Upgrading the Södermalms tunnels

Konrad Aurin looks at the application of fire protection boards to two existing road tunnels in Stockholm

IN SWEDEN'S capital, Stockholm, an important roadway crosses Södermalm island from north to south. The Söderleds tunnel connects the Central and Johanneshov bridges. The 1,580m-long tunnel has two tubes. At both ends, small tunnels and ramps connect the tunnel, bridges and roads.

On the stretch between Brännkyrkagatan and Folkungagatan, an earlier tunnel called Södergatan was built in 1944 in a cut-and-cover trench. Between 1964 and 1966, it was extended 150m under Åso High School. The tunnel as it is today was started in 1984. The construction work finished on schedule in January 1991, with the Clarion Hotel at the south end.

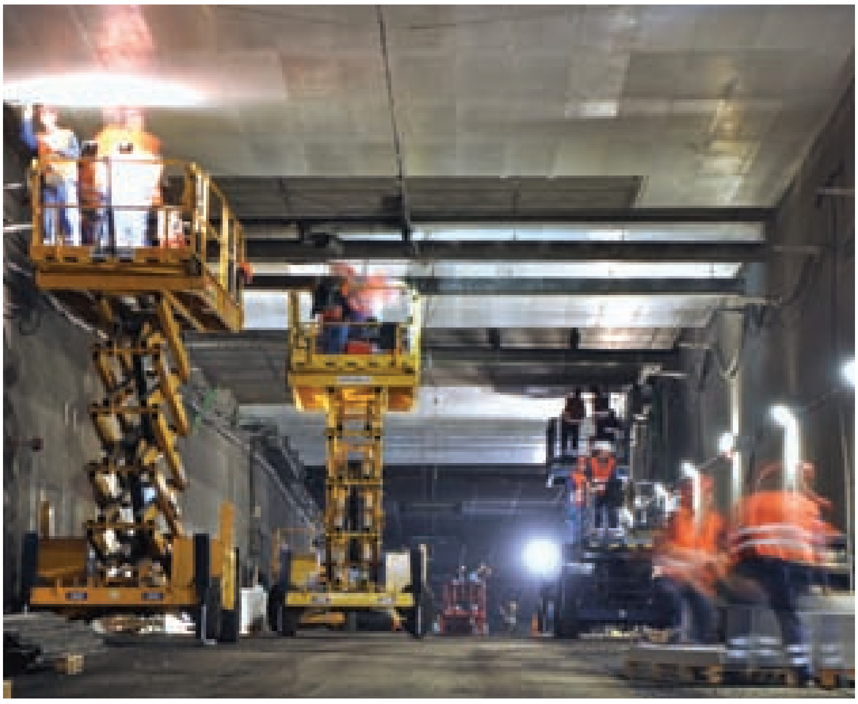
The main tunnel is one of the primary connections between the north and south of the island and, on average, carries around 80,000 cars/d.

The plans to begin the refurbishment of the Söderleds tunnel started in early 2004. Due to high traffic volumes in the city, the refurbishment of the east tube was divided into three sections to be completed between 2005 and 2009.

For the west tube, complete refurbishment was the preferred solution to shorten the time closed and decrease costs. The tunnel was planned for closure on July 4 and re-opened on November 27, 2009, 16 hours ahead of schedule. This short period included hydro-demolition of damaged or contaminated concrete and shotcreting, casting the cable channel, sewage, barrier elements, fire protection, electrical installation, ventilation, coating and asphalting.

The contract was awarded at the end of 2011 to a joint venture (JV) comprising Strabag Sweden and E-Schakt. Due to the short time-frame, the large amount of work and the heavy work traffic, the JV was keen to change the original fire protection design.

In 2004, the design was based on a sprayable application of a fire-protection product with a thickness between 25mm and 60mm. This application included the hydro-demolition of the concrete surface and the spray application of up to three layers. During the hydro-demolition and spray application, the whole area would need to be closed from other work and traffic, which would have caused problems and delays.



Fire protection of flat concrete

FIRE-PROTECTION UPGRADE

During the past few years, the concrete and steel structures of many existing tunnels have undergone passive fire-protection upgrades. This progress is based on the following aspects:

- New guidelines and temperature-time-curves resulting from experience with serious tunnel fires and from 'real' fire tests;
- General refurbishment of concrete structures and upgrading of M&E safety equipment as a possible way to implement fire protection;
- Combining fire protection and architectural linings; and
- Higher HGV traffic volumes and new risk analyses.

For a passive fire protection upgrade, different materials, panels, mortar and shotcrete are available. Material thickness depends on the temperature-time-curve, and the maximum allowable temperatures of the concrete surface and rebar.

