THE MAGAZINE OF THE CONCRETE SOCIETY

CONCRETE

Volume 56, Issue 9 November 2022

MYRIAD SEGMENTS

10,000 carbon-conscious, fibre-reinforced precast units for Silvertown Tunnel

EVALUATING CONDITION AND FORM

Guidance on the approach to surveying and testing hardened concrete

RESEARCH AND DEVELOPMENT

Looking at the latest efforts to improve the carbon performance of concrete

CARBON-CONSCIOUS CONCRETE SEGMENTS

As **Banagher Precast Concrete** reaches the halfway point in pouring over 10,000 tunnel segments for the Silvertown Tunnel in London, **Christoph Stieler** looks into some of the innovative carbon savings on the project.

Silvertown Tunnel, London

Client
Transport for London (TfL)

Contractor
Riverlinx CJV (Ferrovial, BAM Nuttall and SK Ecoplant)

Precast supplier
Banagher Precast Concrete

> "Both tunnel tubes are designed in such a way that the well-known London double-decker buses can drive in both lanes without restrictions."

Riverlinx CJV (BAM Nuttall, Ferrovial, SK Ecoplant consortium) is designing and constructing a new 1.4km twin-lane tunnel linking North Greenwich and Silvertown under the River Thames for its client Transport for London. The route was chosen so that the new road connection can be seamlessly integrated into the existing infrastructure on both sides of the river. In addition to the construction of the tunnel, Riverlinx's project scope also includes precast concrete cut-and-cover, approach structures and portals.

Launched in September, the Silvertown tunnel boring machine (TBM) – with a drilling diameter of 11.97m and christened 'Jill' after London's first female bus driver, Jill Viner – is the largest TBM ever used in the UK.

The Silvertown Tunnel is designed as a two-tube road tunnel. Both tunnel tubes are designed in such a way that the well-known London double-decker buses can drive in both lanes without restrictions.

The inner-city location of the construction sites with specific conditions means that the entire logistics for both tunnel drives will be handled from the Silvertown side. After the first drive, the TBM will be rotated 180° in the rotation chamber on the south side of the Thames and will then tackle the second drive from south to north.

SEGMENT DESIGN

The original design plan envisaged a two-shell lining of the tunnel consisting of segments, waterproofing and secondary lining to guarantee permanent watertightness. During the project evaluation phase, in joint consultations with the holding company and TfL, a single shell design was given priority. Projects with comparable conditions, such as the Sluiskil Tunnel built in The Netherlands in recent years and the Rotterdamsebaan Tunnel, show that a single-shell construction meets the requirements.

For the Silvertown Tunnel a 2m-wide and 400mm-thick segment ring consisting of nine segments with right/left conicity (30mm on both sides) was chosen. With the exception of the small keystone, no screws are used in the longitudinal joints. Guiding rods in the longitudinal joints in conjunction with dowels in the ring joints allow the ring to be assembled securely.

REINFORCEMENT

The design allows for steel-fibre-reinforced segments for large sections of the Silvertown Tunnel. Segments with reinforcement cages (150kg/m^3) are used in sections with high loads (low cover in the area of the approach/destination shaft, critical ground conditions, etc). In order to be able to produce the cross passages without expensive propping, the five rings of each cross passage are provided with shear force coupling elements, so-called bicones. A high-density reinforcement cage with a steel content of over 300kg/m^3 ensures that the forces are safely diverted.

FIRE TESTS

In the run-up to segment production, large-scale fire tests were carried out. Special test segments, each equipped with 50 temperature sensors, were tested for their suitability for fire at Efectis NL. The toughest fire test was to pass the RWS fire curve from the Rijkswaterstaat, the Dutch Ministry of Transport. The segments were exposed to a temperature of 1350°C for a period of two hours.

COATING

A particularly high sulfate content in the soil originally led to a different specified concrete class for the segments. Although the use of a CEM III B cement would have met the requirements with regards to sulfate attack, the passing of the fire tests in combination with the limestone used would have been questionable. In addition, due to the slow strength development, the planned stripping time of approximately 12 hours would not have been feasible.

