

# Shotcrete in China's Longest Tunneling Project

By Kelly Blickle

In the Guanjiao Mountains of western China, at an average altitude of 11,483 ft (3500 m), two parallel railway tunnels 21 miles (33 km) long are being constructed. This is the longest tunneling project ever undertaken in China, and the world's longest high-altitude railway tunnel.

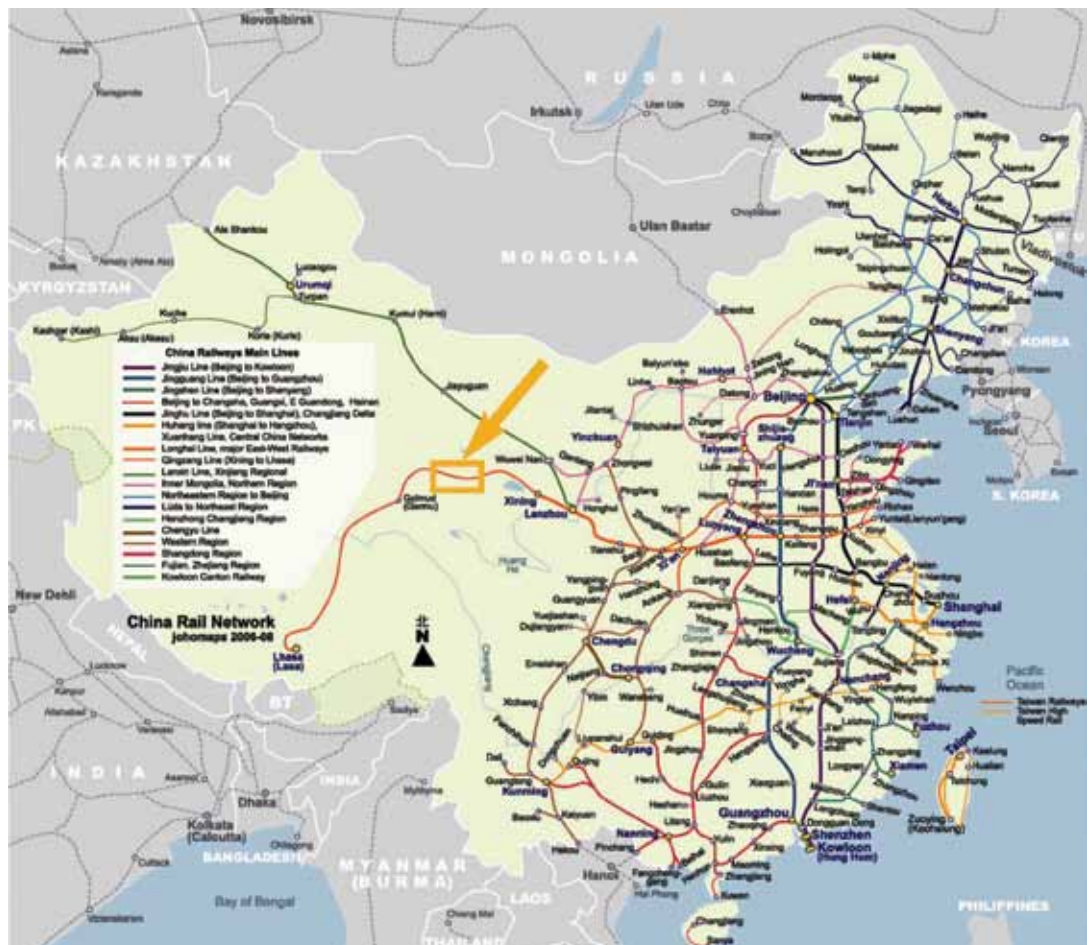
The tunnels form part of a 506 mile (814 km) long transportation route inaugurated in 1984 connecting Xining, the capital of the Qinghai Province, and the city of Golmud, situated further west. Between 2000 and 2005, the railway line was extended by 709 miles (1142 km) from Golmud to Lhasa, capital of the Tibet Autonomous Region (Tibet Railway).

## Faster to Tibet

The new tunnel structure will replace the older, 2.5 mile (4 km) long Guanjiao Tunnel

situated 984 ft (300 m) higher, which is only accessible via very windy access tracks. Thanks to the perfectly straight route through the mountain situated at a lower altitude, journey times will be shortened considerably, and fuel savings will be significant. The sections of the new Guanjiao Tunnel have been designed for train speeds of up to 99 mph (160 km/h).

The two single-track tunnels, which are 131 ft (40 m) apart, are driven up from all four entrances to create an excavated cross section of approximately 967 ft<sup>2</sup> (90 m<sup>2</sup>). Progress is made both with the use of tunnel-boring machines and the New Austrian Tunnel Method (NATM), which integrates behavior of the geology under load and the monitoring of the performance of support during excavation and construction. There are a total of 11 inclined shafts with a length of



Survey of the main Chinese rail lines

9.5 miles (15.26 km) and one auxiliary pilot tunnel of 6 miles (9.8 km) in length parallel to the main tunnel. As part of tunneling operations once excavated and with walls strengthened by shotcrete, the side wall and base are built by moving a few yards at a time.

