1. Introduction

The Transbay Transit Center Program is a landmark undertaking for the San Francisco Bay Area. The Program will enhance regional transit service by improving the bus and rail connectivity of eight major transit providers in one multi-modal facility in downtown San Francisco, resulting in the largest such facility in the United States west of New York City. Responsibility for the completion of the design, construction, and the subsequent operation and maintenance of the Program resides with Transbay Joint Powers Authority (TJPA), a collaboration of Bay Area government and transportation agencies. A full description of the Program can be found on the TJPA’s website (www.transbaycenter.org) [1].

The Caltrain Downtown Extension (DTX) is a vital element of the Program. The DTX project involves the construction of approximately 1.7 miles of underground structures that will extend the existing Caltrain commuter rail service and the future California High Speed Rail Authority (CHSRA) system into the new Transit Center (TC) into the heart of downtown San Francisco (Figure 1).

The rail extension will be constructed largely under city streets by a combination of mined tunnel and cut-and-cover methods. The construction of the tunnel will encounter challenges such as difficult ground conditions including low rock cover, extensive utilities, and the presence of historic buildings along and above the alignment. These challenges are further exaggerated by the magnitude of the proposed tunnel structures.

This paper discusses these challenges and the solutions developed to overcome them by the project team during the development of the preferred project configuration, and outlines the proposed approach to the contract packaging, procurement and schedule for the forthcoming tunnel construction.

2. Project Description

The DTX project will wind from Seventh and Carolina Streets before turning northeast along the existing Caltrain Yard at Fourth and King Streets along Townsend Street from a new proposed underground station at Fourth and Townsend Streets. The alignment will turn northwest and proceed along Second Street before turning northeast again north of Howard Street to enter the
Figure 1. General Plan of DTX Alignment
beneath grade trainbox at the TC (Figure 2). The TC will provide three platforms and six tracks for Caltrain and future CHSRA service.

The DTX alignment consists of six primary structure types: a retained cut, cut-and-cover tunnels, a cut-and-cover station box, a mined tunnel, ventilation shafts, and cut-and-cover tailtracks. The mined tunnel stretches approximately 0.6 mile and varies in dimension to a maximum of 42 feet high by 60 feet wide. The cut-and-cover excavations are similarly massive, stretch nearly 0.7 mile in length and reach depths of up to 70 feet and widths of up to 175 feet. The retained cut portion of the underground construction is approximately 0.2 mile in length and will span approximately 40 feet in width. The retained cut will contain a two-track approach to the Fourth and Townsend Underground Station which will expand to three tracks as it enters the station. The remaining 0.1 mile of underground construction comprises a section of cut-and-cover tailtracks which extend past the TC down Main Street. The limits of each of the construction methods are indicated in Figure 1.

3. Functional and Logistical Challenges

The DTX Project is not without external challenges. The system must meet the operational and functional requirements of the operators: Caltrain and California High Speed Rail Authority (CHSRA). The Transbay design schedule is advanced significantly ahead of the operators’ capital programs. Therefore, required design parameters, operational procedures and rolling stock have not yet been determined by the operators and may not become available until after the DTX design is complete. The operational procedures impact assumed headways and platform dwell times while the rolling stock choice affects the required clearance envelopes, platform and walkway heights and allowable radii for curves along the alignment. As the operators are stakeholders in the Program, but not the client, the project schedule has required that assumptions be made until information from the operators becomes available. For example, clearances were developed using an envelope of potential rolling stock for Caltrain and CHSRA. Platform and emergency walkway heights have been based on this fabricated clearance diagram.

The project team has coordinated with the operators to obtain information as soon as it becomes available for issues such as fire life safety requirements and emergency response procedures. The operators are also provided with project design submittals as they become available for their review and comment to facilitate the coordination effort.

4. Technical Challenges

The DTX project is constrained by ground conditions, low rock cover, extensive utilities, and fragile historic buildings adjacent to and above the alignment. These challenges have shaped the engineering design as well as the proposed construction methods along the project alignment. These challenges and their proposed solutions are described in the following sections.
4.1 Ground Conditions

The ground conditions vary greatly along the DTX alignment as is shown in Figure 3. The southern portion of the alignment (between the start of the project alignment near Carolina Street and the intersection of Townsend and Third streets approximately) is located bayward of the historic 1848 shoreline and is adjacent to an inlet of the San Francisco Bay. The southern portion of the alignment (on the right portion of Figure 3) consists of loose surficial fill that ranges in thickness from 10 feet to 30 feet which is primarily composed of debris from the 1906 San Francisco Earthquake and is partially classified as California hazardous waste. The fill is underlain by a 10-foot to over 110-foot-thick layer of compressible clay, locally termed Bay Mud, under which is a thin layer of marine deposits. The marine deposits overlay layers of dense Colma Sand or Old Bay Clay as the alignment moves east along Townsend Street. Both the Colma Sand and the Old Bay Clay are approximately 60 feet to 80 feet in thickness and are underlain by thin layers of Alluvium and residual soil, which rest above the highly weathered bedrock of the Franciscan Formation. The bedrock ranges in depth from near ground surface to over 200 feet beneath grade. A relatively shallow groundwater table and the potential for amplification of seismic waves through the Bay Mud during a seismic event cause further design and construction challenges.

