

# Continuous Conveyor Design in EPB TBM Applications

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**ABSTRACT:** While continuous conveyors have become the muck removal system of choice in long, hard rock TBM tunnels, they have gained acceptance in soft ground tunnels only recently. Soft ground, EPB TBM-driven tunnels provide a challenging environment for continuous conveyors due to the variety of materials present. The design of both horizontal and vertical soft ground conveyors will vary depending on the types of excavated material, amount of water present, and other factors. This paper will address the challenges of effective conveyance in different ground materials by analyzing conveyor performance in several recent EPB TBM projects.

## INTRODUCTION

Continuous conveyor systems were first utilized regularly in mining applications, and have since been adopted as one of the primary means of muck removal on hard rock tunneling projects. In recent years, conveyor system design has advanced considerably, from computerized monitoring systems to self-adjusting curve idlers to km long steel cable belt systems. Continuous conveyors for soft ground TBM projects are a fairly recent edition in the tunneling industry, with considerable advantages over muck cars including increased safety and efficiency.

### CASE STUDY #1: LOWER NORTHWEST INTERCEPTOR SEWER, SACRAMENTO, CA

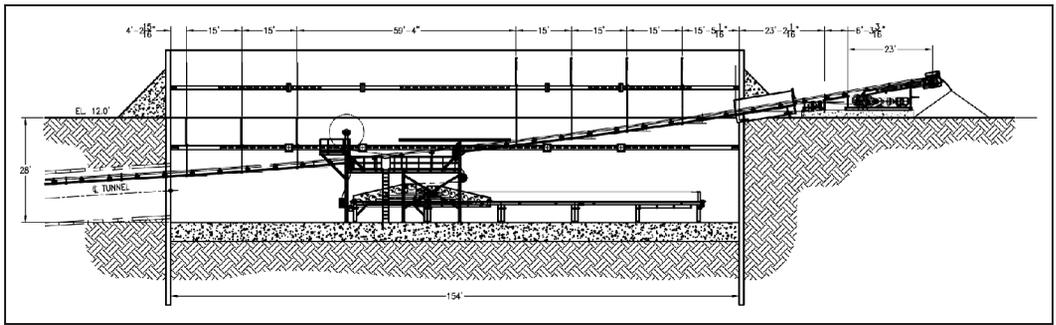
One of the first EPB TBM projects to utilize continuous conveyor design was the Lower Northwest Interceptor Sewer (LNWI) Tunnels, excavated by Affholder, Inc. in 2005. The project is part of the Sacramento County Regional Sanitation District's (SRCSD) interceptor expansion project, which will ultimately extend approximately 320 km (200 mi) and provide service throughout the region (Togan et al, 2007).

Two 610 m (2000 ft) long river crossings were tunneled by a 4.59 m (15.1 ft) EPB TBM at steep grades through stiff clay, silt and sand. The first tunnel was excavated a 6% downgrade below the river, while the following section was completed at a 6% upgrade from below the riverbed, making

muck removal via muck car a difficult proposition. Affholder settled on a continuous conveyor design (see Figure 1).

During machine operation, an extensible fabric-belt conveyor (30" BW) was constructed behind the TBM and back-up system at the tailpiece and back-up car assembly at the last deck. The muck was discharged from the screw conveyor into the loading hopper of the tailpiece at the front of the tailpiece back-up car, which elevated the conveyor into the crown of the tunnel. The belt structure was assembled in the tailpiece assembly, which was mounted on top of a tailpiece back-up car. The assembled belt structure then came out of the rear of the tailpiece as the TBM advanced forward. The extensible conveyor was equipped with a 500ft capacity belt cassette with a 100 HP hydraulic power unit and a splicing stand to allow conveyor belting to be added to the system in the open cut. The conveyor system was powered by a 250HP Main Drive, which brought the muck out of the tunnel and through the open cut and discharged it into the muck pit. The conveyor was designed for 2,150 ft and for 2,175 ft lengths at 685 USTPH while running at 600 FPM.

The continuous conveyor equipment was used on the first crossing, then removed and set up for the second tunnel section as well. Both sections of tunnel were mined within a one year time frame. Downtime for the duration of the project was minimal, with no conveyor problems and all downtime occurring due to TBM or segment issues (see Table 1).



**Figure 1. LNWI conveyor system setup**

**Table 1. LNWI conveyor system specifications**

Conveyor Length (south crossing)	2,150 ft
Conveyor Length (north crossing)	2,175 ft
Conveyor Capacity	685 USTPH
Belt Width	30 in
Belt Speed	600 FPM
Main Drive	250 HP
Cassette Capacity	500 ft
Cassette Power Pack	100 HP

## DESIGN CONSIDERATIONS FOR SOFT GROUND CONVEYOR SYSTEMS

### Minimization of Start-Up Time and Maximization of Efficiency

The layout of conveyor systems is designed with swift setup in mind. Unlike many hard rock projects, EPB tunnels are relatively shallow and begin from an open cut. The use of a conveyor system set up at the surface can allow for initial use of the system at startup without having to mine a long starter tunnel.

