Port of Miami tunnel fire protection
A post-fixed facetted system, Promat®-T

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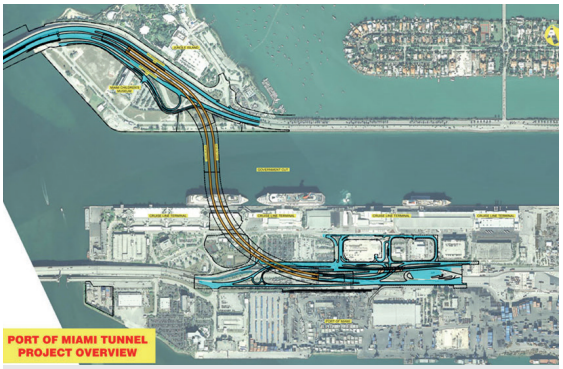
Project background

The Port of Miami Tunnel is a highway tunnel that directly connects the Port of Miami to highways via Watson Island to Interstate Highway, I-395. Nearly 16,000 vehicles travel to and from the Port of Miami (POM) through downtown streets each weekday. Truck traffic makes up 28% of this number (source: 2009 PB Americas Traffic Study). Existing truck and bus routes restrict the port's ability to grow, driving up costs for port users and present safety hazards.



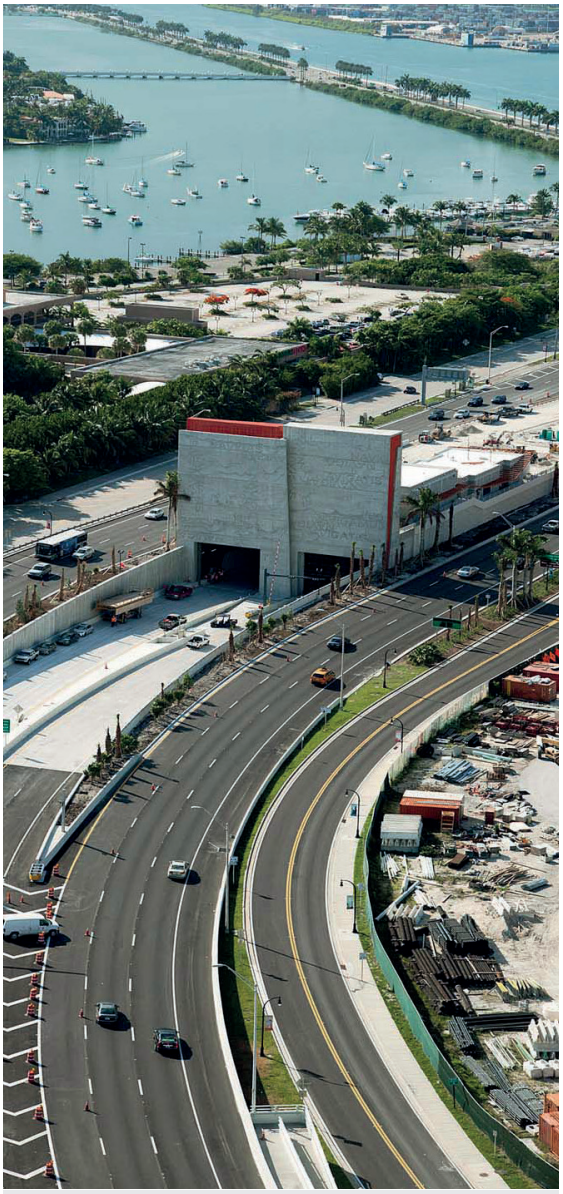
Port of Miami Tunnel Overview

The POMT is a public-private partnership (PPP) designed to transfer the responsibility to design-build-finance-operate-and maintain (DBOFM) the project to the private sector. The Public Sponsors are Miami-Dade County-Florida Department of Transportation (FDOT)-The City of Miami.

The project was launched in 2010 with work beginning on Dodge and Watson Islands while the Tunnel Bore Machine was being procured and built.