The Franciscan Formation rises to near the ground surface near the intersection of Townsend and Third streets as the alignment turns onto Second Street and continues to be near the surface until approximately Second and Harrison streets. The bedrock is interrupted for approximately 650 feet between the I-80 crossing of Second Street to past the intersection of Second and Bryant streets by an approximately 100-foot-deep Paleolithic valley, which is predominantly filled with Colma Sand, interbedded with stiff clay, which is underlain by approximately 20 feet of residual soils above the Franciscan Formation.

Along the northern portion of the alignment between the intersection of Second and Folsom streets and the TC, the bedrock returns from near ground surface to over 200 feet beneath grade. The fill remains approximately 10 to 20 feet thick and is underlain by thin layers of dune sand and marine deposits followed by a layer of Colma Sand which ranges in thickness from 10 feet to 60 feet. The Colma Sand is in turn underlain by residual soil to approximately Second and Tehema streets and Old Bay Clay above bedrock for the remainder of the northern portion of the alignment to the TC. [2]
4.2 Historic Buildings

The majority of the alignment is planned to be in the public right-of-way; however, as the DTX alignment turns northwest from Townsend Street to Second Street, the alignment passes beneath 11 existing buildings. The buildings were constructed in the early 1900s and range from one to six stories in height. All the buildings form a part of the Rincon Point/South Beach Historic Warehouse-Industrial District, and may be eligible for the National Register of Historic Places. The mined tunnel will pass beneath these buildings with approximately 20 to 35 feet of rock cover, a small depth compared to the tunnel span. Additionally, numerous existing buildings line the street adjacent to the cut-and-cover excavations. Most of these buildings range from two to seven stories; however there are several high-rise buildings along the northern portion of the alignment. [3]

4.3 Utilities

The DTX alignment is entirely in the urban environment in downtown San Francisco. As with most urban environments, an extensive network of dry and wet utilities from various stages of the city’s development cross and run parallel to the alignment. The utilities range from small diameter pipes to duct banks which are over 20 feet by 15 feet in cross section and must either be relocated or supported in place during cut-and-cover operations. Additionally, old brick sewers cross the alignment which must be replaced with more current materials then supported in place. One significant sewer relocation along the southern portion of the alignment will require the jacking of a 10-foot-diameter pipe approximately 300 feet under active Caltrain tracks at a depth of 20 to 30 feet. Though the pipe will be buried in the Bay Mud stratigraphic layer, it is not currently anticipated that underpinning will be required for the new sewer pipe.

4.4 Construction Methodology

The technical challenges for the DTX project have shaped the decisions on tunneling methodology as well as the application of these methodologies along the alignment. Limiting ground movements and associated surface settlements to avoid damage to the adjacent and overlying buildings is a critical concern for the project. The ground conditions played a large role in determining the sections of the alignment where cut-and-cover methods and mined tunneling methodologies would be used. The project team strived to maximize the mined tunnel segments to minimize the surface disruptions caused by cut-and-cover operations. Figure 1 shows the zones along the alignment where cut-and-cover and mined tunnel methodologies will be employed.

It was decided to pursue mined tunnel in sections of the alignment which are in bedrock and are relatively uniform in cross-section. The extent of the mined tunnel generally aligns with the extent of the Franciscan Formation bedrock in the tunnel horizon. Several tunneling methodologies were evaluated: the Stacked Drift Method, the New Austrian Tunneling Method/Sequential Excavation Method (NATM/SEM), and Tunnel Boring Machines (TBM). The number of tracks and locations of track crossovers combined with the available right-of-way precluded this use of a TBM. In comparison with the stacked drift method, NATM/SEM offered cost, schedule and risk benefits. NATM/SEM was determined to be the appropriate tunneling method for the DTX alignment as it allows for relatively small ground movements to occur around the tunnel while still mobilizing the strength of the surrounding materials.
With NATM/SEM, materials are excavated in drifts which are shown in the typical tunnel cross section in Figure 4. The project team has demonstrated that ground movements and corresponding surface settlements can generally be controlled to tolerable limits using only three drifts, as indicated in Figure 4. This provides a tremendous advantage to the project in terms of the ability to use larger equipment and achieve better production. Four drifts will be used only when ground conditions require the second top heading such as in the mixed face conditions near the northern portal of the mined tunnel.

