Transbay's downtown rail extension

Bradford F Townsend and Derek Penrice, of Hatch Mott MacDonald, and Steve Klein, of Jacobs Associates, describe plans for San Francisco's Transbay rail extension

Left: Plan of the new system with the tunnel running up 2nd Street
Above: The existing Transbay Terminal area in San Francisco

The existing Transbay Terminal, which opened in downtown San Francisco in 1939 is dilapidated, antiquated, resides in an area of urban blight, and meets neither current seismic safety standards nor the transportation needs of the Bay Area. In 1999, San Francisco voters approved Proposition H, which proposed a new or rebuilt regional transit centre at the site of the existing terminal and also to extend the Caltrain commuter rail service to the new transit centre. The Transbay Transit Centre Program consists of two projects; the Transit Centre Terminal Building (TTC) and the Caltrain Downtown Extension (DTX) and is being administered by the Transbay Joint Powers Authority (TJPA).

The Transbay Transit Centre Program is a landmark project for the Bay Area. It will enhance transit service to the region by improving bus and rail connectivity of six Bay Area transit providers at one downtown multi-modal facility.

Programme phasing

Based on early value management initiatives and studies to meet identified funding and land acquisition requirements, construction phasing was presented to the TJPA Board of Directors in December 2005. The TJPA Staff and Programme Management/Programme Controls (PMPC) consultant consisting of URS, Hatch Mott MacDonald and EPC, recommended approval for the phased programme approach as well as an "up/down" construction method for the Transit Centre Building which allows the Programme and Transit Centre Building to be constructed in two phases.

The proposed phasing is a product of the preliminary engineering and planning stage currently in progress. Establishing the phasing has required an iterative planning process to refine engineering/design, estimate costs, determine work sequence, establish a cash flow estimate, and compare this to available financing. Where the cash flow estimate does not match the available financing, the planning process interjects value management/value engineering and repeats the planning process.

In Phase 1 the above-grade bus terminal portion of the Transit Centre Building and its infrastructure would be constructed. In Phase 2 the below-grade train station is mined out beneath an operating terminal and the Caltrain Downtown Extension (DTX) Project underground commuter rail extension would be constructed.

A critical component of the programme is the Caltrain Downtown Extension (DTX), which incorporates the design, construction and operation of the following infrastructure:

- A 2.5km underground extension of Caltrain rail service along Townsend and Second Streets to the new Transit Centre building
- A new underground station in the vicinity of Fourth and Townsend Streets in proximity to the Caltrain northern terminus at the Fourth and King Street
- Improvements to the existing Caltrain Fourth and King Street surface station
- Re-configured and improved functional layout of the existing Caltrain yard, located adjacent to the surface station

The 2.5km rail extension will be constructed by mined and cut and cover tunnels. While the DTX Project comprises approximately 1km of mined tunnel, 1542m of cut and cover tunnel, and an additional 756m of open/retained cut construction, which transitions the DTX tunnels to existing grade.

Planning and conceptual design has focused on the development of a project configuration which meets the operational and functional requirements of the rail operators; Caltrain and the California High Speed Rail Authority (CHSRA). The tunnel concepts developed thus far include several potential configurations.