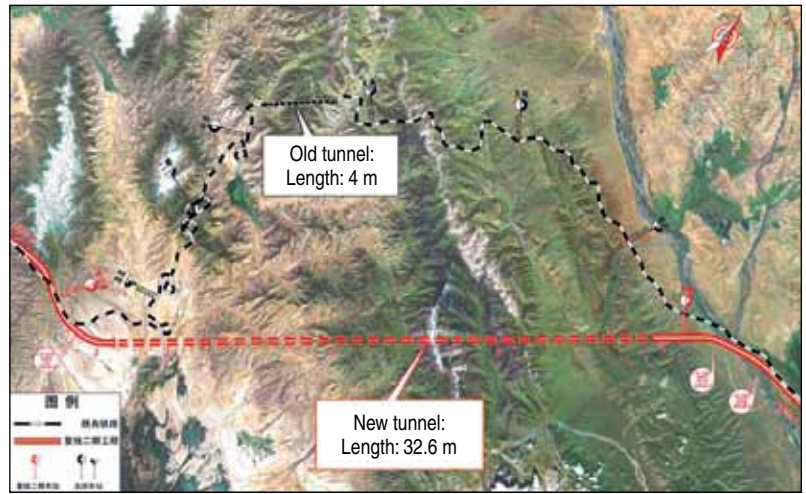
The biggest difficulty of the tunneling project at this altitude is dealing with groundwater and controlling the deformation of the rock section of the carboniferous slate. The construction costs for the new Guanjiao Tunnel come to \$376 million U.S. or 2.5 billion Renminbi in Chinese currency. Up to now, about one-half of the tunneling job has been finished—12 miles (19.5 km) at the entry side and 9 miles (15 km) at the exit side.

## Shotcrete Equipment and Strategy

There are currently two complete PM 500 PC concrete spraying systems reinforcing the excavation at the entry side of the Guanjiao Tunnel for the China Railway 16 Bureau Group. These units are comprised of the dosing pump, spray arm, concrete pump, and air compressor, all mounted on one carrier. Mobilization after each excavation is integral to this project. Each of the concrete spraying system's four-wheel-drive and four-wheel-steer carriers allows them to quickly and easily move around the job site.

With 56 ft (17 m) vertical and 49 ft (15 m) horizontal reaches, the spray arms allow precise and smooth movement for accurate placement of the shotcrete without the need to move the unit once it is set up. The combination of the spray arm with the high-precision spray head allows the operator to accurately apply the shotcrete. Operating the boom by remote control allows increased maneuverability around the unit, which enables a safe viewing of the entire application area.

The supply of air from the onboard air compressor provides the high velocity needed to spray the concrete and to provide the compaction,



*This map illustrates the windy course of the old 984 ft (300 m) high running track and the position of the two new single-track tunnels, which are considerably longer (Note: 1 m = 3.28 ft)*

Illustration courtesy of China Railway 16 Bureau Group



*Transport of the shotcrete unit crossing a pass situated at an altitude of about 11,843 ft (3500 m)*

bond, and strength benefits of shotcrete. The concrete pump and additive dosing pump are controlled by an onboard computer regulating the synchronization of the air, concrete, and additive. With these three components being accurately

<b>Concrete Spraying System Technical Data</b>	
Working height of the SA 14 telescopic spraying arm	13 to 56 ft (4 to 17 m)
Delivery rate of the double-piston shotcrete pump	Maximum 39 yd <sup>3</sup> /h (30 m <sup>3</sup> /h)
Volume of the additive tank	0.26 + 264 gal. (1 + 1000 L)
Delivery rate of the additive metering unit	8 to 185 gal./min (30 to 700 L/min)
Compressor output	14 yd <sup>3</sup> /min (11 m <sup>3</sup> /min)
Volume of the water tank	52 gal. (195 L)
Concrete pipeline	3 in. (80 mm)
Nozzle	2 in. (50 mm)
Power cable	164 ft (50 m), 328 ft (100 m) optional
Pump and boom operation	Cable remote control (radio remote control optional)
Drive output of the carrier vehicle, among other things, with four-wheel-steering, all-wheel drive, rotating cab	101 hp (75 kW)



delivered, high-quality shotcrete and spraying output are ensured in the project.

## Low Temperatures and Lack of Oxygen Take Their Toll

At temperatures as low as  $-33^{\circ}\text{F}$  ( $-36^{\circ}\text{C}$ ) and atmospheric pressure reduced by one-third, the tunneling operations at an altitude of 11,089 ft



*This operator familiarizes himself with the remote control of the modern concrete-spraying system*



*Job-site crew just before starting up the shotcrete unit*

(3380 m) put a strain on workers and machine operators. Typical symptoms experienced by site staff include shortness of breath, exhaustion, headaches, and nausea. In case of emergency, there is oxygen equipment available at the construction site.

The compressor output of the shotcrete unit at this altitude is still at 100% (the result of air volume  $\times$  pressure remains constant), and the low static pressure has an effect on the suction in the shotcrete pump, at least in theory. At a maximum delivery rate of 39 yd<sup>3</sup>/h (30 m<sup>3</sup>/h), however, this loss in output cannot be detected in practice.

Of course, the low temperatures are a problem (the annual average is below  $32^{\circ}\text{F}$  [ $0^{\circ}\text{C}$ ], especially during the winter months. This also results in the formation of ice in the tunnels, which means that the aggregates, additives, and water must be stored in a way to prevent freezing.

## Project Completion

With a planned construction time of 5 years, completion is scheduled for 2012.



*The side wall and base construction follow once the tunnel is excavated*



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