Four excavation support types are proposed for the mined tunnel to accommodate the anticipated variability in rock quality over the length of the tunnel. Each of the support types makes use of a combination of auxiliary support measures including tube spiles, rock dowels, a pipe canopy, sloping core, fiberglass face dowels, and fiber reinforced shotcrete. Figure 4 is an example of one support type which includes a single pipe canopy, rock dowels, fiberglass dowels, and fiber reinforced shotcrete. This support type will be used in zones of tunneling through blocky, disturbed, and seamy sandstone, siltstone and shale of the Franciscan Formation. The tunneling method offers the flexibility to adjust the proposed support measures to suit the actual in situ conditions encountered, thereby helping to mitigate ground movements during construction.

The project team sought to minimize the extent of any cut-and-cover construction along the alignment. As the excavation will occur in an urban environment, street closures and work hours for construction will affect the overall construction schedule and cost. Additionally, the project team has focused on minimization of ground movements, and thus impacts on adjacent structures, as a result of the cut-and-cover excavations. The cut-and-cover construction will begin...
with the installation of deep soil mix shoring walls with embedded steel soldier piles placed under their own weight. The excavation will then proceed with traffic decking placed over the street to allow surface traffic to be maintained during the construction. Steel pipe struts and walers will be placed as temporary excavation support as the excavation deepens.

There are two individual sections along the DTX alignment where the cut-and-cover construction method will be employed. The first of which is along Townsend Street between Sixth Street and just past Third Street, at the southern limit of the mined tunnel. This section also includes the proposed Fourth and Townsend Underground Station. This section will be fairly uniform in cross section and will be primarily constructed in the public right-of-way of Townsend Street. As described previously, the ground conditions on this portion of the alignment are comprised of softer materials. As the tunnel alignment is relatively shallow in this area, mining would require extensive and expensive ground treatment. In this area, cut-and-cover construction poses less risk.

The second section of cut-and-cover construction works will occur between the northern portal of the mined tunnel at the intersection of Second and Clementina streets and the interface with the TC. This segment of cut-and-cover allows for the three-track tunnel to expand to six tracks on a curved entry into the TC, resulting in a structure that varies in width to a maximum of 175 feet. The variation in cross section and excavation size demands that cut-and-cover construction be adopted. The Second Street cut-and-cover tunnel is particularly constrained as the alignment turns from the public right-of-way towards the TC and the number of tracks must increase from three to six. Within the public right-of-way, the limited width precludes the use of internal structural walls, as these would increase clearance requirements and hence structure width. In addition, major communications utility infrastructure above the tunnel constrains the structure depth. Therefore, to overcome these issues, a cast-in-place post-tensioned roof is proposed.

The portion of the alignment past the intersection of Sixth and Townsend streets to Carolina Street will be constructed as an open retained cut, which will be constructed in a manner similar to that described for the cut-and-cover structures.

5. Current Status

The DTX project is currently in the Preliminary Engineering (PE) Phase of Design, which is scheduled to be complete in June of 2010. The goal of this design phase is to define the structural size and limits and the configuration. At the conclusion of this phase, the DTX engineering will be approximately 30% complete.

5.1 Contract Packaging

The development of the DTX Contract Packaging Strategy (CPS) is the responsibility of Hatch Mott MacDonald as a part of the Program Management/Program Controls (PMPC) team. The task has not been without challenges and was discussed in great detail in a paper presented at RETC 2009 [5]. The overall goal of the CPS has been to develop a strategy which allows the DTX project to be constructed in the shortest timeframe possible. In addition to allowing the DTX project to open for revenue service earlier, benefits of this approach include the minimization of impacts of escalation, the minimization of time-dependent costs such as program and construction management, and importantly, the minimization of impacts to existing Caltrain operations.
The scope of the DTX project has been broken into several construction packages which include 1) Townsend Street cut-and-cover, 2) mined tunnel, Second Street cut-and-cover, and ventilation shafts, 3) track, 4) systems for the tunnel, 5) systems for the buildings, and 6) finishes.

5.2 Schedule

The current PE, thirty percent design, phase is anticipated to be completed in summer of 2010 with the Final Design phase completion in 2012. Advance contracts for utility relocation and survey work will be let prior to the conclusion of final design and are anticipated to commence in late 2011. Contracts for the primary civil works contracts are anticipated to be awarded for construction in 2012, with systems contracts flowing once civil construction is substantially complete. Revenue service for Caltrain is scheduled to begin in 2018.

6. Conclusion

This paper summarizes the technical and outside challenges the DTX Project has encountered. As the DTX design progresses and the construction schedule of DTX and of adjacent projects (i.e., the Central Subway project and the electrification of the Caltrain Peninsula Corridor with the California High Speed Rail Project) are coordinated, the necessity of the Project to provide a regional transportation hub becomes increasingly apparent.

7. Acknowledgements

The authors would like to thank the Transbay Joint Powers Authority for the permission to publish this paper. In addition, the contributions of the other key members of the Project Team are gratefully acknowledged: Parsons Transportation Group – prime consultant, rail design, and open cut construction; Jacobs Associates – tunnel design; and Arup – geotechnical investigations.

8. References


