Promat

Case Study

HONG KONG–ZHUHAI–MACAU TUNNEL

Structural fire protection systems at
Hong Kong-Zhuhai-Macau Tunnel Project

The Hong Kong-Zuhai-Macau Tunnel Project (HZMT) is one of the world's largest and most challenging civil engineering projects.

First proposed in 1983, actual construction began 2009. It is expected to be fully operational by 2020. HZMT includes the world's longest undersea vehicular tunnel.

HZMT is located over busy sea lanes and deep below the choppy estuarial waters of the Pearl River Delta. It links the Hong Kong Special Administrative Region (HK- SAR), Zhuhai city of Guangdong province and the Macao Special Administrative Region.

The province of Guangdong is one of China's most important engines of economic growth. When complete, the HZMT net- work will not only cut travel times significantly but also help accelerate development of the vicinity and its immediate hinterland with a combined population of 80 million people.

Many tough environmental challenges

HZMT is considered China's most important infrastructure project, both technically and politically. With 33 immersed structural elements submerged at depths more than 40 metres below sea level, HZMT pushes the boundaries of what is technically possible. It also includes numerous long span suspension bridges and the creation of artificial islands.

The 6.7km long tunnel component, the world's longest immersed tunnel for vehicular road traffic, is constructed on a soft seabed which required soil improvement to prevent the elements from settling.

Other considerations factored into the exceptionally tough construction process include constant sea trafc navigating some of the world's busiest shipping lanes, an unpredictable annual typhoon season, and many concerns for the threatened China White Dolphin, sometimes know as the Pink Dolphin, whose home range is the Pearl River delta.

One of largest contracts in Promat tunnel history

The Promat team – comprised of personnel from Promat China and the Promat Asia Pacific Regional Tunnel Manager – have been working on the HZMT project for a number of years.

For quite some time it was a challenge to see how Promat could compete with many less expensive systems available on the market. However, in the final analysis, dogged persistence, legendary Promat professionalism, technical

Inset group picture above (from left) Jef Tang (Technical Manager, Promat China Ltd), Tony Li (General Manager, Promat China Ltd), staf of China Communications Construction Company Ltd, Samson Ho (Managing Director, Promat Asia Pacifc group), staf of China Communications Construction Company Ltd, Rick Fox (Regional Tunnel Manager, Promat Asia Pacifc group) and Paul Sparrow (Global Support Manager, Tunnel Business Segment, Promat International NV)

excellence and proven solutions provided the competitive edge required to win this important contract.
The designers chose the RABT curve up to maximum 1200°C. After the fire test it was determined that 25mm thick PROMATECT®-H was required to be fixed directly to concrete in accordance with the design and regulatory specifications.

Approximately 290,000m² of PROMATECT®-H and 8,000 tubes of 600ml PROMASEAL®-A Acrylic Sealant are employed in the HZMT tunnel making it one of the largest fire resistant board construction jobs for the tunnel segment business of Promat worldwide.

A substantial amount of PROMASEAL® FyreStrip is used to seal various movement joints within the concrete. The Promat team is working closely with the installer to ensure that they have immediate access to solutions for any potential issues as and when they occur.

Actual board installation commenced in early April 2016.

HZMT FAST FACTS

- Hopewell Holdings founder and then Managing Director Gordon Wu originally proposed the idea of the tunnel in 1983.
- A study by the National Development & Reform Commission and the Hong Kong government indicates that this new bridge-tunnel-highway network will provide signifcant macro socio-economic benefts for all in the Pearl River Delta regions. The study is the result of an HKSAR Government proposal to improve linkages between the three places under the "one country, two systems" policy.
- HZMT Advance Work Coordination Group was established in 2003 to coordinate the project.
- Lok Ma Chau cross-border checkpoint operates 24 hours daily for both road vehicle and passenger trafc en route between Hong Kong to Shenzhen.
- The tunnel was due for completion in late 2016 but has been delayed to the end of 2017.

