"Special measures were required to protect existing MIT buildings…"

Stata Center

Deep Excavation Meets MIT's Needs

By Robert D. Hewitt and Mark X. Haley

What do you do when it is not economically feasible to "anchor" an earth support wall into stiff soils to gain fixity? This issue was encountered when construction of the Stata Center at the Massachusetts Institute of Technology (MIT) required excavation for a 3-level underground garage with bedrock at a depth of greater than 120 feet. The solution consisted of a concrete diaphragm wall, braced with a combination of tieback anchors, corner bracing, and inclined raker braces.

Special measures were required to protect existing MIT buildings, including one masonry structure located only 5 feet from the edge of the excavation. Geotechnical instrumentation was used to monitor the performance of the excavation support system and the building foundation elements.

The Ray and Maria Stata Center for Computer, Information, and Intelligence Sciences (Stata Center), designed by architect Frank O. Gehry and Associates for the Massachusetts Institute of Technology (MIT), will provide classrooms, parking facilities, and office space. The above-grade, cast-in-place concrete structure consists of two 9-story towers, with 3 to 5 stories in areas around the towers. The below-grade space comprises two parking levels and one high-bay truck dock and materials handling area. The permanent foundation system consists of a 4-foot-thick concrete mat foundation and reinforced concrete below-grade walls constructed by slurry trench methods.

Site Conditions

A layer of urban fill and organic soil is present from the ground surface to a depth of approximately 20 feet. The near surface soils are underlain by a thin sand layer, and a 90-foot-thick layer of soft, silty clay. Bedrock below the site is at depths ranging from 120 to 132 feet. Groundwater levels range from 5 to 11 feet.

"Bedrock below the site is at depths ranging from 120 to 132 feet."

Concrete Diaphragm Wall Construction

A 30-inch thick, reinforced concrete diaphragm wall was designed to provide lateral earth support during excavation, and to be used as the permanent foundation wall system. The wall alignment was pre-trenched through the fill soils prior to wall installation to remove below-grade obstructions. Concrete guide walls were constructed to facilitate horizontal control of the below-grade wall construction within verticality tolerances. The wall was installed using bentonite slurry and was constructed in panels typically 25-feet long. The panel length was reduced to 15 feet or less in front of directly adjacent structures to minimize the open length of slurry trench below adjacent foundations.

The Stata Center concrete diaphragm wall was constructed directly adjacent to the first row of caissons supporting an adjacent three-story, masonry building. A soil improvement program, consisting of pressure grouting of the marine sand, was conducted in advance of concrete diaphragm wall construction to stabilize the sand during slurry wall installation.

A combination of tieback anchors, internal corner braces, and inclined rakers was used to brace the concrete diaphragm wall during excavation. In areas where tiebacks were used, three levels of tiebacks were installed, horizontally spaced approximately 5-feet on center. Design loads ranged from 112 to 128 kips per tieback. Tiebacks were installed at an angle of 20 degrees from the horizontal with a bonded length (in the marine sand and clay) of 40 to 50 feet and an unbonded (free) length of 10 to 50 feet.

"A combination of tieback anchors, internal corner braces, and inclined rakers…"

Two levels of corner bracing were installed after excavating to a depth of 2 to 3 feet below the brace level. Braces consisted of 36-inch-diameter pipe struts and ranged in length from 8 to 120 feet. Corner braces were preloaded to 50 percent of the design load prior to excavation below the brace level. When braces exceeded 60 feet, pin piles were used to provide lateral bracing for the steel member.

Two levels of inclined raker bracing were used at the north wall, due to the prohibition by the city for installation of tiebacks under the city street. Raker bracing consisted of 36-inch-diameter pipe struts extending from embedded plates in the diaphragm wall to kicker blocks embedded in the concrete mat foundation.

The brace loads and wall design were conducted utilizing the finite element program "ANSYS", which also is used to predict wall movements. The analysis is conducted as a "staged analysis" for the various excavation levels.

