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Texas Capitol Complex Expansion

COVER STORY

Completed Phase 1C excavation of Capitol Complex

Complex Retention System for Texas Capitol

In 2016, the State of Texas adopted a master plan to expand its facilities in downtown Austin (Texas Capitol Complex). Phase 1 will add two new state office buildings and five levels of underground parking, with a landscaped pedestrian mall atop the underground parking. This article describes the detailed design of the Phase 1 earth retention system involving 500,000+ yd^3 (380,000+ m^3) of excavation through overburden soils and limestone bedrock.

To facilitate overall project coordination and that of the retention system with adjacent major structures and utilities, all design packages were required to develop Revit (building information) models. The retention system chosen is a combination of soil nails, soldier piling with tiebacks, and rock anchors with a shotcrete facing as a substrate for a below-grade waterproofing system. The excavation required significant rerouting of utilities on a temporary structure that Brierley Associates designed, in coordination with the excavation team, and involved existing utilities located directly underneath existing structures. Preconstruction geotechnical investigations identified a small displacement fault at the site, and construction observations determined that the primary shear plane was in a much more adverse location and orientation than originally anticipated. The original temporary retention system design was upgraded to a more robust permanent retention system in a localized area to address the actual conditions encountered.

Phase 1 of the Capitol Complex Expansion excavated three blocks of the Congress Avenue right-of-way, from MLK Jr. Blvd. (19th Street) to 16th Street and two adjoining surface parking lots. The site was excavated to an average depth of 60 ft (18 m) over a footprint exceeding 10 acres (4 ha), with a total excavated volume in excess of 500,000 yd^3 (380,000 m^3). The Phase 1 plan involved six construction packages, with the excavation package subdivided into three subphases that were developed in staggered intervals (1A: 1801 Congress building; 1B: 1601 Congress building; and 1C: Congress Avenue garage). As each permanent structure package has separate design and construction teams, the state procured a design-bid-build contract for the entire Phase 1 excavation for coordination purposes. BIM (building information management) modeling was utilized for the design to resolve preconstruction conflicts; however, field geotechnical observations during construction proved vital to managing and mitigating project risk.

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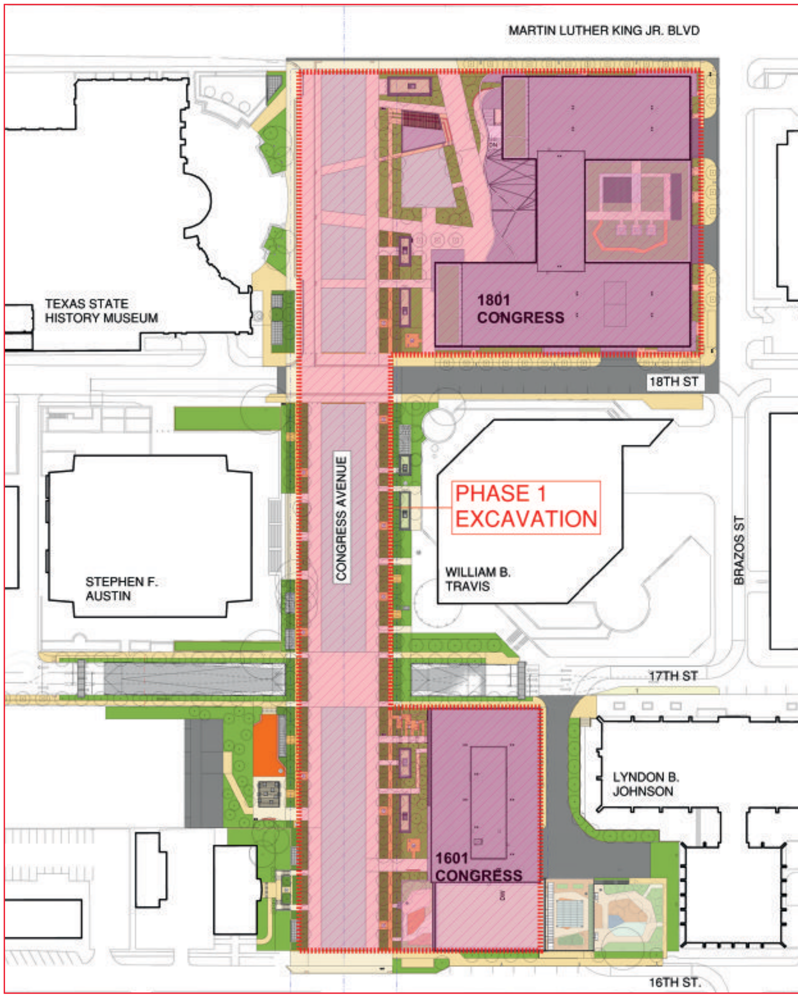
Design Constraints

