Ontario Road Talk

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"Well-Founded" Technology

Rammed Aggregate Piers Improve the Windsor Tunnel Plaza Project

The Ontario Ministry of Transportation (MTO) completed its first successful use of rammed aggregate piers at the site of the Windsor Border project. In July 2013, 226 rammed aggregate piers were installed at the Windsor Tunnel Plaza to support floor slabs and structural footings within the foundation footprint of the new Canadian Border Services Agency building.

Rammed aggregate piers are an innovative soil reinforcement system used to improve poor foundation conditions. The rammed aggregate piers for the Windsor project were designed by GeoSolv Design-Build (Geopier Foundation Company) for the Contractor, Coco Paving / Rosati Construction.

Project Site

The Windsor-Detroit Tunnel is one of three border crossings linking Windsor, Ontario and Detroit, Michigan. The tunnel opened to traffic in 1930 and is a single tube under the Detroit River, 1.6 km long carrying one lane of traffic in each direction with toll and inspection plazas on each side of the border.

Improvements to the Canadian Plaza of the Windsor-Detroit Tunnel were part of the $300 million Let's Get Windsor-Essex Moving (LGWEM) strategy, jointly funded by Ontario and Canada.

The overall purpose of the project was to improve capacity and operational efficiency at the Canadian plaza while addressing existing traffic concerns and anticipated future needs of border traffic in the Windsor-Detroit corridor.

This work included a new Canada Border Services Agency Commercial Building and a new Detroit-Windsor Tunnel Maintenance Building.

The original design for the building foundations was conventional strip and spread footings on engineered fill. However, two potential issues arose during project design:

- Foundation investigations indicated that the subsurface stratigraphy at the site consists of asphalt and granular base with variable layers of fill over a deep deposit of clayey silt. A contamination study revealed that the fill was contaminated in some areas and would require excavation, trucking and disposal at an approved landfill, followed by replacement with engineered fill.
- A need for sheet piling / shoring for excavation of the fill since the new Canada Border Services Building footprint lies only 2.2 m (7.2 feet) from the roadway curb.

Figure 1: Rammed aggregate piers are placed within the foundation footprint of the new Canadian Border Services Agency Building in Windsor.

Rammed Aggregate Piers Improve the Windsor Tunnel Plaza Project, continued

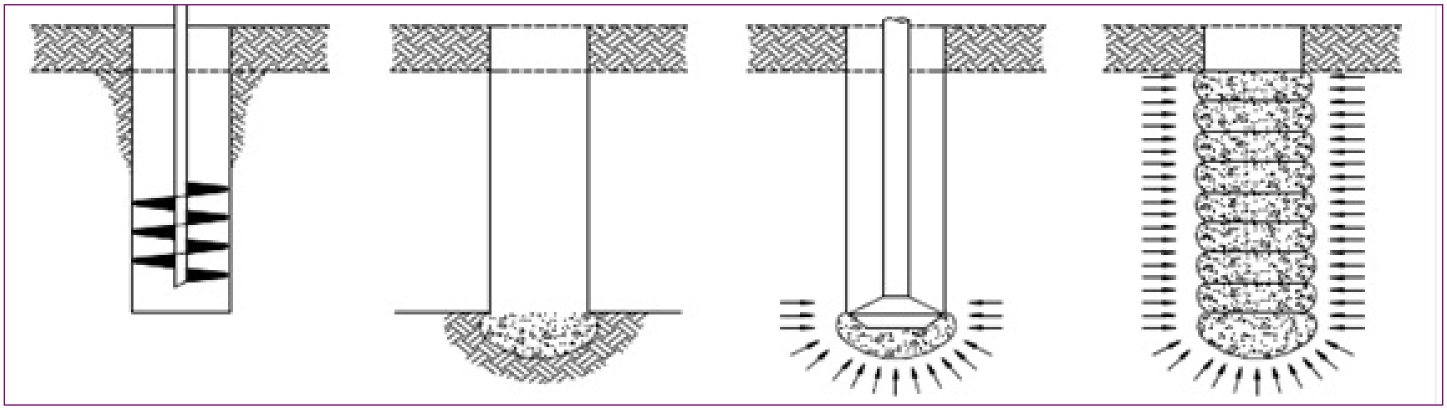

Figure 2: Rammed aggregate pier construction process – (1) auger the hole, (2) place open-graded stone, (3) tamp bottom bulb, (4) tamp well-graded stone in thin lifts.

The original design would have required excavation of the existing fill within the building footprint, supply, installation and compaction of engineered fill to the underside of floor slab granular base, and placement of conventional footings with form wall and backfill.

Rammed aggregate piers were selected as an alternative to excavating the fill layer. This option reduces construction costs, eases construction and reduces construction truck traffic in Windsor's downtown core.

Rammed Aggregate Piers

Rammed aggregate piers are installed by drilling 760 mm (30 inch) diameter holes and ramming thin lifts of well-graded aggregate into the holes forming very stiff, high-density aggregate piers. The drilled holes typically extend from 3 m to 7.5 m (10 to 25 feet) below grade and 2 m to 6 m (7 to 20 feet) below footing bottoms. The first lift of aggregate forms a bulb below the bottoms of the piers, providing pre-stressing and pre-straining of the soils to a depth equal to at least one pier diameter below drill depths. Subsequent lifts are typically about 300 mm to 600 mm (12 to 24 inches) in thickness.