WHAT
Direct fixed tunnel lining

WHERE
Tunnel of the Hong Kong-Zhuhai-Macau tunnel project (HZMT) in the Pearl River Estuary between Hong Kong and Zhuhai of Guangdong province, China mainland

WHEN
Completion scheduled for end 2017

MAIN CONTRACTOR
China Communications Construction Company Ltd

INSTALLER
Shenzhen Baoying Construction Group Co, Ltd

PRODUCTS & USAGE
PROMATECT®-H
25mm thick x approx. 290,000m²
PROMASEAL®-A Acrylic Sealant
600ml x 8,000 foil tubes
PROMASEAL® FyreStrip

FIRE PROTECTION PERFORMANCE
Maximum 1,200°C for RABT fire curve

1. Project background

When the Hong Kong-Zhuhai-Macau fixed link opens, motorists will be guided out of western Hong Kong on a 5 km long bridge. From there, an immersed tunnel will take them underwater some 6.7 km under the Pearl River Estuary before they ascend a 23 km bridge that takes them to a choice of either Macau or on to Zhuhai in China's Guangdong province on the mainland. COWI is participating in the design of the immersed tunnel along with CCCC Highway Consultants Co. Ltd. and Shanghai Tunnel Engineering & Rail Transit Design and Research Institute.

Fire Protection in a tunnel is all about safeguarding people's lives and preventing property damage. A tunnel fire can be a major disaster and images of catastrophes in Europe will always remain in our minds. Safeguarding people's lives means installing and maintaining escape paths and it also allows the fire brigade and other emergency services to intervene in safe conditions.

Fire Damage to a tunnel can have enormous financial consequences. The repair costs are huge, but the effects on the infrastructure are even larger. Tunnels have been out of service for months after a fire. For example, after the fire in the Channel tunnel, the direct repairs cost some €87 million with additional costs in lost business, replacement of infrastructure, materials (e.g. train carriages), bringing the economic loss to €211 million.

Thus it is critical to protect the world's tunnels and infrastructure, such as the Hong Kong Zhuhai Macau tunnel project (HZMT). HZMT is considered China's most important infrastructure project: with 33 immersed structural elements submerged at depths more than 40m below sea water. HZMT also includes numerous long span suspension bridges and the creation of artificial islands. The 6.7 km long tunnel component of HZMT is the world's longest immersed tunnel for vehicular road traffic. The tunnel will, for example, exceed the length of the current record holder – the Oresund fixed link's immersed tunnel between Denmark and Sweden – by about 40%. Promat also provided the structural protection on this tunnel.

When designing the fire resistance requirements for this tunnel the designers need to evaluate what traffic type and traffic volume were to be using it and, based on this research and local standards, the designers chose the RABT curve which simulates a fast rising very high temperature fire. This fire curve heats to maximum 1200°C within only 5 minutes (massive thermal shock to the concrete) and stays at 1200°C for 2 hours. It is then subject to a gradual cooling phase of 110 minutes which simulates a real fire – total test time 230 minutes. After the official fire test, it was determined that 25mm thick PROMATECT®-H was required to be fixed directly to concrete in accordance with the design and regulatory specifications along with Promat's installation methods. This fire test was repeated to show consistency of the result.

2. Companies involved

Owner:
Project Office of Hong Kong-Zhuhai-Macao Tunnel project

Main contractor:
China Communications Construction Company Ltd

Installer:
Shenzhen Baoying Construction Group Co, Ltd

Design:
COWI

Eternit Guangzhou
PROMATECT® H manufacturer

Promat China
Design, technical and commercial consultants

PROMAT Australia
PROMASEAL® Fyrestrip manufacturer

Promat Tunnel Segment
Design, technical and commercial consultants

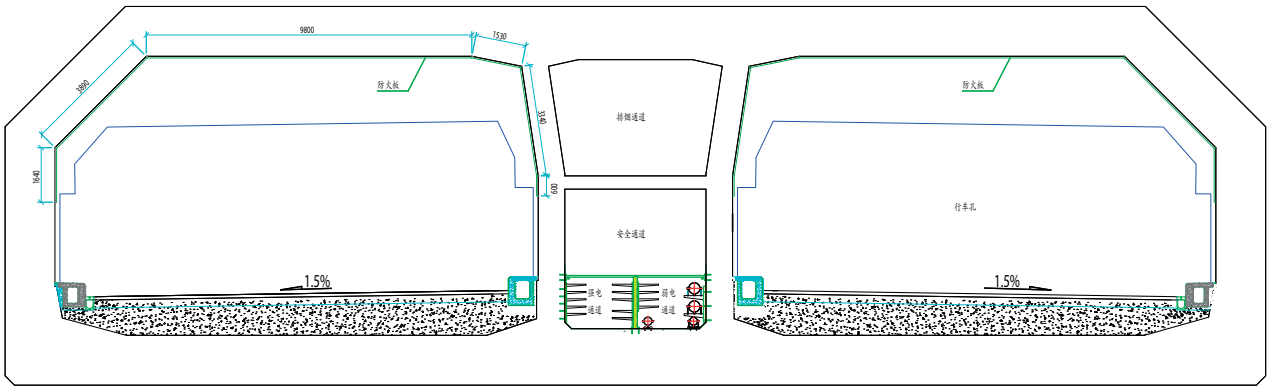


Fig 1: Tunnel cross-section

3. Technical specifications and specific requirements

Fire curve is RABT modified to meet with the local Chinese standard – maximum temperature of 1200°C for 2 hrs, with a further cooling period of 110 minutes (see graph in Fig 2).