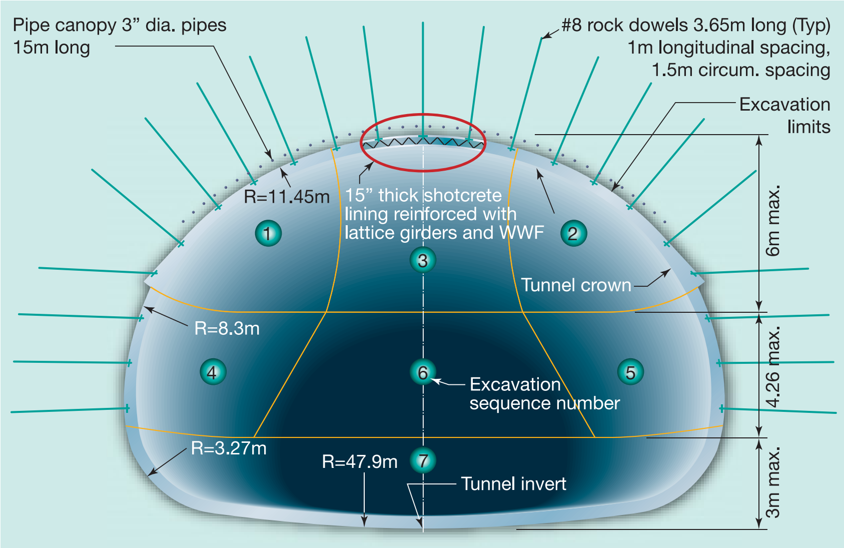
The configuration and cross-section of the tunnel are being determined by on-going parallel studies involving rail operation simulations and rail engineering evaluations. The outcomes of these studies have a significant impact on the tunnel construction methodology and the project cost. Some of the objectives of these conceptual engineering studies are to determine the:

- Rolling stock dynamic envelope and corresponding tunnel clearances
- Number of tracks required to provide sufficient operational capacity
- Locations of crossovers and other special track work
- Ventilation and fire-life safety requirements

Alignment

The DTX transitions from at-grade to below grade within the existing Caltrain Yard at 4th and King Street. Thereafter the DTX route is largely within the City-owned street right of way, on Townsend, 2nd and Main streets.

Construction of either a twin or three-track tunnel has obvious cost implications and will also impact the tunnel configuration and selection of the method. Due to this width constraint a three-track tunnel can only be accomplished using a large multi-track single bore. In contrast, the twin-track tunnel can be constructed as either a single or twin bore configuration, however the practical length of twin bore tunnel that can be constructed is limited to about 740m due to the necessity for crossovers between adjacent tracks to satisfy rail operations requirements.



Above: **Fig 2 - Cross section of the three track tunnel with excavation stages**

Clearances

A composite vehicle envelope has been developed based upon current technology, which accommodates a range of vehicles that could be used. Preliminary tunnel clearances have been developed using this design vehicle envelope with appropriate provisions to satisfy California Public Utilities Commission (CPUC) General Order 26D.

However, the CPUC requirements mainly address freight lines and the Transbay Joint Powers Authority (TJPA) programme does not intend to bring freight rail traffic into the new Transbay Transit Centre. The current clearance diagrams developed to meet these requirements require a tunnel some 7m high (above the rail) and 11.7m or 16.8m wide for the two and three-track options.

Passenger dedicated lines (PDLs), similar to the currently proposed rail extension, would typically have smaller clearances. In due course, the project will coordinate with the CPUC to confirm interpretation of General Order 26-D in reference to PDLs for reduced clearances to optimise tunnel size.

Geology

An extensive geotechnical investigation has been conducted over the past two years, with 54 borings completed for the alignment - of which 25 were along the mined tunnel section - totalling 954m of borehole.

The mined tunnel section of the DTX traverses an area of high bedrock composed of Jurassic to Cretaceous sedimentary rocks of the Franciscan Formation. These rocks are generally highly fractured and sheared. In the mined tunnel section, the Franciscan bedrock is generally within 1.6m-2.2m of the ground surface, and groundwater levels are about 3.3m-6.6m below the ground surface.

Soil deposits along the DTX alignment include artificial fill, Bay Mud and other marine deposits, Colma Formation, and colluvium at the northern and southern sections of the alignment. A soil deposit will be encountered in one area of the mined rock tunnel, on 2nd Street between Bryant Street and Interstate 80. In this area a paleovalley of colluvium and Colma Formation extends into the tunnel horizon. Ground improvement may be required prior to tunnel excavation.

