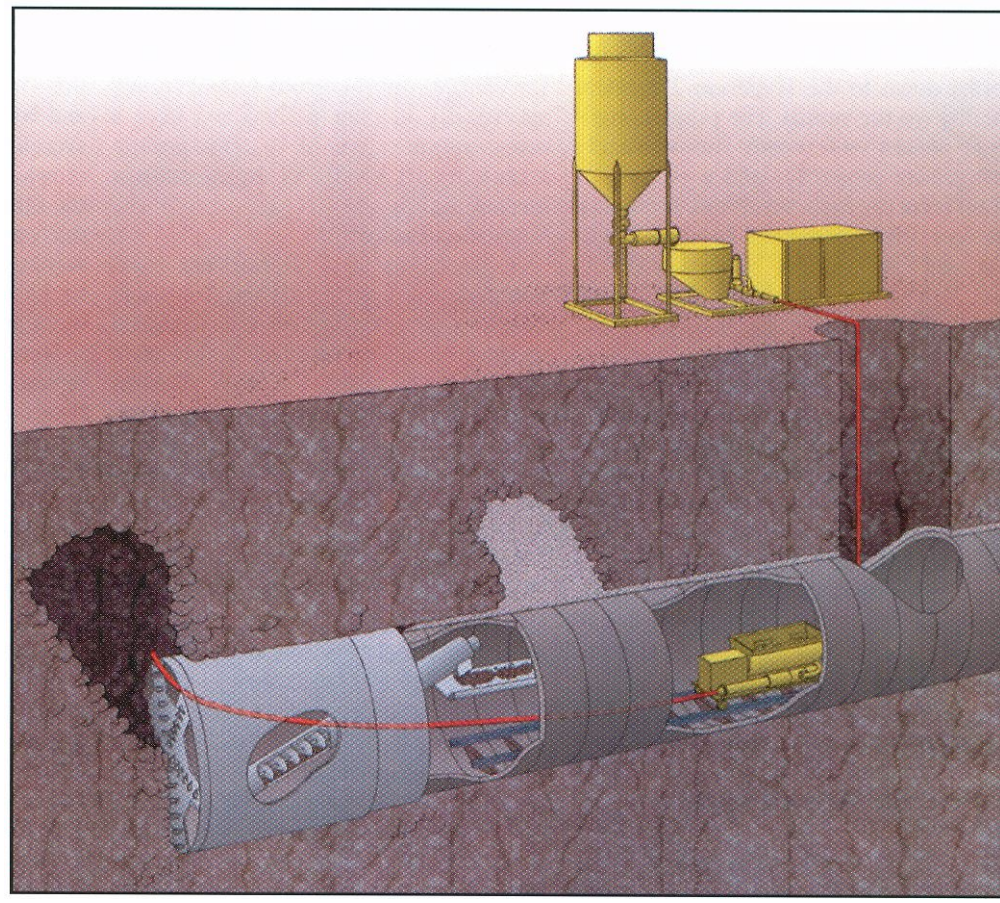
# *Pacific Grout Rescues TBM and Backfills Tunnels*

*by Pat Stephens*

**Low density cellular concrete has proven its use as** a backfill, stabilization and support for all types **of structures-tunnels,** casings pipes, abandoned pipes **and underground spaces, and** the filling of voids. Pacific In**ternational Grout Co., based in Bellingham, \Vash., has success·** fully applied the product in **complex operations which sal**vaged TBM operations as well as backfilled more than eight **miles of tunnel.**

### *TBM Rescue*

After many difficult experiences, such as the deep Trans-**Missouri River Tunnel, which** was 330 ft deep and 15,000 ft long, with only one workshaft at **each end, Pacific International** Grout was asked to help solve a problem in Portland, Ore. Twin, three-mile-long by 21-ft diame**ter tunnels \vere under construc**tion for the Tri-County Metro**politan Transportation District** of Oregon (Tri-rvlet).



**This drawing illustrates the process of filling voids and ground stabilization used to rescue TBI\:I operations.**

**After advancing the starter tunnel 196 If. to what seemed to** be "good rock," the TBM was **assembled to start mining. After advanc**ing only 150 ft in approximately two and **one-half months, mining operations \vere halted. The trouble \vith mining \vas the quality and configuration of the rock.** The rock would not stand up long enough **which prevented the cutterhead from** cutting a ftlil face. The highly fractured **basalt rock. \vith mud seams between each. \vould ravel ullcontrollably in front of and above the cutterhead. creating voids lip to 50 CII yd in size.**

**A variety of mining techniques and TBM modifications were made. A final** attempt and test to solve the problem was scheduled for December 1995. During **the test, Pacific International Grout ex**perimented and developed a process of squirting quick-set, low-strength gel through the cutterhead.

**Grout** Solution

The process was quite simple. When the TBM had created a void or had lost ground, the TBM was shut down. Miners **then prepared to grout. Access was made to the cutterhead via the conveyor.** Buckets and doors on the cutterhead were sealed with foam, rags, etc., to prevent leakage.

Smaller openings did not present a **problem, as the grout can be adjusted to set in seconds or minutes.**

Multiple lances were inserted into the void through the cutterhead for injection. Grout was injected at this point until **voids were filled. An increase in pump discharge pressure was the indication that** the void was full.