With the project site in a dense urban area involving numerous stakeholders, the excavation had to address the following constraints:

- Installing anchors beneath adjacent buildings, several of which contained critical state infrastructure, such as data centers. At one adjacent building, anchors had to be installed between existing drilled shafts, and at two others, directly beneath shallow spread footings.
- Accommodating for the presence of existing utilities, which often required relocation or temporary support to span the excavation.
- Accommodating foundations for a temporary utility support structure immediately adjacent to the excavation.
- Allowing for a potential utility tunnel and deep foundation elements of the new structures within the retention system anchor envelope. Design of these elements was not advanced past the concept level until after excavation began.
- Incorporating a "blindside" waterproofing system, which required tight excavation tolerances to accommodate a thick exterior basement wall.
- Installing anchors in severely limited space in the upper lifts of the retention system in Phase 1A due to the permitting schedule; existing structures and utilities also constrained the top rows of anchors to varying degrees in Phase 1B and 1C.
- Allowing for future Phase 2 construction, which requires excavation up to the existing Phase 1 below-grade structure where 16th Street and Congress Avenue intersect.

Geologic Setting

The site is characterized by clayey surficial soils underlain by limestone of the Austin/Atco Group, which, in turn, is underlain by the Eagle Ford Shale. The excavation section is entirely within the Austin Group; however, the lowest anchors in some locations were bonded into the Eagle Ford formation. The surficial soils are typically less than 6 ft (2 m) thick, but are locally up to 12 ft (4 m), are stiff to very stiff fill, alluvium, and completely weathered limestone. Austin/Atco limestone is a low-strength rock with an average compressive strength of 2,900 psi (20 MPa) and generally good-to-excellent rock quality. Although discontinuities in the rock mass are generally widely spaced, numerous joints and slicken-sided fractures were noted during geotechnical investigation. More importantly, a mapped displacement fault that crosses the site approximately parallel to Congress Avenue was also inferred by the subsurface investigation, but its location and dip direction could not be precisely defined, and it was therefore estimated from predominant regional geology. Groundwater is generally perched atop the harder, underlying slightly weathered/fresh limestone strata and accumulates within fractures or depressions at the contact between soil and rock units. The rate of flow into the excavation was generally correlated with precipitation events and proved to be manageable with grading and sump pumping.



Phase 1 excavation limits (background credit, Page/Texas Facilities Commission)

Retention System Components

The large dimensions of the excavation — 125 ft (38 m) to 400 ft (120 m) wide — meant internal bracing to restrain excavation surfaces was considered impractical. Subsurface license agreements were obtainable when required from owners of adjacent buildings, favoring an anchored system approach. Due to the phased installation and construction, anchors were in service for an average of 18 months, and were installed from July 2018 to August 2020. Final abandonment of the remaining temporary anchors will occur in August 2021 as the entire below-grade structure is completed.

In general, the anchored system consists of two levels of short nails in the surficial soils for local face stability, and five levels of longer rock anchors bonded in the underlying Austin limestone for global stability. Up to seven rows of rock anchors were required in more critical areas. The horizontal and vertical spacing of anchor rows was varied to match anchor capacity to demand; this allowed for just three overall types of anchors with a consistent design load for each type over the approximate 3,000 total anchors required for the project. The soil nails were Grade 75 tendons installed in 6 or 8 in (150 or 200 mm) diameter cement-grouted holes and were not tensioned. The rock anchors were 1.38 in (35 mm) diameter, 150 ksi (1,000 MPa) tendons installed in 4 in (102 mm) diameter cement-grouted auger drill holes. Rock anchors adjacent to structures were prestressed to limit the potential for movement, while passive anchors were utilized otherwise. Ultimate bond stresses varied from 10 psi (70 kPa) in the soils, to up to 130 psi (900 kPa) in the limestone.