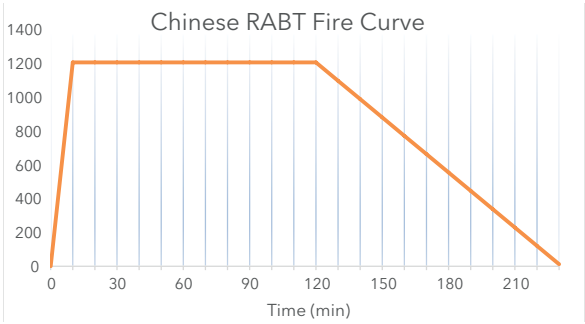


Fig 2: RABT FIRE CURVE to Chinese standards

Board fire protection system is the preferred method of protecting this structure. Spray was not considered by the client.
All steel fixings used are 316 grade anticorrosive stainless steel (see Fig 3).

Fig 3 Fixing anchor

4. Testing

RABT for boards to protect concrete for two hours. This type of test report issued by the government fire test laboratory (CNCF or NFTC) according to the test standard GB 28376-2012 is a pre-requisite for any qualified bidder. Failure criteria is reached when the interface temperature exceeds 380°C and/or the rebar temperature exceeds 250°C, 25mm below the interface.
The additional fire test for the concrete slab as mentioned above was required to be carried out as soon as the installation work commenced, the board samples for the test were randomly selected by the owner at the building site. This was for confirmation of performance.
Expansion joint test. The integrated expansion joint system had been tested by CCCC in the fire test lab of Central South University. The system tested was comprised of 25mm PROMATECT®H (with steel frame) +25mm ceramic fibre. (50mm was used on the project). The test specimen simulated the designed structure size of the element joint, the maximum temperature limit on water-tight rubber is 150°C.
Fixings pull out test. It is imperative that the fixings are tested for pull out strength given the dynamics of the tunnel environment with positive and negative pressures constantly in force. During the installation work, the pulling out force test for fixings was required to be carried out at site by supervision engineer, the test ratio is around 0.1% of the total volume of fixings.

- For every 10,000 pieces of board, the board sample by randomly selection was required to be tested in third party laboratory for physical performance as required by standard GB 28376-2012.
- For every 20,000 fixings, the fixings (randomly selected) were required to be tested in a third party lab for strength performance and raw material evaluation.

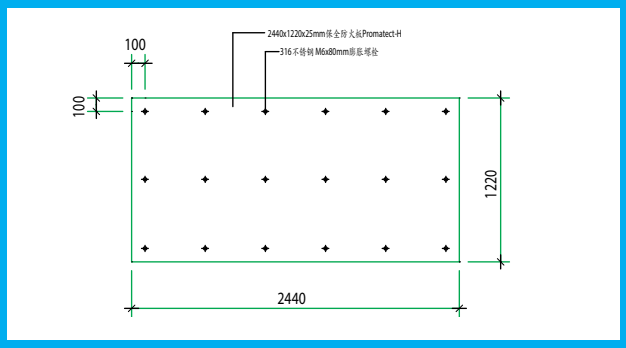


Fig 4: Fixing Pattern

Fig 5a: Site visit with Promat and CCCC management teams

Fig 5b: Jeff Tang and René van den, Bosch Global Manager Tunnel Business Segment, alongside our PROMATECT ® H boards

Fig 6: Boards on barge ready to be off-loaded onto the man-made island

5. Products

PROMATECT®-H, 25mm thick, approx. 290,000m²

- Direct fixed to concrete linings using anchor bolts (see fixing pattern Fig 4)
- Also used in conjunction with the expansion joints

PROMASEAL®-A Acrylic Sealant, 600ml foil x 8,000 pieces

- Used for minor expansion / control joints (see Fig 11)

PROMASEAL® Fyrestrip approximately 2,600 lineal meters was installed

- Used as expansion joints.

6. Construction cost

RMB 8 billion – over 1 billion Euro (tunnel only).

