THE BAYONNE BRIDGE LIFTED FROM REINFORCED EARTH® WALLS

Sherif AZIZ, John SANKEY, Mike SISON

Reinforced Earth Company, USA

Spanning the Kill Van Kull and connecting Bayonne, New Jersey with Staten Island, New York, the Bayonne Bridge is the 4th longest steel arch bridge in the world. The Panama Canal Expansion project, to be completed in 2016, will allow passage of longer and wider ships carrying more than twice as much cargo. However, those stacked containers would not fit beneath the bridge's 46 meters navigational clearance. Consequently, the Port Authority of New York and New Jersey decided to raise the bridge's roadway by 19.5 meters, which necessitated a matching rise of the approach roadway on each end of the bridge. This case study addresses the use of Reinforced Earth® walls to build the new approaches. The case study also provides a brief background on the specific technology, the special needs presented by the use of this technique for the Bayonne Bridge project, and the design engineering and construction challenges met particularly for accommodating a gantry crane.

1. BRIDGING THE KILL VAN KULL

The Bayonne Bridge is an historic 510 meter long span crossing the Kill Van Kull and connecting Bayonne, New Jersey and Staten Island, New York in the USA. It was at one time the longest steel arch bridge when completed in 1931, and it remains the 4th longest span of its type to this day. The story of the Bayonne Bridge raising was driven by a maritime infrastructure background, because the Kill Van Kull provides a primary shipping channel for access to major New York area port facilities (Fig. 1). With the completion of the Panama Canal in 2016, passage of longer and wider ships en route by way to and from the New York shipping channel needed to be accommodated. However, the Panama Canal bound ships would not fit beneath the Bayonne Bridge's 46 meter navigational clearance that was originally set to meet the needs of the U.S. Navy. So the Port Authority of New York and New Jersey decided to raise the bridge's roadway (though not the arch itself) by 19.5 meters, requiring a matching rise of the approach roadway on each end of the bridge.

Figure 1. Bayonne Bridge crossing of New York Channel

1.1 Selection of Reinforced Earth Walls

With the need to develop the new approaches on retained fill and partially on a viaduct, the Port Authority decided to use Reinforced Earth walls which were a well-known technology to not only support the roadway over compressible base soils, but also to literally serve as a supporting base for launching the bridge span itself. Wall heights vary by location, but as much as 10 meters of the needed 19.5 meter rise was accommodated by Reinforced Earth walls. For the walls, the Port Authority selected smooth rectangular fascia panels measuring 1.5 meters by 3 meters (Fig.2).

The project was constructed in 2 phases to maintain traffic flow; first northbound (New York to New Jersey) with all traffic using the old roadway, then southbound while all traffic uses the newly-constructed northbound lanes. All lanes will finally be open with project completion in mid-2017. Walls with temporary Terratrel®, a wire-faced mechanically stabilized earth wall system (Fig. 3), were used to support the half-wide Phase 1 roadway, with Phase 2 Reinforced Earth construction later joining to and burying the temporary wall. Since the temporary wall was wire mesh, it essentially behaved like the rest of the embankment rise and did not result in a hard spot in the center of the finished roadway.

Figure 2. Reinforced Earth with rectangular panels

Figure 3. Temporary Terratrel wire facing for Phase 1

1.2 Wall Application

Since the Reinforced Earth technology was invented by Henri Vidal over 50 years ago, more than 50 million square meters of wall area have been constructed worldwide. The technology essentially consists of fascia (either precast concrete panels or wire facing) with a connection and reinforcing strips (Fig. 4). The reinforcing strips for the Bayonne Bridge project were galvanized steel ribbed strips measuring 50 mm wide by 4 mm thick. Alternating compacted select granular fill and the reinforcing strips combine by interfriction and tension to form a coherent gravity mass that acts as a retaining structure. The length of the reinforcing strips is typically at least 70% of the mechanical height of the wall. It is important to remember that the entire coherent mass is the wall system rather than just the fascia itself.

