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A variety of precast concrete products play a crucial role in the construction of Europe's largest infrastructure project.

By Shari Held

Photo courtesy of Crossrail Ltd.

Rows of precast concrete segments await transport at Chatham Dockyard.

As the largest infrastructure project in Europe, Crossrail is an endeavor that's decades in the making. During its construction, Londoners go about their day-to-day business unfazed. But 130 feet below the 2,000-year-old city, a cast of thousands quietly works to complete the world-changing project.

In all, Crossrail consists of 26 miles of new tunnels for the Crossrail/Elizabeth line. Once fully operational in 2019, the new line will connect commuters to the London Underground and National Rail, allowing them to leave their cars at home and travel all the way across London and beyond. Reduced motor traffic will greatly benefit London motorists, who spend 12 working days per year sitting in gridlocked traffic.[1]

Forty railway stations – 10 of them new – are included in this gargantuan, $19.6 billion project. And precast concrete plays a key role in the construction of the project's numerous tunnels, platforms and stations.

In many ways, Crossrail is a project of numbers. It employs 10,000 workers located at 40 sites throughout London. Each tunnel-boring machine weighs 1,000 tons. And during the tunneling phase, those TBMs moved 7.5 million tons of earth to make way for the 15-billion-ton railway. But Linda Miller, project manager for the Connaught Tunnel and Farringdon Station, thinks one particular statistic stands out from the rest.

"My favorite number is that it's going to create 200 million more passenger journeys per year," she said. "That's gobsmacking!"

SETTING THE STAGE

Crossrail Limited, the company established to build the new railway line, went to great lengths to ensure the project's success. Early on, Crossrail Ltd. gathered experts from throughout the world and pioneered innovative technologies to tackle potential issues.

The biggest obstacle to project approval was the fear that tunneling would damage London's existing structures and infrastructure. To mitigate potential damage, Crossrail Ltd. positioned thousands of movement-detecting prisms on buildings throughout London. The prisms relayed terabytes of information that Crossrail Ltd.'s state-of-the-art data center analyzed. The data was then provided daily to project managers.

"We knew if the ground or a building was moving within 1 to 3 millimeters," Miller said.

Crossrail Ltd. took proactive measures to ensure it could correct those situations on the fly. Workers assembled 25 composition-grouting shafts measuring 16 or 20 feet in diameter and 65 feet deep next to the route before tunneling began. If an area showed signs of settling, they pumped grout into the shaft to gently lift the ground. The strategy paid off.

"We didn't tip any buildings," Miller said. "We didn't create any exploding utilities. We didn't – even by a millimeter – affect the running of the current London underground tube systems."

LINING THE TUNNELS

Eight TBMs and 210,000 precast segments were required to line the 26 miles of tunnels necessary for the project. Seven segments, each weighing approximately 6,600 pounds, and one keystone weighing about 2,200 pounds make up one tunnel ring. Typically, the segments were reinforced with steel fiber. Steel rebar was used for sections located under bridge abutments and floating slab track.

"With precast, you get a much higher quality of product," said Andrew Thomas, Crossrail Ltd. quality engineer. "You control it a lot better by manufacturing off site. I don't think anything else would have been as successful as precast."

To meet the demand for such large quantities of precast, Crossrail Ltd. created three factories that operated around the clock.

"We needed to make sure that all the mixes that were designed were robust enough and durable enough to last 120 years in quite a corrosive environment," Thomas said.

Polypropylene fibers were also used to give the precast increased resistance to spalling under fire conditions.

TUNNELING 130 FEET UNDERGROUND

Tunneling began in May 2012 and ended in June 2015. The TBMs tunneled about 328 feet per week. The process was methodical. Locomotives transported the precast segments and keystones into the tunnel, where they were loaded into the TBM's "belly." The TBM's cutter head then bored through the earth, depositing the soil above ground via a conveyer system. When the TBM cleared enough space to construct a ring, its robotic arms positioned the precast segments. Workers then bolted them together using hydraulic drills. Once a ring was complete, the TBM propelled forward to begin boring for the next ring.