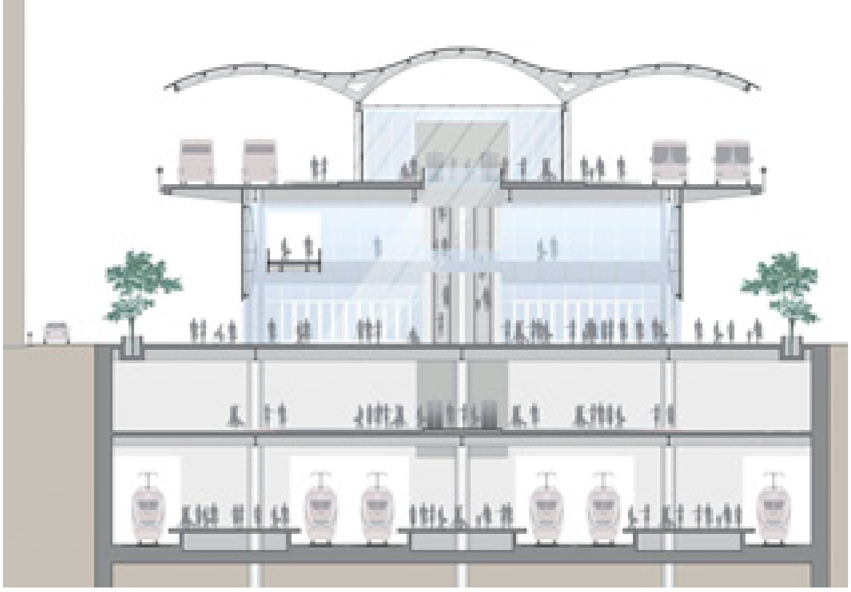
Franciscan Formation

The Franciscan Formation is a highly deformed rock mass that includes weak, sheared, fine-grained sediments and stronger rock blocks of various lithologies. The resulting rock mass is extremely variable and it possesses a chaotic structure of disconnected rock blocks surrounded by a weaker matrix. Locally these rocks are referred to as a 'mélange'. The mélange matrix is composed of stiff clay, sheared shale, and disaggregated rock fragments. Blocks within the mélange are predominantly sandstone and siltstone, although blocks of stronger rock like chert and greenstone are sometimes present. For the purposes of the conceptual tunnel evaluation, the alignment was split into two distinct reaches.

Reach 1 - Borings in the northern 263m of the mined tunnel found that over 85% of the rock mass in this area is composed of mélange matrix. The clay content of some core runs was up to 90%, and only a small number of discrete blocks of sandstone and siltstone were observed. The mélange matrix in this reach is extremely weak and extensively sheared, and in places is pulverised to crushed rock fragments.

The strength of the clayey mélange matrix was evaluated based on UU triaxial tests. These tests indicate an average compressive strength of about 0.68MPa. The UCS of sheared shale samples that could be tested are higher, ranging from about 1.1MPa-2.75MPa. However, much of the mélange matrix was so pulverised that it could not be tested in the laboratory.

Rock mass quality was assessed from the



Above: A schematic of the above and below ground Transit Centre Station

RQD values indicated on the core logs and estimates of the RMR and Q determined. For this reach, almost 70% of the core runs had a RQD of zero, and none of the values were above 25, which is the upper boundary value for 'very poor' quality rock. RMR and Q values also indicated low rock quality for this reach with overall ratings of 'very poor' for the RMR system and 'exceptionally poor' for the Q system.

Reach 2 - Borings drilled in the southern 789m of the mined tunnel section found mainly strong sandstone and siltstone blocks (about 75%), containing much less of the weak mélange matrix. The rock in Reach 2 is still highly fractured, but in general, the sandstone and siltstone blocks are much stronger than the mélange matrix.

The sandstone in this reach varies considerably in strength, from weak to strong. High variability in the UCS test results appears to be a result of defects in the rock samples caused by shear failures along pre-existing, but healed, fractures, rather than through intact rock. UCS values for the sandstone range from about 9MPa to 131MPa, although one test result from previous investigations recorded an UCS of 187.5MPa.