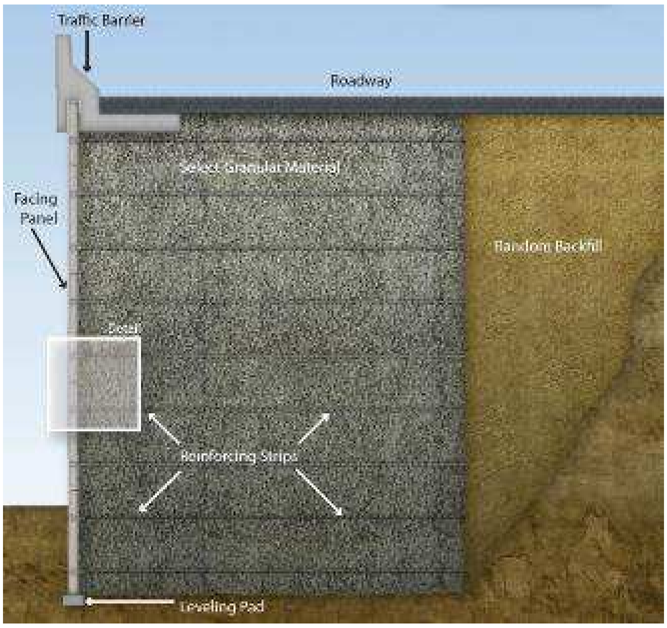

Figure 4. Reinforced Earth wall section

2. PROJECT DESIGN ACCOMMODATING GANTRY CRANE LOADING

The biggest design challenge occurred at the outset of design when the Contractor wanted to expand the use of the permanent Reinforced Earth and temporary Terratrel walls to support the placement of the foundations for the viaduct erection gantry crane (Fig. 5). Such an application, though not common, was first applied by Terre Armée at Dunkerque, France Port in 1970.

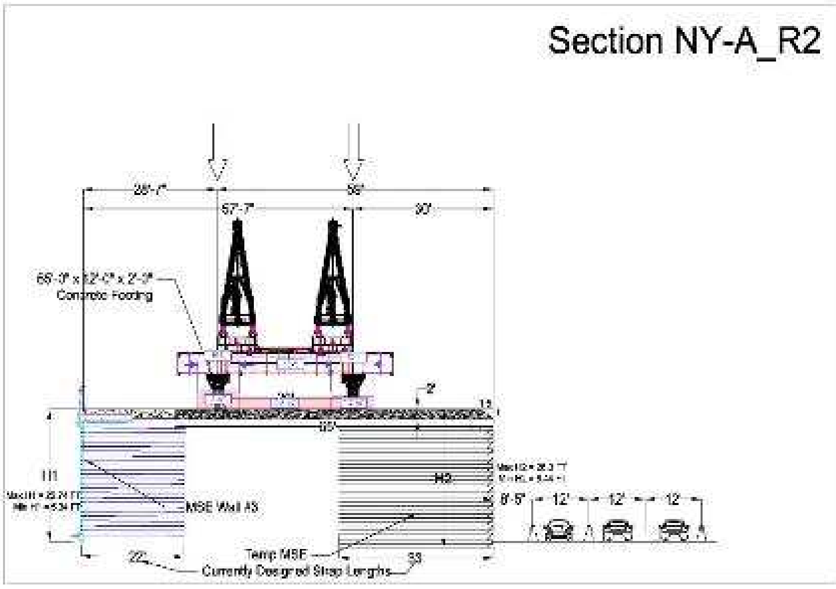

Figure 5. Gantry crane loading schematic

Loads at prescribed locations along the wall were used to determine the extra quantities of reinforcing strips needed to safely support the gantry. Distributed vertical and horizontal loads from the gantry crane were based on a Bousinesq Method distribution (ca. 1885) considering equipment bearing loads at approximately 191 kPa. Foundations for the gantry crane were maintained well behind the fascia to prevent loading in the active zone common to Reinforced Earth walls (approximately 30% of the mechanical wall height). Keeping the distribution of the crane loads primarily within the Reinforced Earth mass resulted in reducing any additional bearing concerns in the compressible foundation soils underlying the wall alignment.

The distributed crane loads were applied consistent with AASHTO LRFD (2012) using a load factor of 1.35. Both reinforcement pullout and reinforcement tensile load requirements increased dramatically due to the gantry crane.