**The pumping and injection gear was removed and cleaned. The duration from** start to stop was approximately four **hours, and the TBM \vas running again. It** should be noted that in addition to the **mining crew, three men additionally were required.**

**Among the many critical aspects of using portland cement-based materials to control ground around and in front of the** cutterhead was rhe quality control of the **process. Grout \vas designed to set quick**ly and obtain enough strength to hold the **machine. In addition, strength was a key concern regarding grip and rock face** support. Finally, it was imperative that

the grout would not adhere to the shield or foul cutters. This proprietary system accomplished these functions successfully.

### *Tunnel Backfill*

Pacific International Grout accepted the enormous task of backfilling the 47,000-ft long North Outfall Replacement Sewer (NORSj tunnel in Los Angeles in 1990.

NORS is located in the Culver City/Los i\ngeles area and extends over eight miles from Baldwin Hills (to the north) down to the Hyperion Treatment Facility (to the south). The project alignment passes underneath approximately 180 private properties and a number of significant surface structures including the San Diego Freeway, Imperial Highway, and Los Angeles International Airport (LAX). At the airport, the tunnel length extends over 14,000 ft and the alignment passes underneath three runways at an average depth of about 60 ft.

The project includes a main trnnkli.l1e more than 42,000 ft long, a diversion system totaling more than 5000 ft, and 18 manhole structures extending to depths between 19 and 100 ft below the ground surface. The main line is the third in a series of pipes conveying sewage to the Hyperion Treatment Plant. The diversion system includes five separate lines completing connections to the main outfall sewers adjacent to NORS. The diversion system provides a means to direct flows from incoming tributary sewers into or away from the three main lines.

### Alignment

The NORS alignment is located in the northern part of a physiographic basin known as the Los Angeles Basin. The alignment extends across the Ballona Gap, the Baldwin Hills, and the El Segundo Sandhills. The geologic evolution of this area has been influenced by several tectonic disturbances, sea-level changes, and the advance and recession of glacial ice sheets. The geologic history has created a complex stratigraphy of marine and continental sediments.

GrOlmdwater levels along the majority of the NORS are below the pipe invert excluding the Baldwin Hills area at the north end ofthe alignment. Ground\vater levels also exist along the horizon of the carrier pipe below the San Diego Freeway in a siphon section.

Boundary conditions created a Ilwnber of challenges for the placement of the cellular concrete. The limited number of shafts and access points along the alignment required pumping distances as much as 10,800 ft and 2-hr. delayed settimes on the grout.

Other challenges included the siphon section below the San Diego Freeway where four 20-in. PVC pipes were positioned in the crown at the annular space for ventilation. the grout was designed specifically to remain fluid and have a designed unit weight of 40 pcfto prohibit crushing the 20-in. PVC by injection or buoyant uplift.

### Grouting Procedure

A proprietary backfill concrete injection plant was constructed and shipped to Los Angeles. The system was designed so that the slurry was fed to this plant from the surface, via 4-in. steel slickline and high pressure pumps. At the plant, the slurry was remixed, foamed and then pumped into the annular space behind the carrier pipe at rates averaging 105 cu yd per hour.

Diversion 4, a 2900-lflateral of96-in. diameter PCCP was selected for an initial test section. Before production grouting took place, the diversion alignment was separated into three zones, with the placement of two bulkheads. Two of the zones were 150 ft in length and the third was 300 ft long. The first two zones were backfilled in two lifts and the third section was backfilled monolithically. Core samples of the cellular concrete taken behind the carrier pipe indicated that the properties of the cellular concrete did not vary significantly bet\veen modes of backfilling.

Based on the results of a number of quality control tests, it was decided that the carrier pipes could be backfilled in monolithic pours. Furthermore, the contractor could lay PCCP on a continuous operation without the need for intermediate bulkheads. Backfill concrete was placed right behind the pipe laying, so as not to interfere with production.

### Slurry Supply

Once production started, the system required a continuous supply of slurry. Cement slurry was batched and pumped through a temmie nlbe into the re-mixer, which in nun fed the slurry pump in the shaft. The slurry pump in turn fed the portable plant in the ttmnel through the steel slickline.

Grout placement inside the tunnel \vas a bit more complicated. Because of the rapid rate of grout being placed, a "progressive manifold system" had to be designed. The foamed concrete was pumped from the hopper car through a system of 4-in. hose. For a IOOO-ftsection of carrier pipe a network of valves and laterals was set up on 250-ft centers attached to grout ports in the tunnel crown. As the tlUmel sections were filled, the laterals \vere closed and hoses \vere moved 250 ft and reconnected. In this manner, a 1000-ft section of tUlUlel could be backfilled in one day using a minimum amOlU1tof hose and labor.

Quality control was maintained both topside at the slurry plant and inside the tunnel at the point of injection. Unit weight was checked and adjusted on the hour. Adjusting the density of the foamed grout inside the tUIU1el\"'as a function of simply turning a valve for adjustments of as little as ~'pef.

Progress of placing backfill concrete on the NORS project provided the contractor with cost savings while furnishing a high quality product. During backfill operations, a crew of three miners were able to continuously place 105 cu yd per hour. The maximum volume placed in Olle day was approximately 1200 cu yd. The longest tunnel section grouted in a single day was approximately 1200 ft and the maximum distance pumped was more than 10,000 ft. The NORS Tunnel was completed one year ahead of schedule.

*Pat Stephens is president o/Pacific International Grow Co., Be/ling/WI}], Wash. Joseph Gildner co-aurhored the section on the .'IOIIS Project alld is aPE. specializing in underground consfl'l.lcfi01l. He current(v serves as project engineer for the Tri-Cou/l.~V Transportation District 0/ Oregon.*