The Tunnel Boring Machine 43ft diameter arrive in Miami in June 2011. The Tunnel Bore Machine and trailing gear was assembled on Watson Island and began mining the Eastbound Tunnel towards Dodge Island November 2011. On July 2012 the mining of the Eastbound Tunnel was completed as the Tunnel Boring Machine broke out on Dodge Island – Port Miami. In 3 months the Tunnel Boring Machine was repositioned and launched from Dodge Island and began mining Westbound Tunnel towards Watson Island.

On May 2013, mining of the Westbound Tunnel was completed as the Tunnel Bore Machine broke out on Watson Island.



Port of Miami Tunnel Watson Island Portal

Port of Miami Tunnel Dodge Island Portal

Port of Miami Tunnel Breakout on Watson Island Portal

Companies involved

The Port of Miami tunnel project is a highly complex project which is being built through a Public-Private Partnership (PPP or P3) that includes design, build, finance, operation and maintenance of said project. It is a 35-year concession agreement between the Florida Department of Transportation (Owner) and MAT Concessionaire, LLC (Concessionaire), which includes 55 months for design and construction carried out by Bouygues Civil Works Florida (BCWF)

- Public Private Partnership (PPP)

  - Public Sponsors
    - Florida Department of Transportation (FDOT)
    - Miami-Dade County
    - City of Miami, Florida

  - Contractor
    - Bouygues Civil Works Florida (BCWF)

  - Operator & Maintenance
    - Transfield Services

  - Equity Partner
    - Meridian Infrastructure (90%)
    - Bouygues Travaux Publics (10%)

  - Federal Support
    - Federal Highway Administration (FHWA)
    - Transportation Infrastructure Finance and Innovation Act (TIFIA)

- Team Members

  - Florida Department of Transportation (FDOT) / Owner Team Members:
    - CSA Group – Construction Project Manager:
      CSA Group is a Full Service Project Delivery and Program Management company with strong engineering and architectural design history with Project Delivery services that extend from Feasibility Studies through project commissions, Maintenance and operations.
    - Stantec Consulting – Public Information Specialist
    - Parsons Brinckerhoff – Owner's Representative & Construction Engineering & Inspection Team
      Parsons Brinckerhoff is a global consulting firm assisting public and private clients to plan, develop, design, construct, operate and maintain thousands of critical infrastructure projects around the world.

  - MAT Concessionaire, LLC Team Members:
    - Concessionaire: MAT Concessionaire, LLC
    - Design Build Contractor: Bouygues Civil Works Florida (BCWF)
      Bouygues is a global player in construction services including designs, build and operates building and structures which improve the quality of people's living and working environment public and private buildings transport infrastructures and energy and communications networks. A leader in sustainable construction.
    - Jacobs Engineering
      Jacobs is one of the world's largest and most diverse providers of professional technical services, that include scientific and specialty consulting as well as all aspects of engineering and construction, and operations and maintenance.
    - Tunnel Operator / Maintenance: Transfield Services Industry
      Transfield Services is an operations, maintenance and construction services business, operating globally in the resources, energy, industrial, infrastructure, property and defense sectors.
    - Efectis Group – Efectis Nederland BV – Center for fire safety in the Netherlands
      Performed full scale fire test to determine the spalling temperature of the concrete segment lining

Technical Specification and Requirements

In order to comply with the Concessionaire Agreement requirements for the Cut & Cover, Cross –passages and Tunnel Sections, the Fire Protection had to meet NFPA-502 edition 2008. Chapter 7 applies: Road Tunnels - Section 7.3 Protection of Structural Elements

Section 7.3.1:

Regardless of tunnel length, all primary structural concrete and steel elements shall be protected in accordance with this standard in order to:

- maintain life safety and provide a tenable environment
- mitigate structural damage and prevent progressive structural collapse
- minimize economic impact

Section 7.3.2 defines the thermal design exposure to the concrete lining:

The structure shall be capable of withstanding the Rijkswaterstaat (RWS) time-temperature curve that is acceptable to the AHJ.