With the help of a detailed analysis of the soil reports, the areas with potential for high sulfate attack could be pinpointed. The segments in these sections are given an epoxy-based protective coating on the outside. The triple application of paint (primer, first and second top coat) is time-consuming but the most economical method for the 52 rings concerned. The coating takes place immediately after demoulding in the production hall. This means that no additional equipment line is required and the existing vacuum lifters and turning device can also be used.

SEGMENT PRODUCTION

The Riverlinx joint venture commissioned the Ireland-based precast manufacturer Banagher Precast Concrete to manufacture and supply a total of 1122 reinforced concrete rings (10,100 segments and keys). Banagher Precast developed the concrete for the steel-fibre and cage-reinforced segments – limestone aggregates from its own quarry and 40% GGBS in conjunction with polypropylene

LEFT:
Silvertown tunnel – TBM in launch chamber.

INSET:
Storing completed segments ready for the Silvertown project.

ABOVE:
Silvertown TBM, named 'Jill' after London's first female bus driver.

BELOW:
Casting fibre-reinforced tunnel lining segments at Banagher Precast.

micro-fibres allow for a concrete that combines the sometimes-conflicting requirements of fire protection, chemical resistance, a short stripping time and low carbon.

The steel-fibre concrete is being used in 6750 units eliminating the requirement for steel cages, hence greatly reducing the cost and CO_2 content of units.

An area of Banagher's production facility has been dedicated to the project. For enhanced efficiency and quality control, a static mould system has been chosen. The mixing plant is equipped with automatic metering devices for steel fibres and polypropylene fibres. A semi-automated concrete distribution system allows the individual moulds to be filled safely and effectively. Each precast ring consists of eight segments and a key; in order to ensure programme 36 moulds were commissioned and casting takes place once a day.

Mild temperatures of the Irish climate, insulated production halls and light covers over the precast moulds eliminate the requirement for energy-hungry heat or steam curing, helping carbon reduction of what is inherently a high embodied-carbon product.

Unique to the Silvertown Tunnel project, Banagher committed to planting one hardwood tree for every precast ring manufactured. A hardwood tree absorbs approximately 20kg of carbon per year; planting 1200 trees will therefore eventually absorb 24 tonnes of carbon annually.

Manufacturing segments in an established factory setting not only achieves consistent quality but also negates the requirement to set up on-site – requiring less mobilisation of plant and people, while eradicating the waste associated with creating and dismantling a temporary factory.

As part of this contract, Banagher has expanded its concrete testing laboratory and gained accreditation by the Irish certification body INAB (UKAS equivalent). Among other things, the tests required for the steel-fibre concrete can now be carried out on-site and the laboratory is also qualified to test chloride migration according to BS EN 12390-18[1].

After the 28-day strength has been reached and the quality check has been carried out, the segments are transported to the construction site in London.

CROSS-PASSAGE CONNECTIONS

A total of seven cross passages will connect the two tunnel tubes and ensure safe escape and rescue routes. Depending on the geological conditions, various construction methods – such as ground freezing – will be used to create the cross passages. The use of highly reinforced special segments with transverse force coupling elements (bicones) will enable the segment shell to be opened without further temporary support measures.

CUT-AND-COVER SECTIONS

In addition to the two approximately 1200m-long TBM driven tunnel tubes, tunnel sections are being constructed using the cut-and-cover method at both ends of the bored tunnels. The selected dome profile is based on the tunnel profile of the bored tunnel and enables a structurally favourable construction.

OUTLOOK

The bored tunnels are expected to be completed by September 2023. The cross-passage work will continue until spring 2024. Commissioning of the entire project is planned for mid-2025.

Reference:

1. BRITISH STANDARDS INSTITUTION, BS EN 12390. *Testing hardened concrete. Part 18 – Determination of the chloride migration coefficient*. BSI, London, 2021.