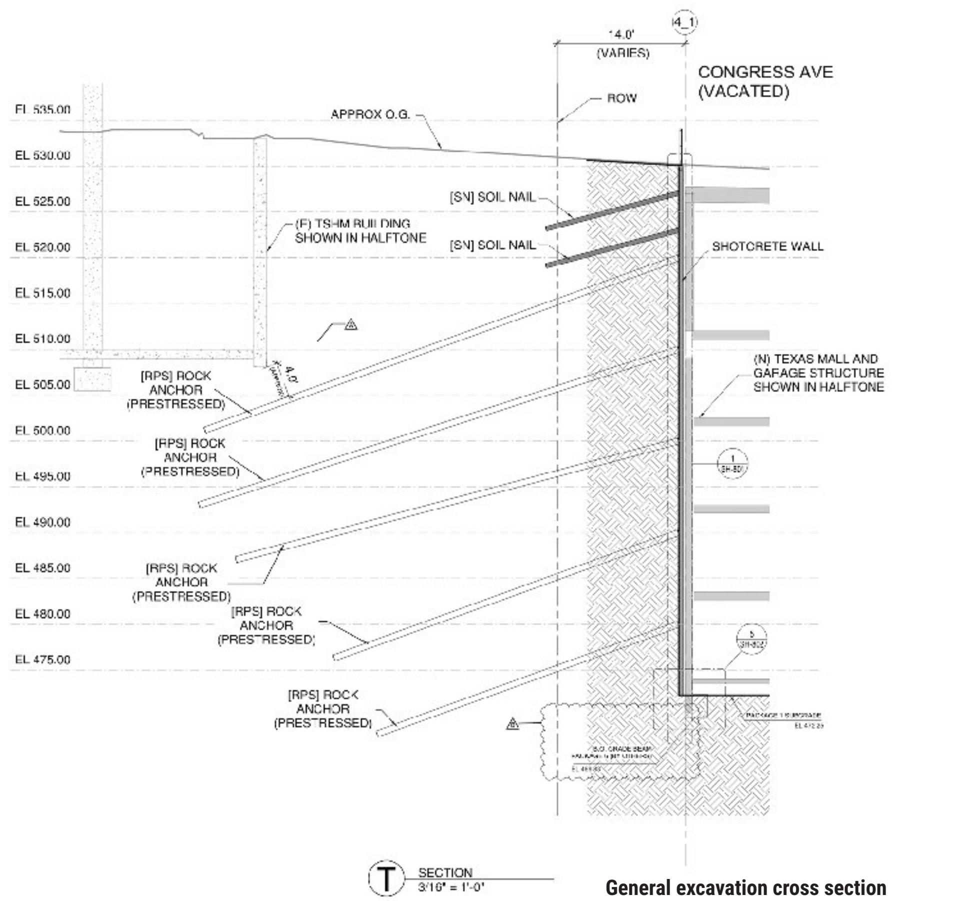
Performance and proof test loads varied from 20 - 200 kips (90 - 900 kN) and were based on the material into which the anchors were bonded, and the actual grouted bond length: a 5 ft (1.5 m) minimum to 15 ft (4.6m) maximum. Lateral deflections for the retention system were restricted to 0.5 in (12 mm) adjacent to structures and 1.0 in (25 mm) elsewhere. Surcharge loads varied from 250 psf (12 kPa) for street traffic to 1,200 psf (57 kPa) for heavy cranes. Foundation loads from adjacent structures with influence on the retention system were considered on an individual basis.

In total, over 50 unique cross sections were developed over the excavation perimeter. Design computations were performed with SLOPE/W software for local and global stability analyses, and an internally developed spreadsheet to evaluate potential planar sliding within the rock mass, based on the estimated fault location and orientation.

