Digging Deep into the Details

A preservation and restoration project at the historic Kansas capitol building required a detailed geotechnical analysis.

By Scott T. Anderson

When government officials initiated a restoration and expansion project of the Kansas Statehouse in Topeka, their primary concern was preservation of the historic landmark building, which was built in phases from 1866 to 1903. The initial purpose of the expansion plan was to create a parking structure below ground that would not interfere with the overall Italianate style architecture of the capitol.

At the same time, planners took a fresh look at the existing basement. Over the years, it had filled up with a mass of unsightly crisscrossing pipes; mechanical, electrical, and telecommunications cables; and other equipment. State and local leaders wanted to restore it to its former architectural grandeur while modernizing ventilation, plumbing, electrical, and communications equipment. They also wanted a convenient, yet unobtrusive place for parking.

First, the expansion plan called for an underground parking structure at the north end of the building that is expected to be the largest underground structure in Topeka with two parking floors and 550 spaces. Second, underground vaults were designed in four quadrants of the cross-shaped building to house equipment, making electrical, mechanical, and communications equipment, as well as parking, more transparent.

At the same time, a greater utilization of workspace was accomplished by moving offices into the basement; this would allow the first floors to be restored to their original soaring loftiness. Ground-level and upper floors of the once-grand building had lost their original character over the years because of dropped ceilings and partition walls that were required to cramp in a surfeit of governmental offices. A visitor's center was also planned for the north lower level.

Aerial view of parking garage and northwest mechanical vault construction.

Issues and Challenges

While plans sounded feasible on paper, structural engineers raised various issues about the safety of the existing structure because a masonry building such as this is extremely vulnerable and susceptible to movement during construction. For the safety and stability of the existing structure, new construction would require extensive subsurface exploration to develop a thorough understanding of subsurface conditions. Specialized geotechnical engineers were hired to conduct advanced laboratory testing, such as triaxial testing and direct shear testing to characterize the subsurface materials.

The original plan called for underpinning each individual limestone foundation block. Due to the irregular shape of each block, the required amount of support would be indeterminate until the moment of construction. This method, then, was subject to huge cost overruns.

Innovative Plan

The plan that was ultimately accepted consisted of a blend of conventional and unconventional support for the historic limestone block foundations. The design encompassed a unique lateral and vertical tensioning that, in fact, saved an estimated $3 to $4 million for taxpayers compared with the initial proposed plan.

The owners turned to geotechnical expertise for numerical modeling before

Completed soldier pile and lagging wall (with tiebacks) for northwest vault construction, looking south.

excavation began. To estimate the effects construction might have on the old building, they sought data on the character of subsurface materials; this would help set building parameters for structural engineers. Geotechnical engineers also needed to measure the soil movement around the building, and determine any building movement before and during construction phases.

The geotechnical engineering team members set up an extensive instrumentation program that includes:

- Inclinometers to monitor lateral deformations of the support system.
- Tilt meters to monitor the inclination of the structure itself.
- Borehole extensometers to monitor vertical movement of the structure (heave or settlement).
- Seismographs to monitor vibrations associated with the excavation of the parking garage into the hard limestone bedrock.
- Optical surveys to survey points on the exterior as well as the interior of the building, which were tied to benchmarks off-site. Measurements were used for monitoring building movement.

In addition, to gauge the normal movement associated with thermal cycles, building monitoring began before construction.

Karl Terzaghi and Ralph B. Peck, the "fathers" of geotechnical engineering, originated this approach, called the "Observational Method." While it goes above and beyond usual collection methods, gathering as much data as possible for a vulnerable structure provides the best possible opportunity to solve issues before irreparable damage can occur. Also, it allows the setting of action levels, where courses of action are thought out before construction and are based on the readings of the instrumentation. This can be used to speed or slow construction depending on the results of the instrumentation readings.

Findings

North and south wings, the site of the future underground garage and the rotunda, are founded on bedrock. The concern about movement is minimal in this location.