Section 7.3.3: defines the thermal failure criteria of the load bearing structures:

After a 120-minute period of fire exposure, the following failure criteria shall be satisfied:

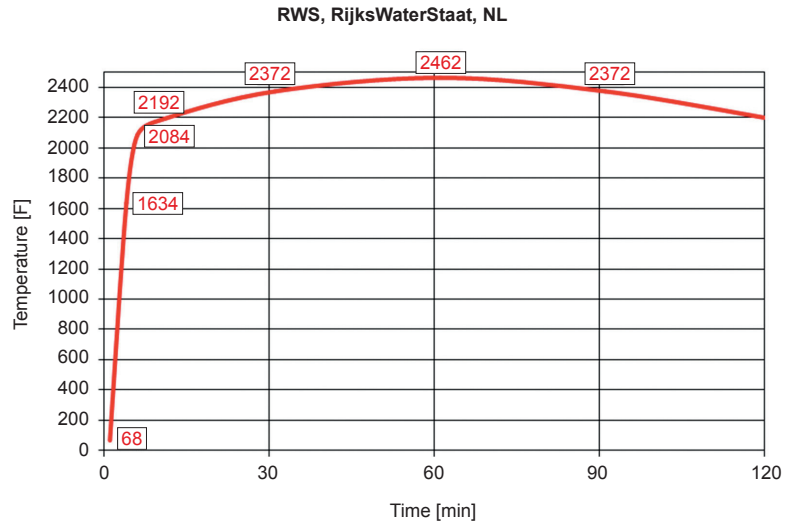
- Tunnels with Cast in–situ concrete structural elements shall be protected such that:
  - The temperature of the concrete surface does not exceed 380°C (783°F).
  - The temperature of the steel reinforcement within the concrete [assuming a minimum cover of 25mm (1in.) does not exceed 250°C (482°F).
- Tunnels with concrete structural elements shall be designed or protected such that explosive spalling is prevented.

Section 7.3.4: defines material properties of passive fire protection materials that are used for protection of structural linings. This aim, amongst others reasons, to prevent that such materials do not become a hazard in itself when exposed to fire.

Structural fire protection material where provided, shall satisfy the following performance criteria:

- the material shall be noncombustible in accordance with ASTM E 136 or equivalent international recognized standard.
- the material shall have a minimum melting temperature of 1350°C. (2462°F).
- it shall not produce toxic smoke or fumes under fire exposure in accordance with ASTM E 84 or equal international standard.

It shall meet the fire protection requirements with less than 5 percent humidity by weight and also when full saturated with water, in accordance with the approved time-temperature curve tested in accordance with RWS Fire Test Procedure 1998-CVB-R1161 (Rev.1).