While tunnel boring is typically straightforward, difficulties can occur. This was the case for the

Eight massive tunnel boring machines cleared the way for the 26 miles of tunnels required for the project.


Photo courtesy of Crossrail Ltd.

Connaught Tunnel, which runs under the Royal Dock. Connaught Tunnel opened in 1878 and hadn't been in service since 2006.

"When we first met the Connaught Tunnel, it was completely deserted and overfilled with high grass and weeds," Miller said.

Workers widened and deepened the tunnel to accommodate modern, full-sized trains. But Miller hadn't planned on having to build a cofferdam to pump out more than 3 million gallons of water.

"We were very proud to be the team that breathed life back into the Connaught Tunnel as part of Crossrail," he said.

PRACTICALITY AND AESTHETICS

Once tunneling was complete, focus turned to the stations. The existing 30 stations were located above ground. Five of the 10 new stations, including Farringdon, were mined underground structures. For these stations, glass fiber reinforced precast concrete was used for the internal cladding.

When it opens, Farringdon Station will be one of the most important transportation hubs in central London. Its public areas are clad with a sophisticated design crafted from disc-shaped GFRC panels. Some segments are single-curved while others are double-curved. These curved edges help reduce blind spots and enhance passenger navigation.

Netherlands-based Sorba supplied the precast concrete for Farringdon. Each station had its own suppliers since all stations were constructed simultaneously.

"It was quite a challenge to get all the concrete we needed at the correct time and with the correct quality," Thomas said. "We achieved it, but it certainly took a lot of collaborative effort."

The mix used to form the panels contains a special plasticizer that gives the concrete a consistency like chewing gum. Within 20 minutes, a skin forms on the surface, acting as a mold for the mix. This allows the mold to be manipulated over a steel arched form and secured in place until the concrete is strong enough to hold its shape. Once fabricators achieve the correct consistency, they begin creating the curved precast shapes.

All of the tunnels have common characteristics to keep a passenger's journey consistent. But once a passenger rides up the escalator to the station's entrance, consistency transitions to the unique. Every station is designed to reflect the characteristics of its environment.

For example, Farringdon's eastern ticket hall features metal

Architectural renderings depict Farringdon Station's public areas, which are clad with disc-shaped GFRC panels.

sliding-screen gates. This serves as a nod to watchmakers, goldsmiths, ironmongers and blacksmiths, and the Brutalist architecture of the nearby Barbican Centre. The western ticket hall pays tribute to Hatton Garden, the center of the U.K.'s diamond trade. Its ceiling was built using white, reflective, diamond-shaped precast concrete segments.

"That's something we could only really do with precast," Thomas said.

Precast was selected for its acoustic properties as well as its architectural aesthetic. Sophisticated computer modeling was employed to test how the public address and voice alarm speakers would interact with the station.

After "many iterations," designers discovered that precision holes located in specific places in the discs produced the desired acoustic properties.

Prior to Crossrail, GFRC had not typically been used for rail stations.

"We've shown what a fantastic material it is with regards to acoustics, light reflectance and aesthetics," Thomas said. "It will definitely be used for future U.K. construction projects."

JOURNEY'S END

Although Crossrail isn't quite complete, it's already considered a huge success. And it's still on track for meeting its original schedule.

The project sets new industry standards, notably in the area of used technologies, which other transport networks are adopting. Strategic planning, cutting-edge equipment and innovative materials – including precast concrete – were undeniably important to the project's success.

"All those kinds of things pull together to make us feel bloomin' proud," Miller said. "I've never felt so inspired than in the incredible work that Crossrail Ltd. has done." **PS**

Shari Held is an Indianapolis, Ind.-based freelance writer who has covered the construction industry for more than 10 years.

Endnotes

[1] businessinsider.com/traffic-congestion-in-london-2015-8