Ramming takes place with a high-energy bevelled tamper that makes the aggregate denser and forces the aggregate laterally into the sidewalls of the hole. This action increases the lateral stress in the surrounding soil, further stiffening the stabilized composite soil mass. The end-result of the rammed aggregate pier installation is a significant strengthening and stiffening of subsurface soils that then support high bearing capacity footings.

The system controls foundation settlements and is designed to limit post-construction settlements to less than 25 mm (1 inch) with a maximum differential settlement of 20 mm (¾ inch).

Design

The compacted aggregate pier system is designed to support pier spread footings and strip footings based on the following criteria specified in the contract:

- Factored geotechnical resistance at Ultimate Limit States (ULS) of 225 kPa.
- Geotechnical reaction at Serviceability Limit States (SLS) of 150 kPa.
- Estimated long-term total settlement of ≤ 25 mm defining the SLS geotechnical reaction.
- Estimated long-term differential settlement of ≤ 20 mm defining the SLS geotechnical reaction.
- Design long-term uniform pressure on floor slab of 25 kPa.
- Design life of the building structure of 50 years.

Footing loads for spread footings supported on rammed aggregate piers ranged between 50 kN and 270 kN at SLS. Rammed aggregate piers supporting the floor slab were designed to support a load up to 25 kPa.

The design for this project included a system of rammed aggregate piers that were more widely spaced under floor slabs than under footings, typically ranging from 1.5 m to 3.5 m.

Rammed Aggregate Piers Improve the Windsor Tunnel Plaza Project, continued

Construction

Following removal of topsoil and pavement, the rammed aggregate piers were installed. Augered excavations for the aggregate piers fully penetrated the existing fill and advanced about 1 m into the underlying native grey silty clay. This formed a crust of soil upon which the footings are supported. The contractor then excavated to expose the tops of the piers and compacted the footing base using a "jumping jack" type tamper. The footing was then placed over the improved ground. More than 200 rammed aggregate piers were placed within the building footprint.

For wet excavations, one to two lifts of clear stone (19 mm or ¾") were placed and compacted using a hydraulically operated compactor. Installation then continued by placing and compacting 350 mm to 400 mm thick lifts of Granular A. Compaction of each lift was considered adequate after 20 seconds had elapsed. After 20 seconds, there is generally no further vertical displacement of the compactor.

Several Dynamic Cone Penetrometer Tests were carried out by the contractor using hand-held equipment on the finished surface of the compacted Granular A. Results of the tests met the criteria of at least 15 blows per 45 mm penetration as an indicator of acceptable density.

A full-scale modulus load test was performed on a non-production aggregate pier installed on-site to verify the parameter values selected for design. The test results showed acceptable performance.

Cost Savings

Using rammed aggregate piers at this site resulted in significant project cost savings. This innovative method eliminated the need for sheet piling / shoring to protect the roadway – a savings of $375,000, excavation of contaminated fills and trucking off-site to disposal at an approved landfill – a savings of $280,000, and engineered replacement fill – an additional savings of $145,000.

Environmental Benefits

Implementing rammed aggregate pier foundations reduced environmental impacts such as exhaust emissions, noise, and traffic from an estimated 1100 truckloads that would have navigated through the downtown core removing contaminated fill and supplying engineered fill.

Figure 3: Bevelled tamper increases lateral pressure.

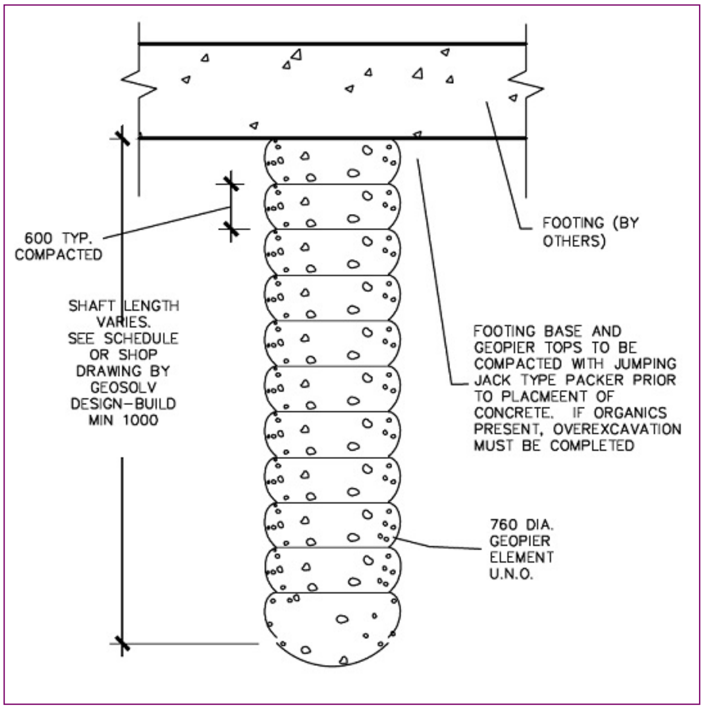

Figure 4: Typical rammed aggregate pier for a footing.

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Future MTO Applications

The ministry anticipates future applications of rammed aggregate piers to include improved foundations for embankments, retaining walls and retained soil systems, commercial vehicle inspection facility buildings, ferry terminal buildings and slope stabilization. In addition, recycled concrete can be used as aggregate for the rammed aggregate piers. ●

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Photos provided by Tulloch Engineering and Thurber Engineering.

Figure 5: Conducting the Dynamic Cone Penetrometer Test (DCPT) with hand-held equipment.

Figure 6: Modulus test set-up.