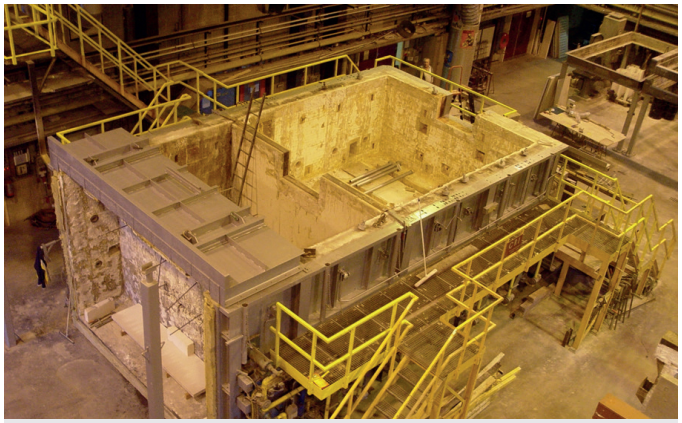


NFPA-502 RWS 120 minutes t-T curve

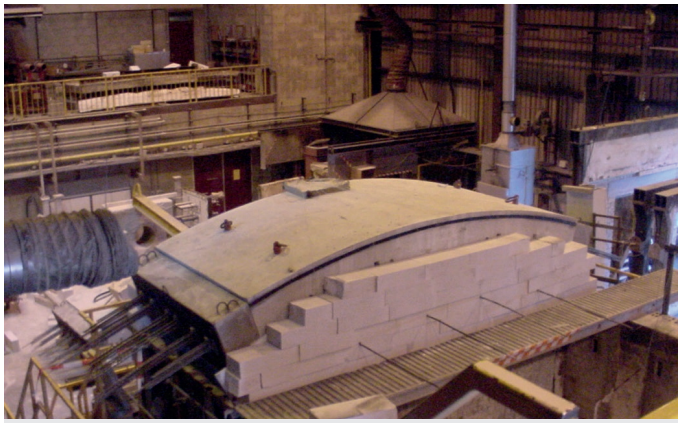
Fire testing options

Fire testing laboratory

The usual practice to conduct project specific fire tests for tunnels is to have segments or slabs sent from the project to an accredited fire testing laboratory. Project specific requirements such as time-temperature curve, restraint, realistic loadings etc. will be applied during a fire test. The advantage of this approach is that the exact concrete mix design and geometry are taken into account during such as test as the concrete specimen originates from the job site. Another advantage is that the full system is fire tested at once including all the system components such as anchors, anchors spacing, mesh for spray systems, gaps, joints etc.



Efectis full scale furnace



Efectis full scale furnace with loaded segment

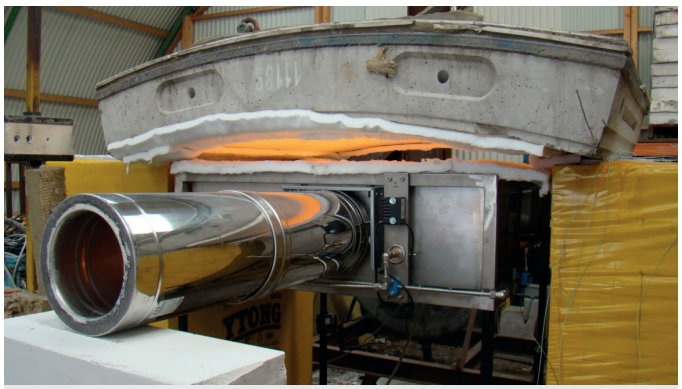
For spalling tests on pre-cast segments, however, the disadvantage is that one may be over estimating the thickness. The fact that no spalling has occurred during a fire test using a certain thickness, does not say anything about the accuracy of the chosen thickness to prevent spalling. A thinner thermal barrier may have provided sufficient thermal protection but that cannot be concluded from just one test, so another test will have to be conducted. As per the 2008 edition, NFPA 502 introduced the RWS fire testing procedure. At that time, the US based fire testing laboratories were not familiar with the RWS testing regime amongst other factors such as. The furnace lining, the burner capacity, and the adaption of furnace software to be able to run RWS type time-temperature curves. To the best of the authors knowledge, up until the date of this publication there is no accredited fire testing labs in the US that can run RWS fires for tunnel linings. However, the existing accredited labs will aim to comply with RWS testing requirements in the near future.

To mitigate this situation, the Port Of Miami Tunnel main contractor could have shipped 5 segments to Europe for fire testing purposes at approximately 20,000 lbs (9,070 kg) each. This would have resulted in substantial transportation costs.

As a result of the above, the Port Of Miami Tunnel main contractor commissioned Efectis The Netherlands to come up with an innovative solution, which resulted in the use of the mobile furnace.

Mobile furnace testing

In essence a mobile furnace is a gas fired insulated device (approximately a 4'x4'x3' box) which is left open at one of the 6 sides to expose a surface to a pre-set time-temperature curve. It has ventilation openings to control and extract the combustible gasses. It has a sleeve in the side in which a water cooled furnace camera will be installed to visually monitor the performance and behavior of the exposed surface.