7. Elevated working platforms (EWP)

Very early on it was clear that to make installation efficient, elevated working platforms would be required to get to the workface effortlessly. Through consultation with Promat and our experience with many of these types of platforms Baoying designed and manufactured six of these EWP. These platforms had adjustable "wings" that could be folded away or lowered, depending on the location of the installation (see Fig 10).

8. Logistics / installation procedure

Product is shipped by truck from Eternit Guangzhou factory to Zhuhai port facility of CCCC where it is unloaded onto a barge. The barge then makes the 20km sea journey to the West island where it is unloaded by crane onto trucks on the island. It is then delivered to the designated areas required by Baoying, the installers. Full size boards are trucked to the tunnel at the location of installation. Some boards are taken to the on-site cutting facility (see Fig 7), where they are fabricated to the onsite requirements – the angled haunches seen in cross section have an angle to be fabricated into the board so as to minimise gaps.

The boards are then lifted onto the elevated working platforms by forklift ready for installation. The boards are lifted into position using automatic lifters (see Fig 8b). Once in position the holes are drilled, bolts are inserted with hammer initially and then tightened using a cordless screw gun to the required torque.

9. Expansion joints

Main expansion strips located at every segment joint, (180 m). This joint was designed between Promat and CCCC. This integrated expansion joint system was tested by CCCC in the fire test lab of Central South University. The system tested was comprised of 25mm PROMATECT®H (with steel frame) +25mm ceramic fiber (50mm was used in real project). The test specimen simulated the designed structure size of the element joint, the maximum temperature limit on the water resisting rubber seal is 150°. Minor expansion joint was used within the segment itself 22.5m centres, and consisted of a 10mm joint filled with Promat Sealant (see Fig 11).

PROMASEAL® Fyrestrip (see Fig 12). This was used behind the PROMATECT H to supplement the fire resistance of the joint as well as to limit air leakage through the joint.

Fig 9: Installation of boards and elevated working platform

Fig 7: Cutting facility with boards ready to cut on the island

Fig 8a: Note angled cut at haunch

Fig 8b: Automatic board lifters (yellow)

Fig 10: Lifting onto Elevated Work Platform with forklift

Fig 11: Minor control joint

Fig 12: Fyrestrip

10. Timing

Promat started supplying in March 2016 and final shipments for the thermal linings (PROMATECT®H) will be complete in September 2017. It was critical that the factory kept up production with installation requirements for the PROMATECT®H boards. The Promat factory in Australia were required to produce and deliver the PROMASEAL Fyrestrip in time for installation and this will also be finalised in 2017.

11. Installation rates

At times, there were up to 60 installing staff onsite and they were achieving 3m² per man / per hour quite regularly, with total m² installed per week up to 7,500 m².

PROMATECT®-H

Calcium Silicate Board

PROMATECT®-H is a non-combustible matrix engineered mineral board reinforced with selected fibres and fillers. It is formulated without the use of formaldehyde or corrosive Magnesium Oxy Chlorides.

PROMATECT®-H is off-white in colour and has a smooth finish on one face with a sanded reverse face. The board can be left undecorated or easily finished with paints.

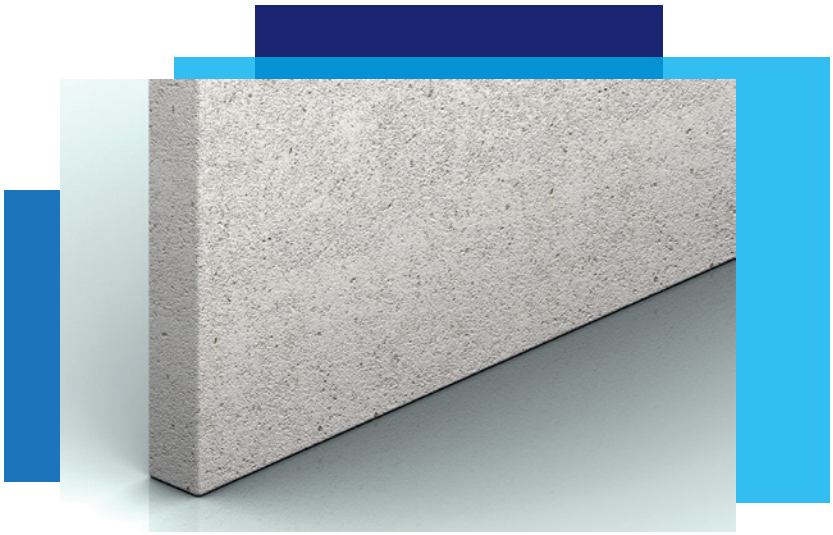
PROMATECT®-H is resistant to the effects of moisture and will not physically deteriorate when used in damp or humid conditions. Performance characteristics are not degraded by age or moisture.