The results imply that the fresh, unfractured sandstone can be very strong, but most of the test samples contained healed fractures or other defects that tended to reduce their strength. The siltstone is weaker than the sandstone, with strengths from approximately 1.4MPa to 27.5MPa.

Some 45% of the rock core in Reach 2 is 'poor' or 'fair' (RQD of 25 - 75) and only about 55% is 'very poor' (RQD less than 25). Less fracturing and higher rock strength in Reach 2 resulted in higher RMR and Q ratings, but discontinuity fillings with sheared shale and clay tended to lower the ratings. Ratings in Reach 2 are generally 'fair' to 'poor' for the RMR system and 'extremely poor' to 'very poor' for the Q system.

Mined tunnels

For the evaluation of the NATM/SEM method to be used, preliminary numerical analyses using finite difference methods and the computer program FLAC were conducted to predict the stresses and displacements in the ground and support elements during the various excavation stages. These analyses were used to check the drift size, round length, and excavation and support sequence. Generally, the results indicated that the proposed drift arrangement and sequence were conservative.

To mitigate the risk of damage to overlying buildings as the tunnel alignment turns under a city block between 2nd and Townsend streets, it was proposed that additional ground support be provided by a grouted pipe canopy. The pipe canopy would consist of 76-102mm diameter pipes installed about 300mm apart in the arch.

Additional rock bolts, greater shotcrete thickness, and reduced round lengths would be considered for improved control of ground movements within sections of the tunnel where there is a greater risk of damage to properties and utilities from ground movements.

For the twin-track tunnel, a total excavated width of about 15m and height of about 11.9m would be advanced using seven drifts; three in the top heading, three in a top bench, and one at the invert. The same sequencing would be used for the three-track tunnel, which has a total excavated width of about 20.1m and an excavated height of about 13.1m (figure 2).

After completion of the tunnel excavation and installation of the shotcrete lining, a waterproof membrane would be installed on the inside of the initial lining before placement of the final concrete lining.

Cut and cover tunnels

It is paramount that major streets such as those on the DTX alignment are not taken out of service for prolonged time periods. The construction of the cut and cover tunnel sections on Townsend Street, Second Street and Main Street must be carefully planned to minimise surface disruption.

In general where DTX construction occurs within street right-of-way, the excavation will be decked over. Limited outages of entranceways for periods of a few hours only would be negotiated and coordinated between the construction contractor and affected businesses or residences.

Construction processes that could impact surface traffic and the proposed mitigation in each case are indicated below.

- Utility relocations – limited utility relocation will be undertaken in advance of the main cut and cover tunnel construction
- Installation of support of excavation walls - from the surface using daytime closures
- Installation of street decking – which comprises interlocking precast concrete panels, supported on structural steel beams spanning between the support of excavation walls

Once the traffic decking is installed, surface operations would continue normally with excavation and construction of the tunnel sections conducted largely out of the public view. With excavation depths of up to 22m and widths up to 55m, with high ground water and adjacent high-rise buildings, the cut and cover tunnels are complex and represent a significant construction challenge.

Project status and implementation

The DTX Project is part way through preliminary engineering Phase 1, which comprises evaluation of alternatives and engineering design development to a conceptual level. The goals of this project phase are to define the configuration of DTX in terms of number of rail tracks, to ascertain structure type and limits, and to refine the project cost estimates prepared to date through concept development and via a system of Value Management initiatives. It is expected that the preliminary engineering Phase 1 will be concluded in late 2007.

While the design studies and conceptual engineering continue, the project owner, TJPA, will be identifying and securing the funding necessary to construct DTX.

Once the funding plan is finalised, currently scheduled for 2008, the project will proceed to preliminary engineering and final design. Project construction is anticipated to commence in 2012 for advance contract work, with bids for the primary tunnel contracts following in 2013. T&T

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