Instead of the rule-of-thumb 70%-of-height reinforcing strip length mentioned as a minimum, strip lengths ranged from 120% to almost 150% of height. This reinforcement supports the gantry crane as it cantilevers off the abutment end of the Reinforced Earth wall (Fig. 6) to erect the precast segmental viaduct. After setting the first segment atop the first pier, additional segments were designed and erected by the balanced cantilevered method and post tensioned in place.

Figure 6. Gantry crane cantilever from Reinforced Earth

3. WALL DESIGN KEEPING PACE WITH CONSTRUCTION

Wall design and supply, including consideration for the gantry crane loading as already discussed, was performed by The Reinforced Earth Company (USA) prior to the start of installation of the Reinforced Earth and Terratrel wall systems. The design package consisted of design drawings and corresponding calculations approved by the Port Authority. Some of the other design considerations of particular importance were block outs to support utility alignments, skewing steel strip reinforcements to avoid piles and accommodate tight corners, and top outs (traffic barrier and coping mountings directly on precast fascia panels of Reinforced Earth).

Installation of the Phase 1 walls (both permanent and temporary) began in New Jersey in April 2014, and in New York in late May of the same year, with all walls completed by August 2014. These walls were on the project critical path since their completion was required to mobilize and assemble the aforementioned gantry. Numerous changes were made to the original design package to accommodate the crane and later obstructions encountered during the construction of the walls. With the use of AASHTO No. 57 angular stone (20 to 25 mm diameter) as select backfill for the Reinforced Earth backfill, the wall erection crews were able to work quickly and in virtually all weather, with little risk of poor compaction or effects of varying wet weather conditions. This was especially helpful in congested areas such as wall corners at the abutments (Fig. 7), where large diameter pipe piles required skewed reinforcing strips and more careful, methodical backfill placement and compaction.

Figure 7. Use of stone backfill and skewed strips eases wall construction

An unexpected utility problem on the New Jersey side threatened to delay the project schedule. The presence of an old brick sewer, originally thought to be abandoned at the outset of design, was in fact found to still be active and directly in line with plans to install 6 meters of overlying backfill. A temporary solution was developed using Terratrel as a "blockout" in the permanent fill so that the remainder of the Reinforced Earth wall could be constructed (Fig. 8). The blockout was sized to the rectangular panel column space left open in the Reinforced Earth wall and the permanent wall construction proceeded normally. Once the sewer relocation was complete, the Terratrel blockout was easily filled in with the appropriate Reinforced Earth installation.

Figure 8. Terratrel "blockout" to install Reinforced Earth

One of the last construction measures needed to complete the Reinforced Earth walls was the installation of coping and traffic top outs (Fig. 9). The installation of these precast elements greatly simplifies installation and saves on labor costs. In the case of traffic barriers as depicted in the schematic shown on Figure 4 earlier in the paper, the precast element is simply fit on top of the Reinforced Earth wall with corresponding leveling concrete, and then joined to a cast-in-place moment slab by way of rebars protruding from the base of the barrier.

Figure 9. Precast coping used as a top out

4. CONCLUSIONS

Reinforced Earth walls represent a dependable technology to not only support roadway and bridge construction, but also as a basis to incorporate loadings from heavy lifting equipment such as gantry cranes. The use and presence of heavy lifting equipment needs to be addressed at the outset of design, since the number and lengths of reinforcements has to be adjusted accordingly. Close cooperation between the Owner, Geotechnical Consultant, Contractor and Design/Supplier is a common element in the successful completion of Reinforced Earth projects, but even more so for the Bayonne Bridge project. Accommodating significant design changes while being on the critical path was required, and doing it all while maintaining traffic on a major New York area highway. Though the final construction of the bridge will not be completed until 2017 when it is opened for traffic, the artist's depiction of the final structure is shown as follows (Fig.10).

Figure 10. Raising of the Bayonne Bridge

REFERENCES

- *American Association of State Highway and Transportation Officials, Load Resistance Factor Design (2012), Section 11 on Walls, Abutment and Piers.*
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