With all components pre-assembled in place at the surface, switching from an initial muck box setup to continuous conveyor often takes a day or less. Crews simply pull the belt onto the system to start mining. By comparison, installation of a rail muck car system can take much longer. Once mining begins, reliability and system availability of a conveyor system are typically much greater. Even in tunnels using up to five muck trains and multiple California switches, the time required to remove muck from the tunnel cannot compare to conveyor muck removal. In addition, muck cars generally require a much higher level of routine maintenance.

### Variable Ground and the Role of Additives

Variable ground is very often a given in soft ground tunnels. One project can range from weathered rock to sand to clays with changing permeability and ground water. Injection of additives through the cutterhead, such as bentonite, foam, or polymer, can aid in consolidation of muck and eliminate many of the problems associated with conveying fluidized muck. Maintenance of a smooth flow through the cutterhead and screw conveyor onto the belt conveyor system minimizes belt stoppage and material spillage. Additives also have the ability to control the fluidity of very wet ground and help solidify loose, watery material.

Depending on the ground conditions, different additives are used to maximize efficacy. The type of additive used is based on a standardized curve comparing particle size and distribution based on filtering samples of material through differently sized screens. Ground with less than 30% fines, or particles less than 0.2 mm in diameter, is difficult to fluidize. In this type of non-cohesive ground, bentonite is used for consolidation. For other types of ground with fewer fines, foam consisting of water, surfactant, and additive is used. If water pressure is high and small particles are present, a polymer can be injected in addition to the foam to increase cohesiveness of the material (see Figure 2).

### Water-bearing Ground and Resulting Design Modifications

If a high amount of water-bearing ground is expected, continuous conveyor systems can be designed to minimize associated risks. Incline is kept relatively low for EPB conveyors—a maximum of about 10 degrees, compared to 18 degrees in hard rock tunnels. materials in EPB applications when the material is very fluid, keep the incline to a minimum. In addition, transfer points are entirely enclosed to keep material from spilling out. The enclosed points

are equipped with additional belt skirting, a urethane material that seals the edges.

### Conveyor Cleaning

Further design modifications minimize the wear of conveyor belt and prevent stoppage due to sticky material. Primary and secondary bore scrapers clean off very heavy material, while a belt wash box installed on the surface near the main drive effectively removes fine material from the conveyor before it cycles through the belt storage cassette. The wash box consists of water spray in combination with 'air knives'—pressurized jets of air that remove material from the belt without direct contact. The use of air knives eliminates the need for consumable components that come in direct contact with the belt and must be replaced.

### CASE STUDY #2: UPPER NORTHWEST INTERCEPTOR SEWER, SECTIONS 1 & 2, SACRAMENTO, CA

Northern Sacramento's Upper Northwest Interceptor Sewer (UNWI) Project is unique in several respects—the 5.8 km long EPB TBM driven tunnel is fairly long for soft ground projects, passing through a number of manholes, and the tunnel liner includes pre-cast concrete segments with an imbedded PVC inner liner never before used in North America. The contractor, the Traylor/Shea JV opted for a continuous conveyor system rather than muck cars, because of the tunnel length and the increase in efficiency possible when compared to muck cars.

The new UNWI system will convey up to 560 million liters of wastewater per day from various areas of Sacramento. The entire project, for the Sacramento Regional County Sanitation District (SRCSD), includes nine sections totaling over 30 km. Tunneling is on schedule for completion in

early 2010, and the pipeline is planned to begin operation that November.

The 5.8 km long conveyor system was specially designed for varying ground conditions and water inflows. Design features include sealed transfer points and receiving hoppers. Urethane rubber is used to seal the points and minimize spillage. Additives mixed with the wet ground, such as foam and bentonite, maintain a smooth consistency of muck that will flow on the conveyor even when significant ground water is present. Cutterhead design aids in injection of the additives, using four independent foam injection points that mitigate the risk of clogged lines. Each line continues operation if one is down, keeping cutterhead wear and ground consolidation even at the tunnel face and ensuring a smooth flow of muck (see Figure 3).

During TBM operation, an extensible fabric-belt conveyor (24" belt width) is constructed behind the TBM and over the top of the back-up system in



Figure 2. Conveyor system with consolidated muck and additive: UNWI Project, Sacramento, CA