East and west wings, on the other hand, were founded on glacial till, which is not as stiff as glacial till soils found in the states to the north of Kansas. Construction was planned adjacent (within 10 ft) of these soil-bearing wings, which was a primary issue because this part of the building is most susceptible to movement and instability, even collapse, during construction.

The existing limestone block foundations bear above the finished floor level of the adjacent vault structures and bear on 12 ft of soil that can deform and move, unless restrained.

Modern footings distribute loads better because they typically are continuous strips that are reinforced, whereas the existing footings are individual blocks, free to move and rotate. The existing footings were estimated to have a dead load of approximately 6,000 lb/sq ft, double the recommended load on the same soils today.

The Solution

A support system was designed to provide both lateral (horizontal) and vertical confinement of the soils surrounding the existing foundations.

Lateral or horizontal support—the use of a more or less traditional soldier pile and lagging wall with tiebacks — was used to provide lateral support. The soldier piles are made up of channel steel sections welded together to form a stiff structural member. A pier hole then is drilled and socketed into the underlying

Completed soldier pile and lagging wall — with tiebacks— for northwest vault construction, looking east.

Geotechnical specialty contractor installing tiebacks for soldier pile and lagging wall, northwest vault.

bedrock, the soldier pile is placed into the pier excavation, and concrete is placed around the lower portion of the pile.

A sand slurry with a small amount of cement mixed into it then is placed in the remainder of the hole to provide stability to the excavation. Once all of the soldier piles have been placed, the excavation proceeds on the "outside" of the soldier piles, and wood lagging is placed (attached to the soldier piles) as the excavation proceeds.

Once the excavation reaches a predetermined depth, tiebacks are installed. Tiebacks are steel anchor rods that are placed in a drilled borehole and grouted in place; the tiebacks then are tensioned to help the soldier piles resist the lateral forces imposed by the soil.

Engineers provided vertical support and confinement with tiedown, or compression slabs. The idea behind the slabs was developed as a way to replace the confining pressure provided by the soils adjacent to the east and west wings. The confinement pressure provided by these soils is what allowed the glacial soils to bear the high loads imposed by the massive statehouse structure, and these soils would be removed all the way down to the bearing level of the existing foundations. Numerical models were used to determine the factor of safety following removal of the soils. Because it was determined the factor of safety was low, engineers needed to develop a way to replace the confining load of the soils.

At first engineers recommended a cast-in-place system, but they soon realized that precast slabs would offer great efficiencies in the construction process and also reduce the amount of time that the confining pressure lost. A total of nine to 11 tiedown slabs were used per wing, for each of the northeast, northwest, southeast, and southwest wings.

Rock anchors were installed from the original grade, and then excavations were made for one tiedown slab at a time. The tiedown slab had to be in place and tensioned before beginning the excavation for the next slab. In the end, one to two slabs were placed per day. By only moving a small section of confining pressure at a time, support of the existing structure was preserved.

All in the Details

Removal of the electrical, mechanical, and communications equipment from the basement of the existing building allowed for significantly better utilization of the existing space. Pedestrian tunnels with skylights will provide underground access, connecting the Docking State Office Building, mechanical vaults, and new offices in the vault mezzanine level.

The restoration and expansion of the statehouse, scheduled for completion between 2008 and 2010, will juxtapose the old with the new. While modernizing computer and high-speed communications equipment and integrating modern amenities such as underground parking, it also will become more true to its roots, restoring original interior architectural details such as soaring ceilings, palladium windows, and original wall murals and paint schemes.

Thinking about the solution with an open mind solved the problem more creatively than initially expected and, in a time of tight governmental spending, potentially saved taxpayers millions of dollars.

Paradoxically, the building took a step forward while taking a step backward. Its infrastructure was modernized to twenty first century standards while it was restored to its nineteenth century architectural splendor.

Attention to detail is key to the project—it extends from the architectural design in the upper tip of the rotunda to geotechnical engineering 40 ft below the surface. In the end, its success is rooted in digging deep into the details. GE

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