# MATERIALS HANDLING

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## STATE OF THE ART

Choice of a materials-handling method to be used on a particular tunnel project depends on type of access, size and slope of the tunnel, and material to be excavated. Access during the tunneling operation can be either horizontal through a portal or vertical through a shaft. Transportation tunnels are seldom smaller than 5.2 m (17 ft) in diameter, so large materials-handling units are usually used, although small units are commonly used in soft ground tunnels driven by use of shields. Grades vary from level to 5 percent. Transportation tunnels built under major cities are often in soil, but many tunnels in rural areas penetrate the rock cores of mountain ranges.

Tunnel construction does not exclude any materials-handling techniques commonly used in the construction industry. Prime considerations in the choice of a materials-handling system are economy, reliability, extensibility, and redundancy. Redundancy as used here refers to use of reserve or back-up units to prevent production delays due to breakdowns.

There are five general systems for removing excavated materials from tunnels: Rubber-tired trucks (both self-loading and separately loaded), rail mounted equipment, and conveyors are used for horizontal transport, and hoisting is used for vertical transport.

Self-loaded rubber-tired trucks, commonly known as load-haul-dump units, carry 3.1 to 7.6 $m^3$ (4 to 10 $yd^3$) of material at 6.4 to 16.1 km/h (4 to 10 mph). Separately loaded trucks carry 4.6 to 15.3 $m^3$ (6 to 20 $yd^3$) at 8.0 to 24.1 km/h (5 to 15 mph). Haul speed in both cases is governed by the smoothness of the roadbed. Neither type is limited by grades normally encountered in transportation tunnels. The separately loaded units are usually top loaded and have front-end loaders of 1.5 to 3.8-$m^3$ (2 to 5-$yd^3$) capacity that run on rubber tires or crawler tracks.

In order to pass, the larger units require a width of about 9 m (30 ft). Thus, widened areas must be excavated in single-lane tunnels. Rubber-tired units are seldom used in tunnels with circular inverts because of the extensive overexcavation required for passing. Economics usually limit the use of rubber-tired haulage to tunnels less than 1219 m (4000 ft) long.

Rail haulage is almost always used in long tunnels and in tunnels with circular inverts. Locomotives of 4.5 to 22.7 Mg (5 to 25 tons) haul 1.5 to 11.5-$m^3$ (2 to 15-$yd^3$) muck cars on 27.2 to 36.3-kg (60 to 80-lb) rails laid on 6096 to 10 668-mm (24 to 42-in) gauge at speeds of 8.0 to 24.1 km/h (5 to 15 mph). Haul speed is greatly dependent on the quality of the track. Grade is limited to less than 3 percent with short stretches of 4 percent. Rubber and rail haulage systems both require redundant loading and hauling units.

Reliability is usually lowered when a conveyor is a component of the loading unit. Conveyors are components of many muck-removal systems: overshot loaders, tunnel boring machines, and muck car-loading equipment behind the boring machines. Conveyors are seldom used as the only muck-removal method in tunnels. The high capital investment required and the difficulty of extending the system as the tunnel advances limit the applicability of conveyors.

Hoisting with wire rope is the method most often used for vertical transportation. With vertical hoisting, the material must either be transferred from its horizontal haulage units into skips; or the haulage units themselves can be hoisted. Surge capacity may be provided by dumping into a pocket that in turn dumps into the skip. With rail haulage, the muck car boxes sometimes are hoisted, either with or without the undercarriage and wheels. Shaft size limitations usually require that only one skip or car be hoisted at a time. Lifting capacity usually varies from 3.1 to 11.5 $m^3$ (4 to 15 $yd^3$). Most safety codes permit hoisting with a crane from depths of 21.3 to 30.5 m (70 to 100 ft), but require fixed guides for deeper shafts. Falling materials make shaft work hazardous.

In addition to the removal of excavated material, workers and many other materials must be transported in the tunnel. Large groups of workers are commonly transported in trucks or rail cars fitted with seats and a protective canopy. Small groups use pickup trucks or ride the locomotive. Materials that must be transported include tunnel supports, utility pipes, track supplies, tools, electrical cable, drilling and blasting materials, concrete, and formwork. These are commonly hauled on flatbed trucks or rail cars except fluid concrete, which is either hauled in special vehicles or conveyed through a system of pipes.

**Conway mucker in tunnel (photo courtesy of Goodman Equipment Corporation).**

## FUTURE RESEARCH

### Shaft Transportation

Access to transportation tunnels in urban areas is usually through shafts, which have been materials-handling bottlenecks for years. A continuous method of muck removal up shafts is especially needed. If the shaft occupies a small area, workers and materials can be transported by conventional means. Transfer from the horizontal haulage system and surge storage must be considered.

### Rail Haulage

On tunnel jobs today, rail is the most economical means of transporting large volumes of material over an extensible system. Rail and haulage consumes one-eighth the energy and perhaps one-quarter the manpower that is used for rubber-tired haulage. Although properly designed and maintained rail-haulage systems can keep pace with present excavation rates, higher speeds and greater reliability will be needed in the future.

### Mucking

Muck loading in conventionally drilled and blasted tunnels consumes an inordinate proportion of the excavation cycle. Equipment reliability and redundance are often low.

### Metallurgy

High wear rates on loading points, wheels, tracks, and bearings contribute to low reliability in all systems. Tunneling technology constantly pushes metals to the limits of shock and abrasion resistance.

### Conveyors

Because conveyors provide zero redundance in many materials-handling systems, their reliability is extremely critical. Conveyor downtime delays tunnel advance. Excavation would be greatly improved if conveyors were more reliable, were more readily extensible, and could carry muck up the shafts.

### Pipelines

Pneumatic and slurry pipelines are excellent means to convey fine materials. Pipelines to handle tunnel muck deserve research, especially in the direction of ease in extensibility.