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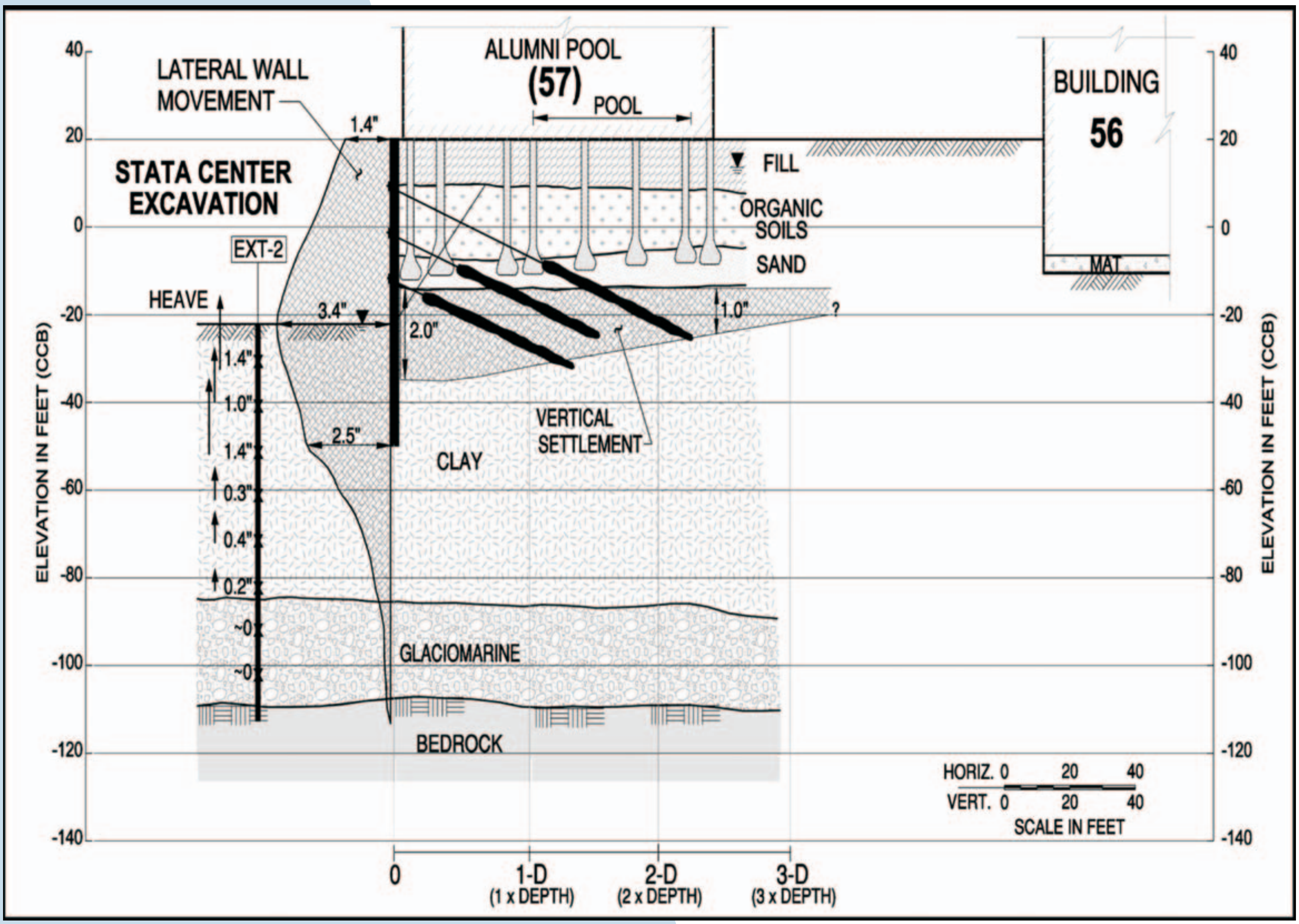

Summary of soil conditions, wall movement, excavation heave, and adjacent building movement near Building 57

Lateral Wall Movement and Adjacent Building Settlement

Lateral movement of the concrete diaphragm wall was monitored using inclinometers installed through the wall and grouted into bedrock. The pattern of wall movement typically consisted of an initial cantilever movement of about 0.5 to 1.3 inches during excavation to the first brace level. Much of this movement was recovered during stressing of the first level of bracing. After installation of the first level brace, the wall rotated about the brace during excavation to the second brace level. During excavation below the second level brace, the wall typically moved laterally below the brace location. The majority of the observed movement occurred during the final excavation stages.

Settlement of adjacent buildings, streets, and utility structures was monitored during construction using survey reference points (SRPs) and borehole extensometers. The settlement of the north wall of Building 57, the building nearest the excavation, ranged from 1.8 to 2.7 inches, and was greater than observed at other adjacent buildings. The maximum calculated angular distortion (between interior columns) was 1:570. Inspection of the mortared block building during and after below-grade construction showed no indication of damage.

Excavation heave was monitored at two locations within the excavation using borehole extensometers that were later incorporated into the permanent mat foundation. The measured heave of the excavation ranged from 1.3 to 1.5 inches, and was observed to essentially stop at both locations after mat placement.

"Excavation heave was monitored at two locations…"

Survey reference points were installed at the base of columns in the completed Stata Center basement level in December 2001 (about six months after the mat foundation was completed). Data observations indicate that the portion of the mat below the two towers has settled 0.5 to 1.0 inches through April 2003 (rough concrete complete). In the area between the two towers (5 above-grade levels), settlement of 0.25 to 0.5 inches has been observed. In the low-rise areas (2 to 3 above-grade levels) essentially no movement (less than 0.25 inches) has been observed. Based on the measured heave during excavation, the observed settlement to date consists of recompression of the heave that occurred during excavation.

