey monitoring of buildings was implemented to ensure safety of the Kerite workers and construction crews. GEI installed a robotic total station on a structure on the opposite river bank and established survey targets on both Buildings #21 and #45. Measurements taken on 15-minute cycles showed only 1/8 in (0.32 cm) settlement during drilling of micropiles within feet of building foundations.

We also established survey targets on the retaining wall prior to tieback installation and lock-off testing. Measurements showed approximately 1/16 in (0.16 cm) lateral movement at the top of the wall during lock-off testing.

## Conclusions

After a 6 month construction duration, during which other site repairs were made, the wall was completed in May 2013. The project not only required intensive planning and design of the finished product, but also thoughtful construction means and methods to minimize impact on both manmade and natural site features. Skillful installation of deep foundations coupled with active real-time monitoring insured that occupied buildings remained safe during construction.

Tieback installation