Efectis full mobile furnace with segment

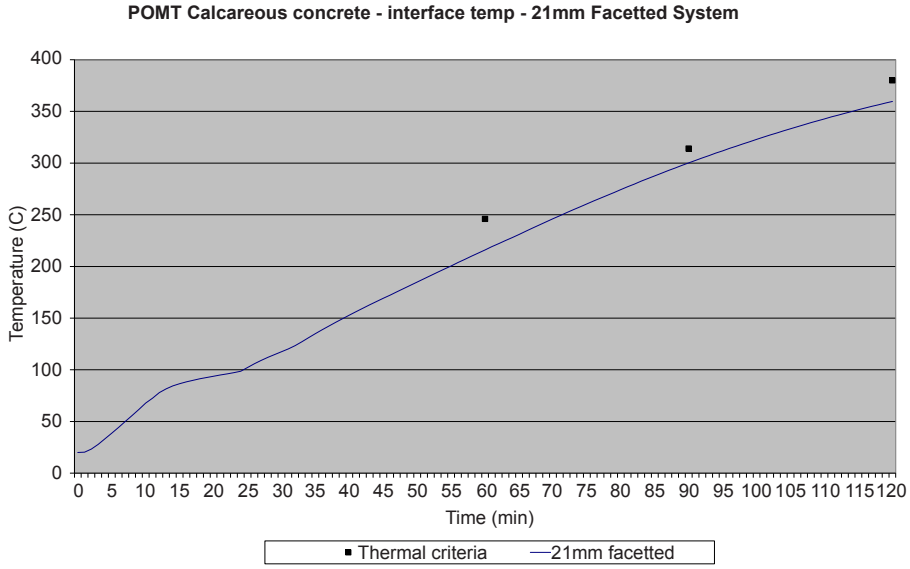
The first generation of mobile furnaces were not able to run RWS type fires, for which reason the expected interface time-temperature development was simulated. This was done by running a lower fire curve, with a limited amount of thermal protection on the concrete specimen. The second generation of mobile furnaces however is able to run a full RWS curve, in which case the expected thickness of the thermal protection in practice will be applied for testing.

In order to demonstrate that the proposed fire proofing material will meet the requirements listed in the "Technical Specification and Requirements", Bouygues Civil Works of Florida and Efectis Netherlands proposed to follow an innovative approach, which has been presented in Efectis report 2012-Efectis-R0528.

This approach can be summarized as follows:

- determination of the spalling temperature of the concrete precast segments used on the Port of Miami tunnel.
- verification of the proposed fire proofing systems with regards to its ability to fulfill the temperature criteria per NFPA 502 edition 2008.

Fire tests to NFPA-502 edition 2008 as referenced above were performed independently by Efectis in Miami, FL utilizing their Mobile test furnace during the month of May 2012. From these tests, it was concluded that the fire proofing material shall guarantee that the temperature at the interface with the concrete will not exceed the below maximum temperatures at the given times when the lining would be exposed to a 120 minute RWS fire.



Interface temperature versus requirements

Time	Maximum interface temperature (calcareous aggregates concrete)
60	246°C
90	314°C
120	380°C

Interface temperature versus requirements

The purpose of these tests was for the manufacturers to demonstrate that their proposed fire protection systems met these temperature requirements.

The advantage of the approach outlined above is that the exact time related spalling temperatures can be defined and that the exact thickness of the passive fire protection system can be determined. However, to be able to do just that thermal test data of system tests has to be available from previous fire tests. These tests should be compatible with the parameters of the specific tunnel i.e.:

- the concrete type and mix design
- the aggregate type (calcareous or siliceous)
- the tunnel diameter
- anchor type, location, spacing including washer details
- joint and gap details between boards
- mesh type and dimensions, applicable for spray systems
- concrete surface preparation regimes

Preferably the determination of the exact thickness, based upon the results of the mobile furnace tests, should be done by means of Finite Element calculations.

Mobile furnace tests can be conducted on site, not necessarily in the tunnel which, in the case of the Port Of Miami Tunnel project, it prevented transporting bulky pre-cast concrete segments to Europe.

The following is a brief description about the Efectis Group and of the Efectis Mobile Furnace test procedure:

efectis group

About Efectis

Efectis is the expert in fire science, engineering, design and modeling, risk analysis, testing, inspection and certification. Efectis covers all fire safety capabilities and know-how in testing and modeling around the world with offices and laboratories located in France, the Netherlands, Spain, Turkey, the USA and the Middle-East area.

For the Port of Miami project, on-site fire tests were done by Efectis. Efectis are the authors of the Rijkswaterstaat (RWS) standard for testing of fire protection for concrete tunnel structures. Many fire tests were done since the late 1970's, and the Efectis/RWS standard forms the basis of the relevant requirements in the NFPA 502 standard.

The MobiFiRe® mobile fire resistance furnace

In 2011, Efectis introduced the MobiFiRe® concept. MobiFiRe® is a Mobile Fire Resistance furnace for on-site testing. The main reasons for its development were the possibility to assess the fire resistance of concrete structures in existing situations, to do easily a large number of tests and therefore have a more accurate result, and to avoid expensive and time consuming transport of large concrete tunnel segments to a fire laboratory.