Sprayable materials allow easy fire protection for difficult or very uneven surfaces, or for concrete slabs with stressed reinforcement, where no mechanical fixing is possible.

Panels give a very flexible installation method with very low environmental impact. In all cases, the fixings are made of steel – either grade A4 or a highly corrosion resistant (HCR) variant.

A major issue for design is the implementation of M&E fixings and base plates, either in contact with, or penetrating, the fire protection material.

To prevent damage, the fire protection material should be separated from any dynamic loads or bending stress that might be transferred from fixings and hangers. At the same time, the radiation transmission and heat sink from steel parts must be reduced as much as possible.

For architectural and lighting design, the fire-protective material can be used as a substrate for different types of coatings to increase reflection and cleanability.

For the Söderleds tunnel, the fire protection upgrade was based on detailed analysis and planning of the existing tunnel and top structure.

Due to the step-by-step construction of the tunnel, there are 17 different cross sections, including rock tunnel, cut-and-cover, and precast and pre-stressed concrete slabs. Above the tunnel are streets, yards, residential, commercial and public buildings.

For the Söderleds tunnel, a fire curve called ZTV-Ing was specified (former RABT), but with an extension from 30 to 60 minutes fire with an additional 110 minutes of cooling.

The results showed a high risk of concrete spalling for ceiling areas, with upper structures above the tunnel experiencing a combination of temperature and bending stresses, a medium risk of spalling in the area without the top structure, such as roads and yards, and a low risk of spalling at the tunnel walls.

A maximum surface temperature of 380°C for areas with a high spalling risk was determined. Limiting this temperature reduces structural damage to the concrete and speeds up any repair work after a fire. The risk without passive fire protection for areas without top structure and for tunnel walls was evaluated as "acceptable".

Täby BrandskyddsTeknik and Fermacell worked out an alternative solution using 20mm Aestuver T boards in place of shotcrete. The dry installation method gives high flexibility during installation, allowing a traffic lane to be kept open at all times.

The approval of this alternative was based on fire and durability tests and thermal calculations.

Fire protection acts as a suspended ceiling

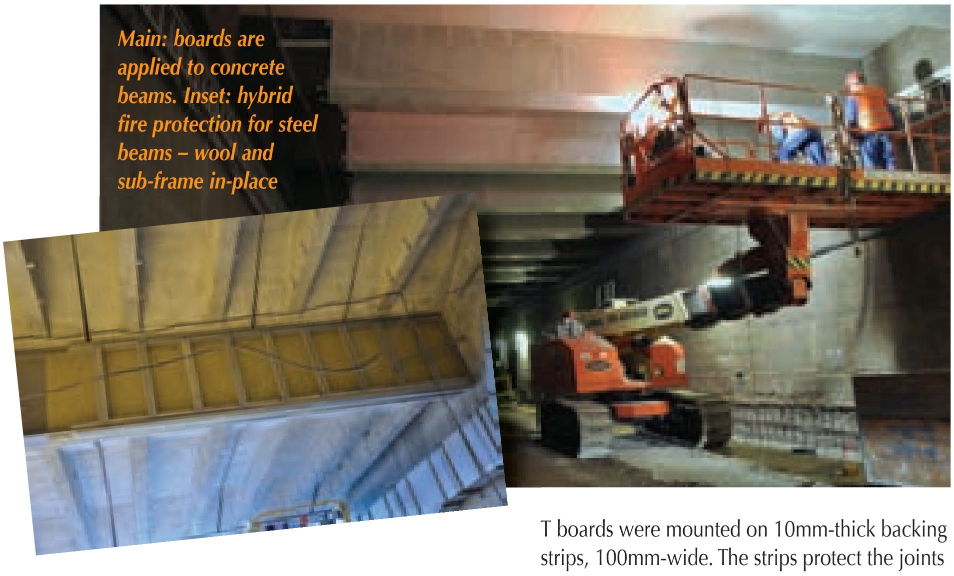
The thermal calculation allows the adoption of results from the test for inclusion in the project specifications.

First, a comparative calculation with a real fire test was carried out to adjust and prove the material and software parameters. Second, thermal gradients for ceilings and beams were calculated. The results showed that 20mm of Aestuver T board on 10mm backing strips for the flat ceiling and beams is sufficient to fulfill the requirements. For the areas with stressed double T- beams, a suspended ceiling was designed.

In the first weeks of the refurbishment, discussions took place concerning additional fire protection to middle-risk areas. Täby BrandskyddsTeknik and the JV convinced the client to maintain the same protection level throughout the tunnel ceiling.