Excavation began in July 2018 for Phase 1A, in which the length of the soil nails in the surficial soils was limited to 10 ft (3 m) to stay within the property limits (i.e., outside the public right-of-way), as construction was anticipated to start prior to final license agreements being obtained. This restriction required a tight 4 ft by 4 ft (1.2 m by 1.2 m) pattern of the 8 in (203 mm) diameter drilled hole soil nails to maintain local stability in the surficial soils with the very low available pullout strength. While a soldier piling alternative was evaluated, the soil nail option proved more economical to construct and provided a significant schedule advantage. In Phases 1B and in 1C (excavated from February 2019-September 2019, and August 2019-August 2020, respectively), longer soil nails could be used, permitting a larger pattern spacing.

In locations with utilities immediately behind the excavation face that precluded soil nails, double channel soldier piling was utilized in certain portions of each sub-phase of excavation to permit the upper level of global stability anchors to be installed beneath the utilities, while still providing facing support. A 5 ft (1.5 m) minimum clearance between the anchors and existing or proposed utilities was required. As soldier piling was not required within the rock stratum, the length could be kept short — pilings were only installed in the upper 20 ft (6.1 m) of the excavation depth. Below the piling, a general section of rock anchors and shotcrete was utilized.

In several locations, the retention system anchors were detailed to accommodate future improvements. Where these improvements could not be installed until after the retention system was abandoned, fiberglass tendons were utilized to minimize the effort required to cut through the abandoned anchors. A reinforced shotcrete facing was required to stabilize the surficial clays and weathered rock between the soil nails. Although shotcrete was not typically required to serve a structural function in the rock, it was provided as a substrate for the basement's blindside waterproofing system.



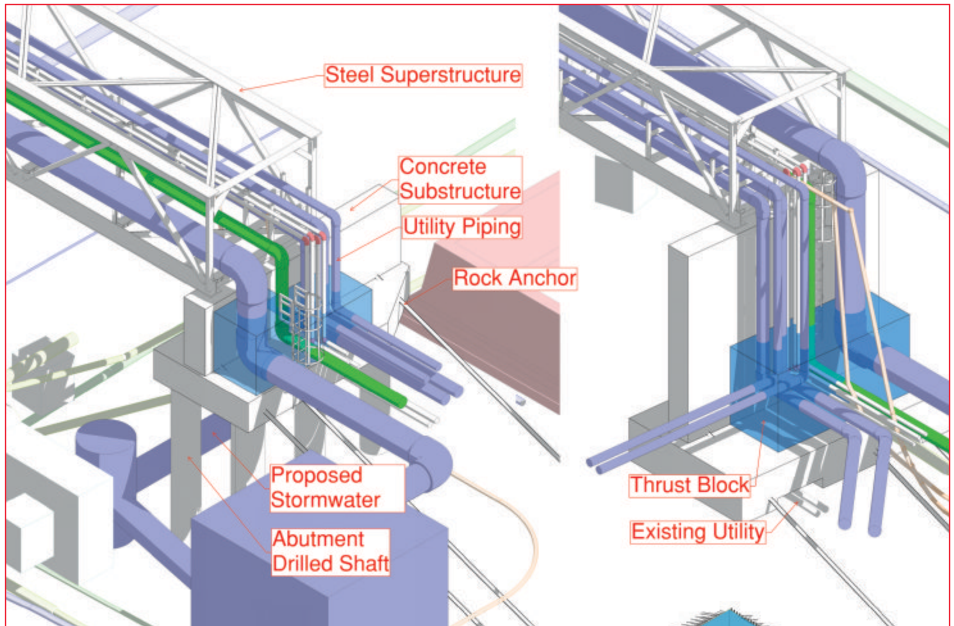
General excavation cross section

Relocated Utility Support Structure

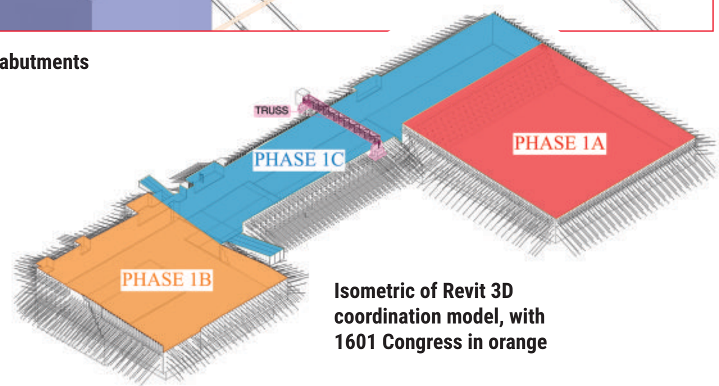
A critical part of the excavation was temporary support of existing utilities over the planned Phase 1C excavation. Fiber optic and chilled water supply/return lines (for climate control of adjacent buildings), as well as storm and wastewater lines, all had to remain in service during construction. The structure developed for this purpose, called the Temporary Relocated