Advantages

- Resistant to the effects of moisture
- Not physically deteriorate when used in damp or humid conditions
- Performance characteristics are not degraded by age or moisture.

Applications

- Tunnel lining, concrete floor and wall upgrading
- M&E services enclosure
- Access panels and hatches, fire doors
- Structural steel protection
- Membrane ceilings
- Cladding to steel ducts, selfsupporting ducts



Fire protection thickness

Fire protection thickness requirements are often specified in the owner operator's engineering codes of practice.

Alternatively, please consult Promat

General technical data

Product generic description	non-combustible, fire resisting calcium silicate board	
Combustibility	DIN 4102, Part 1 BS 476, Part 4 EN 13051-1:A1 (Classification Report WFRGent 11527C)	Non-combustible
Board format (length x width)	mm	2500 x 1250 2440 x 1220 3000 x 1250
Tolerances on length and width	mm	± 3
Board thickness	mm	8 - 10 - 12 - 15 - 20 - 25
Tolerances on thickness	mm	8 - 20 mm ± 1.0 > 20 mm ± 1.5
Density (nominal, oven dry)	Kg/m^3	ca. 870
Alkalinity (approximate)	pH	12
Thermal conductivity λ	W/m°K	ca. 0.175 (at 20°C)
Water absorption	g/cm^3	0.50
Moisture diffusion resistance	μ	ca. 20
Typical moisture content (at EMC*)	%	5 - 10
Surface condition	Front face: smooth, unsanded Back face: textured and or sanded Colour: beige - white	
Storage	Store on flat surface, in a dry area.	

* EMC: Equilibrium moisture content.

Typical mechanical properties

Bending strength (longitudinal direction)	N/mm²	7.6
Tensile strength (longitudinal direction)	N/mm²	4.8
Compressive strength (perpendicular to the surface)	N/mm²	9.3
Screw pull out resistance: screw into board surface - 15mm deep	quick fix screw - 3.9 x 55 quick fix screw - 4.0 x 40 quick fix screw - 4.5 x 50 timber screw - 3.9 x 55 screw inserts (Rampa)	624N 584N 581N 550N 350N
Bolt pull through resistance (board thickness = 25mm)	Bolt M8, washer diameter 30mm	3.220N

Board weights (Kg/m³)

Thickness (mm)	Dry Weight	Weight (20°C, 65% RH)
8	ca. 7.2	ca. 7.6
10	ca. 9.0	ca. 9.5
12	ca. 10.8	ca. 11.5
15	ca. 13.1	ca. 13.9
20	ca. 17.4	ca. 18.5
25	ca. 21.8	ca. 23.1

* Project specific thickness can be manufactured in 1mm increments. Please contact Promat for further information

Quality assurance

Promat products are manufactured to stringent quality control systems to assure that our customers receive materials made to the highest standards.

Operating to these standards means that all activities, which have a bearing upon quality, are set out in written procedures. Systematic and thorough checks are made on all materials and their usage. Test equipment is subjected to regular checks and is referred back to national standards.

The information given in this data sheet is based on actual tests and is believed to be typical of the product. No guarantee of results is implied however, since conditions of use are beyond our control.

Processing & machining

When machining the product with power tools, do not breathe dust and respect the regulatory occupational exposure limits for total inhalable and respirable dust. Wear safety goggles. Avoid contact with skin and eyes. Use dust extraction. In case of insufficient ventilation, wear suitable respiratory equipment to avoid health effects.

Waste disposal

Refer to local legislation. If not available: the board is not classified as a dangerous substance and no special provisions are required regarding the carriage and disposal of the product to landfill. They can placed in an on-site skip with other general building waste.

All physical and mechanical values are averages based on standard production and tested according to internal procedures. The typical values are given for guidance. The figures can change dependent on the test methods used. If a particular value is of prime importance for a specification, please consult Promat Technical Department.

Notes

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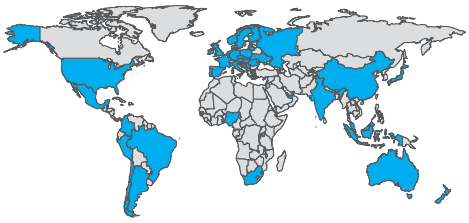

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