In the client's view, it was more than worth spending the extra money to eliminate the risk of a lengthy refurbishment following a fire in an unprotected area.

This view was aided by the good progress of the installation and the resulting attractive aesthetics. The client was involved in the decision-making process and also on the upgrades of the Riddarfjärdsavfarten and Skansbrogatan tunnels. ➔



Main: boards are applied to concrete beams. Inset: hybrid fire protection for steel beams – wool and sub-frame in-place

FIRE PROTECTION SYSTEMS

Flat concrete and precast beams, approximately 17,500m²: The existing flat concrete was in relatively good condition to receive an installation of fire protection boards. The surface was mostly even with only some minor damage. The reinforcement depth was between 40mm and 50mm. Given this scenario, 20mm Aestuver T boards were mounted on 10mm-thick backing strips, 100mm-wide. The strips protect the joints and make the board surface more regular. TBT chose nail anchors for fixing. The joint between ceiling and wall was protected by a vertical, wall-mounted board strip.

Precast and stressed ceiling, approximately 5,000m²: The suspended system was used in two areas. Around 200m of the tunnel ceiling was built using pre-stressed double T-beams with a noise reduction ceiling underneath to protect the building above from the sound of traffic. The fire protection should be suspended under the noise reduction to maintain efficacy.

The TT-cassettes had a precast channel that could be used with a hammerhead screw from which profiles could be hung. Only a small hole needed to be cut in the noise-reduction elements made of steel net and mineral wool. For the support, TBT designed an Omega-profile, which allows some movement between each board. Small structural movements can be accommodated without stressing or damaging the fire protection boards. The boards were fixed together with a 20mm backing strip and self-drilling screws. All steel parts had to be A4-grade stainless.

The second area was located at the end of the tunnel under a hotel complex. Precast and post-stressed TT-elements lay on walls and beams to carry the hotel above. Due to the stressed reinforcement, drilling in the lower 200mm regions of elements was not allowed. So, a bracket was used to have the profiles suspended from the flank of the element beams.

INSTALLATION

Scissor lifts were mainly used to maintain full flexibility during the installation. Seven teams of three workers each installed the fire protection boards from the lifts. On the ground, 3-4 workers took care of the logistics and material preparations.

This system allowed the planning of the installation according to the situation in the tunnel. During the project, the seven installation crews spread out at up to five different places in the tunnel. Often, the installation place needed to be changed due to other conflicting work.

Due to the casting of cable channels on both sides of the roadway, a 1m-wide trench needed to run along the tunnel walls. Side areas were difficult to reach from scissor lifts and it was impossible to work ahead of the digging. A special beam lift was used to access these areas.

The increase in the fire protection area during the project from 15,000m^2 to 22,000m^2 was accommodated in the time schedule without problems. At full working capacity, up to 450m^2 was installed in a day.

SKANSBROGATAN

Next to the southern end of the Söderleds tunnel, a road passes under a hotel. The hotel structure creates the tunnel. Here, the ceiling was made of pre-stressed double T-beams. A 1,500mm-high steel beam spans the middle of the tunnel.

A suspended ceiling was erected, similar to the pre-stressed area at the Söderleds tunnel. In order to reduce thickness and cost, the fire protection of the steel beam is made of a hybrid construction comprising mineral wool, sub-frame and fire-protection boards.

The upgrade had to be executed during January and February 2012. A key criterion was to keep one traffic lane open.

During the installation, half the tunnel width plus 1m was closed to traffic in an alternating sequence. The panel system allows easy installation in any season and when traffic is using the tunnel, without the need for lengthy preparations.

RIDDARFJÄRDSAVFARTEN

On the north side of Södermalm, a small tunnel passes under another hotel complex.

To keep the same protection level and design as the Söderleds tunnel required fire protection for the flat ceiling, encasing pipes and cables, and a wall coating for chloride protection.

At a joint in the tunnel structure, much water leakage occurred due to damaged sealant, resulting in surface water entering the tunnel.

For the ceiling, the same system was used as for the Söderleds tunnel. Encasing transverse pipes was achieved by stainless steel profiles and fire protection boards.

For the leaking structural joint, TBT developed a system which combines drainage and fire protection.

The tunnel walls were impregnated with a silan-based solution plus an epoxy coating to reduce the build-up of chloride salts, as well as providing good light reflection and an easy-to-clean surface.

CONCLUSION

The passive fire protection of an existing tunnel requires a high level of planning, from design to application.

Many details influence the design and materials. In addition, good communication is needed to guarantee successful application. New or upgraded fire protection can lower risk, shorten repair time and form part of the architectural design.

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