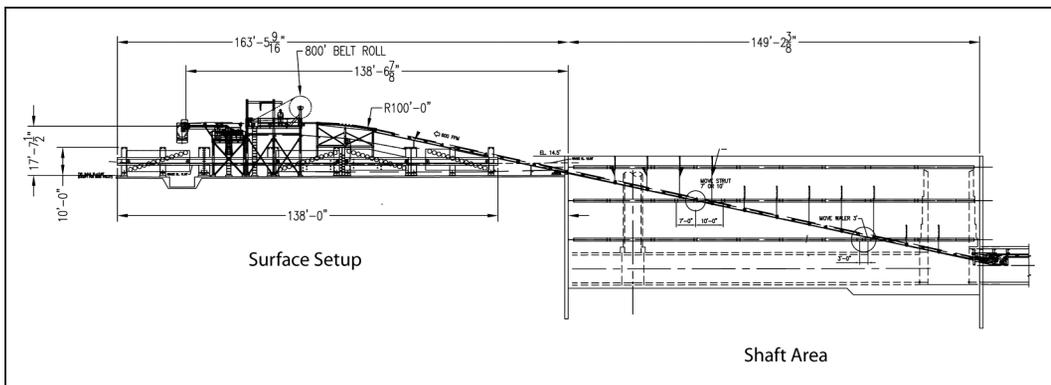


Figure 3. UNWI conveyor system setup

**Table 2. UNWI conveyor system specifications**

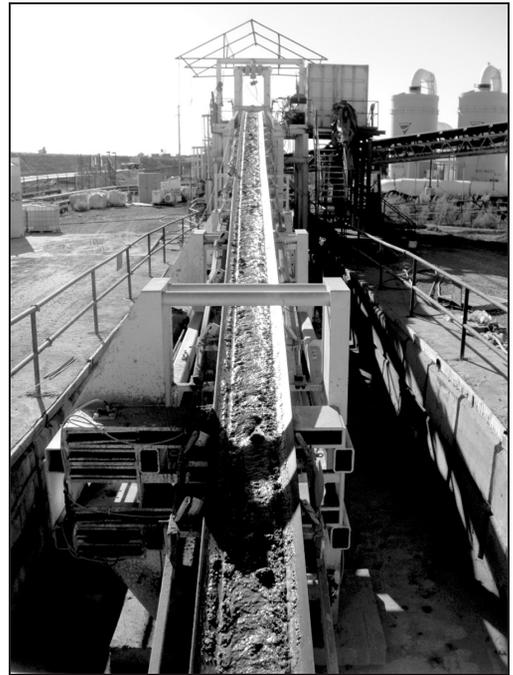
Conveyor Length	19,498 ft
Length of Straight Conveyor	17,260 ft
Length of Curved Conveyor	2,238 ft
Curve Radius	1,200 ft
Conveyor Capacity	250 USTPH
Belt Width	24 in
Belt Speed	600 FPM
Main Drive	200 HP
Carrying Booster Drive (×2)	200 HP
Belt Cassette Capacity	1,150 ft
Cassette Hydraulic Power Unit	150 HP

the crown of the tunnel. The muck is discharged from the screw conveyor onto the conveyor at the front of the back-up system. From there, the conveyor system is elevated over top of the back-up system and into the crown of the tunnel. The belt structure is assembled in the installation window assembly which is mounted on top of a back-up deck, while the assembled belt structure comes out of the installation window as the TBM advances forward. A tripper assembly is located at the open cut in the tunnel and redirects the conveyor up thru the open cut at a 12 degree incline. The extensible conveyor is equipped with a 1,150ft capacity belt cassette with a 150HP hydraulic power unit and a splicing stand, which allows conveyor belting to be added to the system. The conveyor system is powered by a 200HP Main Drive, which discharges onto the stacking conveyor. Two 200HP carrying booster drives are added into the system as the conveyor advances, and are mounted in the crown of the tunnel by using an integrated drive support frame. The frame is designed with adjustable length legs that mount to the tunnel wall at designated distances in the tunnel. The conveyor is designed for a total length of 19,498 ft at 250 USTPH while running the conveyor at 600 FPM.

As the conveyor travels through radii down to 400 m, patented self-adjusting curve idlers transfer the load and enable the system to run through curves. Tunnel muck is discharged from the conveyor into a muck holding bin at the surface adjacent to the launching shaft (see Table 2).

**Conveyor System Performance**

As of November 2009, the conveyor system had performed at high availability and enabled very good advance rates. The best mining day (24 hours in three 8-hour shifts) was 160 linear feet, which occurred multiple times. The best week (five 24-hour days)



**Figure 4. Surface setup conveying muck**

was 690 feet, also occurring multiple times (see Figure 4).

**SUMMARY**

Continuous conveyor systems offer a distinct advantage over muck cars in soft ground conditions. Despite variable geology and ground water, the use of additives can effectively consolidate muck flow and prevent spillage on conveyor belts. Further modifications including water tight transfer points have mitigated the risk of muck loss in all but the most water-logged conditions. Though many equipment suppliers and contractors only recognize a difference in system availability between conveyors and muck cars over a 6,000 ft tunnel length, the advantages are being seen at shorter tunnel lengths as well. Increased safety, reliability and short start-up times are making soft ground conveyor systems a competitive option that may well replace muck car systems in the coming years.

**REFERENCES**

Togan, et al. (2007). Construction of the Sacramento River Tunnels on the Lower Northwest Interceptor Sewer, Sacramento, California. Proceedings of the Rapid Excavation and Tunneling Conference, San Francisco, CA. 741-756.