Elm Fork Project – Eagle Ford Shale:

Tunnel & Shaft Re-Design Prompts Supplemental Geotechnical Investigation Program

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In Fall 2019, Southland Holdings, LLC was awarded the construction contract for the City of Dallas' Elm Fork Project. The project consists of the construction of a 72-inch diameter water main that will extend approximately 1.8 miles starting from the Elm Fork Water Treatment Plant to near where West Crosby Road passes beneath I-35 East Express in Carrollton, TX.

The original design involved the water main invert generally installed between 20 and 40 feet below existing ground surface and extending mostly through alluvial deposits, with portions extending through weathered shale with artesian conditions. The original design was to be installed using a combination of cut-and-cover and microtunneling trenchless construction methods amidst a myriad of existing utilities and surface development features.

However, upon award of the Contract, Southland proposed an alternate design and construction approach, with the pipe lowered sufficiently to allow for construction using tunneling methods, and entirely located within the Eagle Ford shale bedrock. Brierley Associates Corporation was contracted to assist with the redesign of the now deeper various shafts and now longer tunnel. The redesigned project now includes 8,575 linear feet tunneling in total ranging in depth from 65 feet to 75 feet, two tail tunnels each at 40 linear feet, and five vertical shafts ranging in diameter from 18 to 35 feet.

To provide sufficient information for the deeper tunnel and shaft redesign, Brierley developed and implemented a supplemental deep geotechnical investigation program based on a data gap analysis of the original geotechnical program to investigate the properties of the Eagle Ford Group (also called the Eagle Ford Shale). This Group is of the Late Cretaceous Epoch and was deposited in a marine or lagoonal environment. The Eagle Ford Group is primarily composed of organic-rich, fossiliferous marine shales and calcareous marls with interbedded thin limestone layers. The following geotechnical properties are characteristic of the Eagle Ford Shale at the project site:

- Swell potential of the shale unit was evaluated using both the five-point swell test methods recommended by the International Society of Rock Mechanics (ISRM, 1999) and using X-ray diffraction tests to determine the swelling clay mineral content of the rock along the tunnel alignment. Results of the swell and mineralogy testing indicate low swelling pressures are to be anticipated in the shafts and tunnels.
- The susceptibility of the Eagle Ford Shale to degradation when exposed to wetting and drying cycles was quantified by using the slake durability index (SDI). From the test, where no degradation occurs an SDI value of 100 percent is assigned, while an SDI value of 0 percent is assigned for samples which completely degrade during testing. The values of SDI for the Eagle Ford Shale ranged from 0.7 to 32.3 percent for this project, indicating high susceptibility to material degradation or slaking.
- The Eagle Ford Shale material is anticipated to pose a risk of clogging equipment (for both excavation and muck handling) due to the relationship between the high plasticity characteristics and the natural water content (Thewes & Burger, 2004). Clogging potential is evaluated as a function of consistency index and plasticity index. Results of the clogging potential evaluation indicate moderate to high clogging conditions are likely during tunneling.

Five vertical shafts will range in diameter from 18 to 35 feet

- Corrosion potential of the Eagle Ford Shale was evaluated in laboratory tests including pH, sulfates, chlorides and resistivity at two locations. Based on the testing, the pH of the soils is not anticipated to be problematic. Classifications of the sulfate exposure levels from tested rock samples indicate that Class S1 and S2 rock is present at the site.
- Permeability and hydraulic conductivity of the Eagle Ford Shale was analyzed using packer testing, and rising head testing adjacent to the three deep piezometers. The packer test results were analyzed to calculate the hydraulic conductivity of the shale based on water infiltration during testing. No discernible trends were identified by test location or elevation. The rising head test results were analyzed using the Hvorslev (1951) method to calculate the hydraulic conductivity of

The Eagle Ford Group are primarily marine shales and marls with thin interbedded limestone layers

the shale based on the rate of recharge of the water level. The calculated hydraulic conductivity values were used to estimate groundwater inflows along the alignment. It should be noted that though it is considered likely that the variation in bedrock elevation along the southern portion of the alignment is caused by paleochannel erosion rather than by faulting, if the tunnel intersects a fault or sheared zone during tunneling, it would be anticipated that localized increases in rockmass hydraulic conductivity and associated spikes in water inflow could occur over short lateral distances when crossing the feature. The average of the Eagle Ford Shale permeability measurements taken within the tunnel horizon ranged from a minimum of 9.0E-07 cm/sec to a maximum of 9.6E-05 cm/sec.

The five construction and retrieval shafts require redesign of temporary ground support for their excavation in both overburden soils and underlying shale bedrock. The overburden soils generally consist of surficial fill, underlain by alluvial sand, silt, clay and gravel deposits. The alluvial soils in the project area are predominantly silt and clay with sand and gravel deposits confined below the fine alluvium deposits. In these overburden soils, steel liner plates with annular grouting will be used. For smaller diameter shafts, a heavier gauge liner plate will be used, whereas for the larger diameter shafts, steel wide-flange ring beams with a lighter gage liner plate acting as vertical lagging to span between ring beams will be used. The liner plate will extend into the bedrock to provide a transition to the shotcrete lining and provide supplemental groundwater control. Positive means of groundwater control during installation of the liner plate will likely be necessary. In the Eagle Ford Shale, shotcrete with split set rock bolts on a typical pattern with welded wire mesh will be utilized for ground support, with supplemental bolts at the tunnel penetrations.

The tunnel will be excavated using a Southland Contracting Manufactured Single Shield TBM with a 118-inch excavated diameter, with a steel shield with an outside diameter of 116 inches. W-section, cold rolled steel ribs will be used to support

Careful geotechnical investigation and detailed analysis of the data were necessary for the redesigned tunnel alignment

the excavated opening by erecting them inside the 115-inch ID shield with full lagging between ribs. Once the newly erected steel rib is outside the TBM shield, the rib will be expanded using hydraulic jacks and dutchman spacers to match the 118-inch excavated diameter, resulting in full contact with the ground. However, it is assumed that there will be soft areas or areas of sloughing in the excavated perimeter that effectively result in small internal moments. Therefore, the steel rib is designed for the combined effects of moment and thrust. Wood lagging is designed to resist bending between steel ribs and wood lagging is designed to resist the critical loads that are generated from TBM thrust. Steel ribs will be evenly spaced and fully lagged every 4 feet for the full length of the tunnel excavation.

Shaft construction expected to begin on the Elm Fork Project this summer, 2020.

ABOUT THE AUTHORS:

Dave Sackett *has throughout his 35-year career been responsible for geological interpretations of high-resolution onshore, downhole and marine geophysical data, landside and nearshore site characterization, planning and execution of geophysical surveys and geotechnical investigations, and the preparation of geological and geotechnical reports and technical reviews. Mr. Sackett has designed, managed and performed integrated geophysical and geotechnical programs, logged geotechnical boreholes, mapped three-dimensional geologic exposures including tunnel interiors, installed and monitored geotechnical instrumentation, authored technical reports, and designed/managed geoscience projects on five continents.*

Kent Vest *is the Operation Manager of Southland Contracting, overseeing all tunnel and general underground structure preconstruction and construction operations. He specializes in managing projects which incorporate deep shaft sinking, sequential grouting and excavation methods, NATM, tunnel boring machines (hard rock and EPB), segment lined tunnels, microtunneling , and conventional drill and blast excavation. He has extensive knowledge of shotcrete design and methodology. On various projects, Kent has gained a reputation for handling the most challenging situations while preserving safety and quality.*