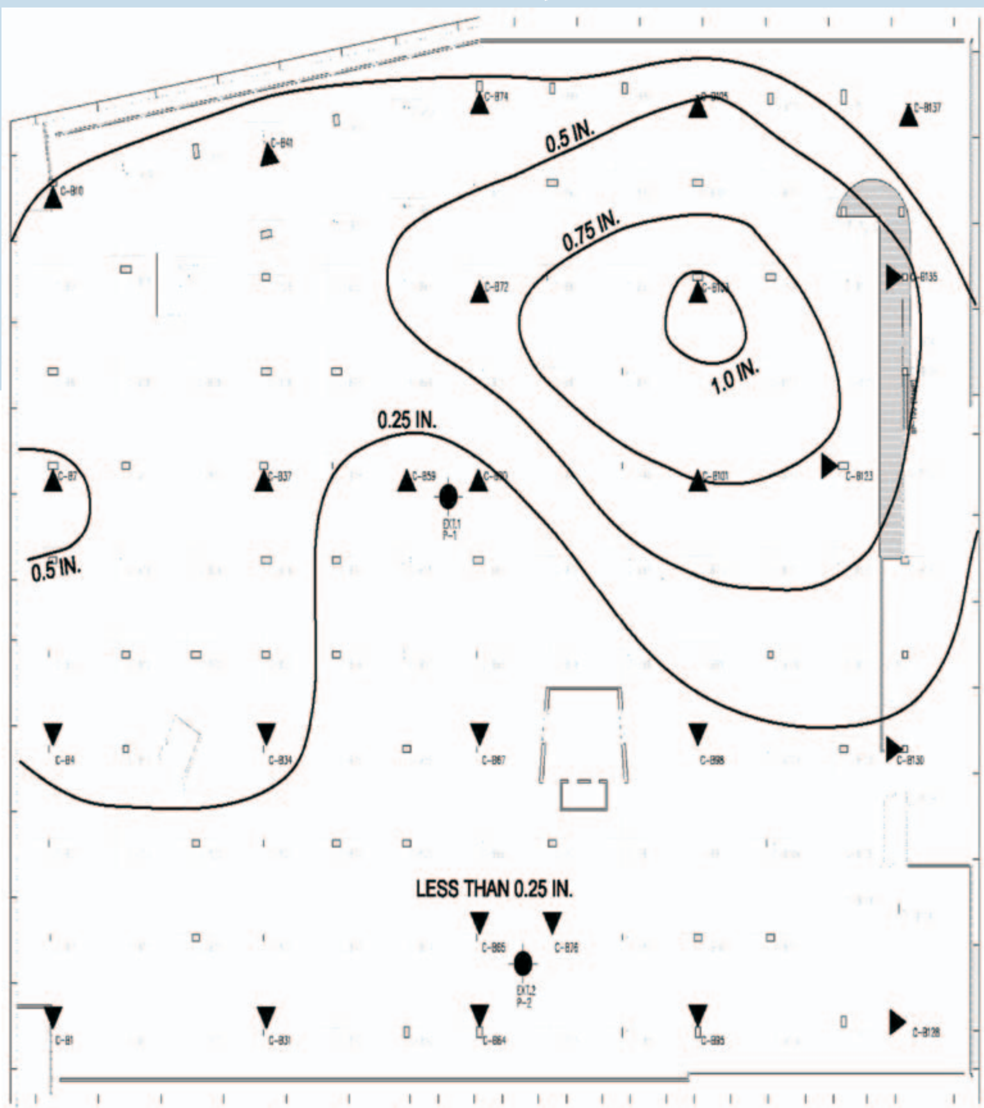

Figure B: Settlement contours showing measured settlement of Stata Center structure through April 2003

Conclusions

Settlement of adjacent structures, although greater than anticipated for one building, did not result in structural damage. Monitoring of instrumentation allowed construction to proceed, and provided early warning of potential problems at the adjacent buildings.

Analyses of instrumentation data indicated that maximum wall movements were similar for the three types of bracing, with the temporary soil berm and raker bracing at the north wall resulting in lower toe movement. Settlement of the new structure observed to date during construction has consisted of recompression of the heave observed during excavation.

"…maximum wall movements were similar for the three types of bracing…"

The use of a variety of bracing techniques and the concrete diaphragm wall resulted in a cost-effective solution for excavation and building support that did not require reaching down to the deep bedrock at this urban site.▪

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Robert D. Hewitt, P.E., a Senior Engineer with Haley & Aldrich, has 9 years of experience including foundation design and installation, excavated soil management, construction dewatering, and environmental site assessments. In addition, Mr. Hewitt is involved in a variety of projects involving controlled blasting, rock excavation, laboratory interface shear testing, environmental site assessments, and static and seismic stability analysis of landfills.

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Errata

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The article makes mention of Ammann & Whitney as a reference, and publishes the firm's web site address. Unfortunately, Ammann is misspelled in both the reference and the web address.

Please note the correct information for the Ammann & Whitney website:

www. ammann-whitney.com

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