Different mobile furnaces were constructed to accommodate a range of fire curves, up to the RWS fire curve for tunnels with a maximum of 1350°C (2462 °F). In the mobile furnaces Efectis has combined its renowned expertise in fire resistance testing and on-site testing. The result of this is a fast and flexible setup which allows the fire test to be performed in a time frame of only a few hours after arrival on site.

Real-time filming from within the mobile furnace allows continuous observation of the tested structure. This can be used to support the analysis of the test. Even more importantly, for concrete test objects observation of the structure enables an instant "stop" of the test when concrete spalling begins. Therefore the damage to the structure can be kept to a minimum. In most cases, only the first few millimetres of the concrete surface need to be repaired.

The test surface of 1m^2 can be large enough to obtain reliable test results, but small enough to prevent unnecessary damage to the structure. The mobile furnaces can be applied to all kinds of structural elements, such as ceilings, floors, roofs and walls, and is suitable to operate safely even in stand-alone mode with its own gas and electricity supply, data logger and measurement computer.

Key advantages of MobiFiRe®

- freedom to choose the testing location;
- testing under fully realistic circumstances;
- avoid the cost of sending a team to witness a fire test;
- possibility to test non-movable existing structures, such as monuments and tunnels;
- cost-effective selection of passive fire protection system;
- for existing structures, no necessity of 90 days drying time of concrete slabs;
- easy testing of different alternative fire resistance solutions in real applications.

Fire tests for the Port of Miami Tunnel

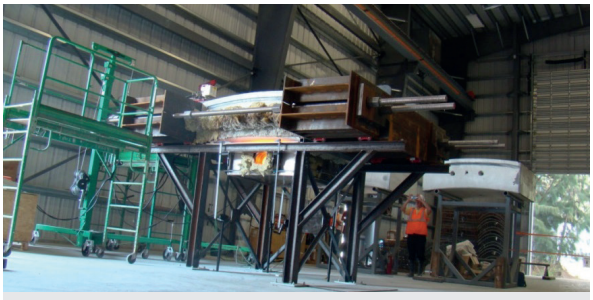
For the Port of Miami Tunnel needed to be protected with a passive fire protection material in order to fulfill the criteria given in NFPA 502 article 7.3, which requires that "tunnels with concrete structural elements to be protected such that explosive spalling is prevented".

To demonstrate the effectiveness of the fire protection system in the Port of Miami Tunnel against spalling of concrete, Efectis was asked by Bouygues Civil Works Florida to perform fire tests with the MobiFiRe® mobile furnace. The mobile furnace was fully prepared in the Efectis laboratory in The Netherlands, including the measurement system and other related equipment, in a light-weight design that was transported to Florida by airplane. Before transport, a complete pre-test was done to verify the correct functioning of the furnace.

On the construction site of the Port of Miami Tunnel, a steel loading frame for the concrete tunnel segments had been constructed by Bouygues according to the specifications of Efectis. This loading frame with hydraulic actuators was designed to represent the concrete compression level present in the real tunnel structure.

During a test series of one week, several fire tests on mechanically loaded tunnel segments were done with different levels of fire exposure. These tests enabled Efectis to determine the temperature criteria that should be fulfilled in order to prevent spalling of the concrete structure for this specific tunnel.

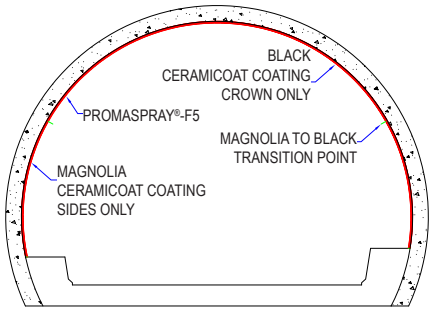
In the next phase of the project, Efectis performed a desk study to evaluate the product documentation provided by fire protection manufacturers in order to meet the established temperature criteria. An important part of the desk study was a detailed evaluation of the provided product test reports, e.g. according to the RWS/Efectis fire testing procedure 2008-Efectis-R0695, to verify their suitability for application in the Port of Miami Tunnel. Only test reports from independent fire laboratories were accepted. The evaluation encompassed the functionality of the full system, including the type and dimensions of the fire protection material, numbers and types of fixings and joint details between the boards. Based on the assessment of the passive fire protection systems Bouygues Civil Works Florida was able to select the best solution.