Utility Support Structure (TRUSS), consisted of a 154 ft (47 m) long steel box truss superstructure supported by reinforced concrete abutments. The location selected for the temporary structure placed the abutments within 5 to 15 ft (1.5 to 5 m) of a 65 ft (20 m) deep portion of the excavation. Also, the structure foundations were located atop existing subsurface utilities that had to remain in-service until rerouted, which severely constrained the abutment foundations.

With limestone nearly at grade on the east abutment, a spread footing with a void form over underlying utilities was utilized. The west abutment required short-drilled shafts into the limestone to address conflicts with an adjacent retaining wall and a proposed temporary gravity stormwater line (which was approximately 10 ft [3 m] below ground surface and would be installed while the TRUSS was in service). The design also had to account for lateral forces from the abutments being transferred into the retention system, with rock anchors installed within the abutments to restrain these loads.



TRUSS superstructure and abutments

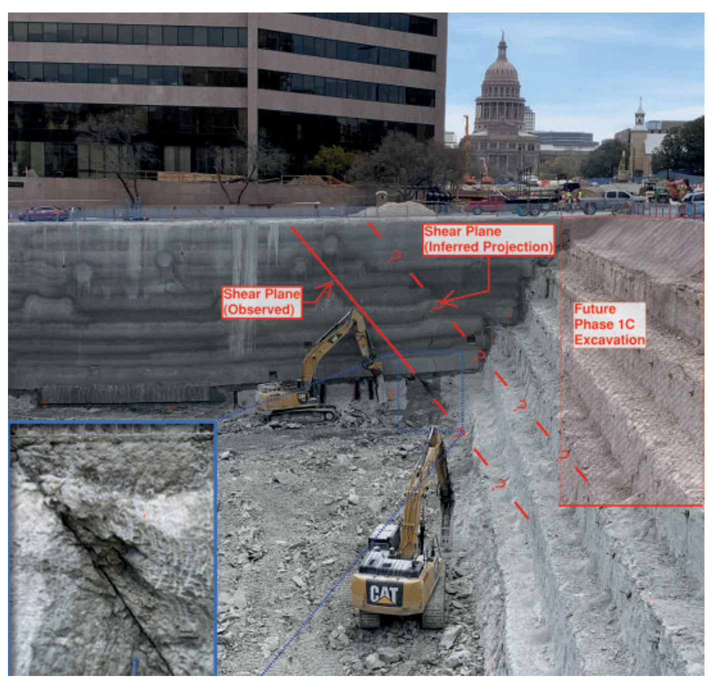


Isometric of Revit 3D coordination model, with 1601 Congress in orange

BIM Modeling

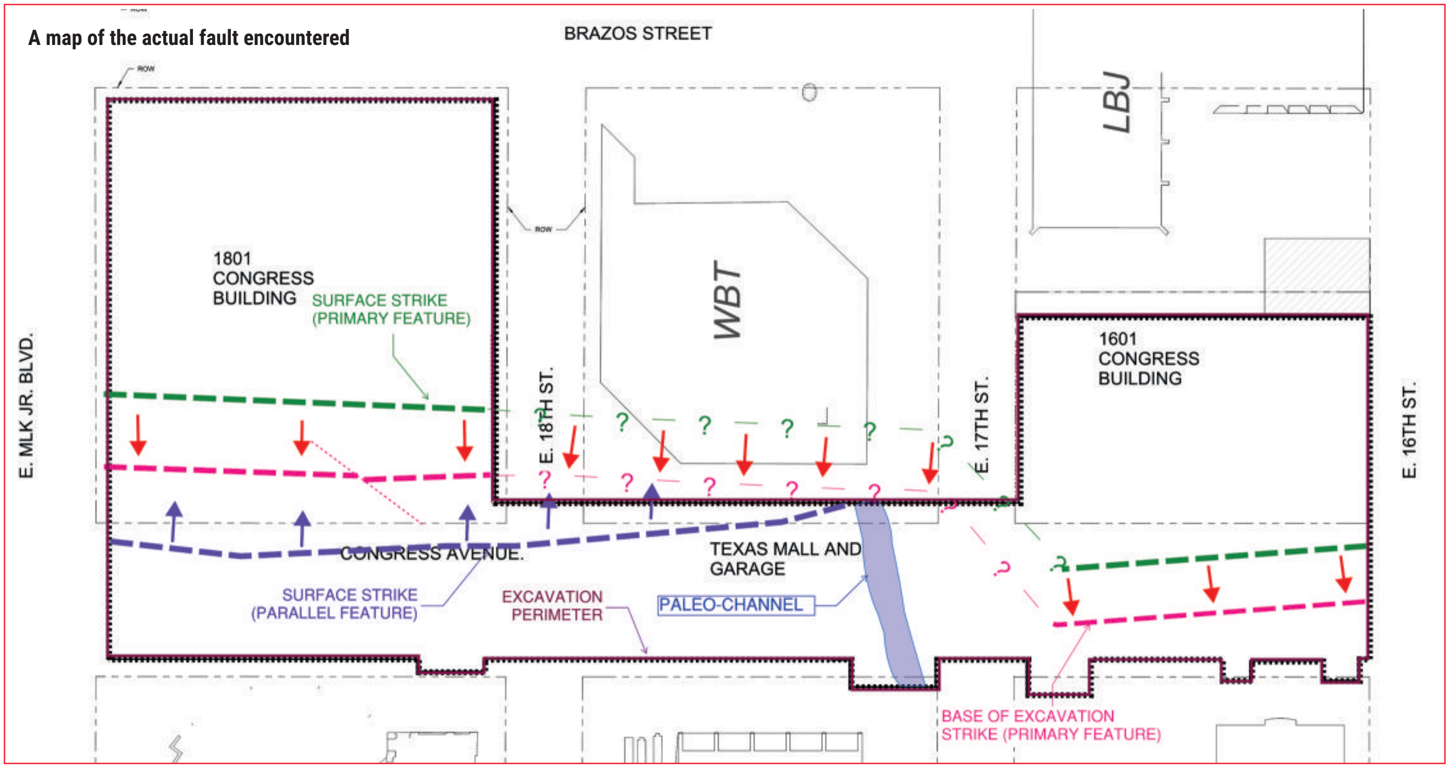
The project required that all permanent structures be designed using BIM (Revit-based) platforms. The retention system was also modeled in Revit, with live models shared via an Egnyte server. To ensure the entire TRUSS system coordinated with the retention system components, both the superstructure and concrete abutments were included within the overall excavation BIM modeling. Every anchor for the retention system (over 3,000 total) was uniquely identified with a tag indicating phase in which it was used, location, length, etc. This automatically prevented duplicate anchor tags during design and facilitated communications between the project team during construction. The Revit model further provided an automated means to develop anchor schedules and manage the procurement of required materials — such as the approximately 90,000 lft (27.4 km) of anchor tendons required. Including the excavation support system in the BIM also facilitated coordination with the ongoing permanent civil and structural design development.

Anchor elements included a tolerance zone to determine potential conflicts with adjacent underground structures and utilities (existing and proposed). Several iterations of clash detection and conflict resolution occurred as the design progressed to reconcile the retention system with the permanent structure and utility improvements. The 3D model also facilitated interleaving the retention system anchors at re-entrant corners to preclude conflicts. As a result of this coordination, the project experienced minimal impacts from underground conflicts during construction (one minor design modification due to a utility as-built location error that affected four anchors).

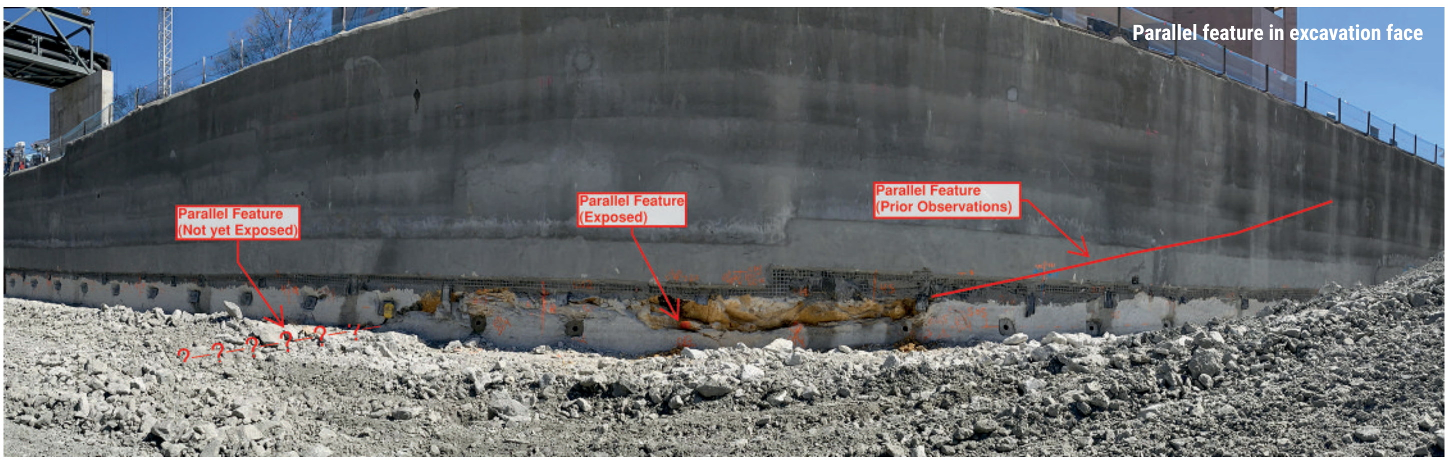


Actual fault plane location and orientation observed during Phase 1A

A map of the actual fault encountered



Parallel feature in excavation face



Splay shears with offset in Phase 1C excavation face

Construction Observation

Design team observation of actual geologic conditions encountered during construction provided critical support for validating design assumptions. As previously mentioned, a mapped fault crossed the site and had been inferred from the geotechnical investigation. Based on observations and geologic mapping during Phase 1A, it became apparent that the actual fault was in a significantly more adverse location and orientation than the initial design had accounted for.

Further observations during Phase 1B indicated the main fault trace shifted significantly to the west; however, the fault was not observed in the north face of this excavation, leading to uncertainty about the trace location between these points. Contemporaneously, supplemental stability analyses using the observation data concluded that the permanent structure design could not be adequately strengthened to stabilize the potential hanging block that would be created by Phase 1C excavation. Because the project schedule also required temporary anchors to be installed before the shear plane location could actually be definitely located, approximately 150 of the temporary anchors were subsequently revised to PTI Class 1 corrosion-protected permanent anchors; the tendons were also increased from a 1.38 in (35 mm) to a 1.75 in (44.5 mm) diameter to resist the approximately three-fold increase in anchor load required by the range of potential fault locations. Permanent drainage holes were also installed through the fault plane to reduce the potential for long-term hydrostatic build up.

Observations during Phase 1C excavation never found the primary fault trace "daylighting" in the excavation face. However, a parallel feature was observed, with a dip direction opposite the primary fault, as well as several splay shears evidencing offset. Additionally, a paleo-channel was found crossing the excavation at the south end of where Phase 1C work occurred. From these collective observations, it is inferred that the primary fault "steps over" in the vicinity of Phase 1C, at the north end of Phase 1B.

Conclusion

Retention system design using BIM software provides a comprehensive way to manage extensive information and address potential conflicts during the design process. A significant number of conflicts were resolved during the design phase for the Texas Capitol Complex project, minimizing unanticipated issues and consequent design changes during construction. However, construction observation and monitoring remain essential — as unfavorable geotechnical conditions more adverse than anticipated by the design can have severe consequences if not addressed. The actual fault location and its geometry were uncovered during Phase 1 construction of the Capitol Complex project, allowing the design to be modified without significant impacts to the project schedule.

Acknowledgements

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Rendering of completed Phase 1 (credit, Page/Texas Facilities Commission)