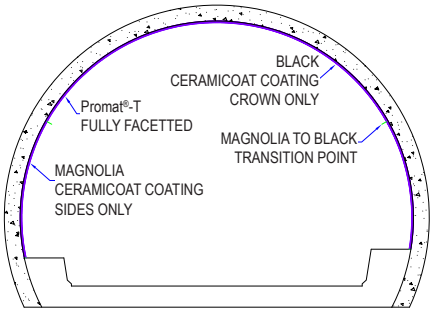
Port of Miami Tunnel Efectis mobile test setup

Other applications of the MobiFiRe®

- Beveren railway tunnel, Antwerp, Belgium
- Kennedy railway tunnel, Antwerp, Belgium
- Koningstunnel, The Hague, The Netherlands
- La Défense tunnel, Paris, France
- Maastunnel, Rotterdam, The Netherlands
- Port of Miami tunnel, Miami, USA
- Venray town hall, The Netherlands



Port of Miami Tunnel
PROMASPRAY®-F5 finish



Port of Miami Tunnel
facetted of postcurved layout

Fire protection options for circular tunnels

Spray system

The reason why the spray system was considered but disregarded is that the pre-cast concrete segments contained a curing agent, which has the (side) effect of causing very dense and non-permeable concrete at the surface. As a result any cement based spray-on passive fire protection material would suffer from bonding issues. The application of a spray system could have been technically justified if (1) the concrete aggregate would have been exposed by means of hydro-milling, causing environmental issues or (2) a structural metal lath would have been installed to the concrete lining to create proper mechanical bond to the concrete. Both means were judged not to be feasible or economical for this project.

Post curved board systems

Calcium silicate aluminate boards come as flat sheets and can be post curved on site to match the tunnel radius, depending on the required thickness and the radius. The board is pushed into the radius by means of manpower. The required thickness in the case of the Port Of Miami Tunnel was 22mm using the Promat®-T board. This system was considered but disregarded because the system was judged to be less forgiving during installation, due to the multiple compound horizontal and vertical curves of the alignment, potentially opening up gaps between the boards. This is a project specific judgment that needs to be made for every project on a case-by-case basis.

Facetted board system

This system consists of fire rated boards with backer strips at all joints, both the circumferential and the longitudinal joints between the main panels.

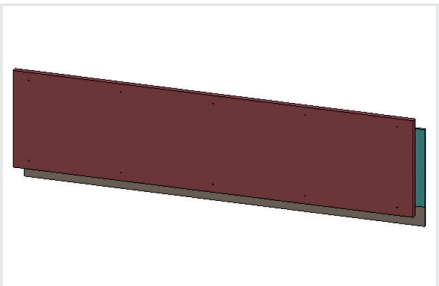
Promat Technical Offer, Main Tunnel

Outline of the system

For the Port Of Miami Tunnel the Promat®-T facetted board system is the passive fire protection system that got selected. It consists of fire rated boards with backer strips at all joints, both the circumferential and the longitudinal joints of the main panels. The main panels have dimensions of 2500 x 600mm (98.4 x 23.6 inches). Fire testing analysis showed the required thickness was 21mm (0.83 inches) to comply with the thermal requirements as per paragraph 4b. The Promat®-T backer strips are 120mm (4.75 inches) wide and 15mm (0.60 inches) thick.

The main panels and the backer strips are anchored to the concrete by means of 10 each - 6mm (1/4") mechanical expansion anchors (non-cut back anchors). ¼" x 4-1/4" - Sup-R-Stud Anchor with 30mm (0.12") both 316 stainless steel washers were selected due to specification requirement of USA - Domestic Manufactured. The distance of the anchors to the edge of the boards was 50mm (2") so the anchors would hold the main panel and the longitudinal backer strips in place. The anchors are spaced equally at 600mm (24").

The circumferential backer strips are held in place in between the two anchored longitudinal backer strips.



Port of Miami Tunnel
facetted panel with backer strip

Port of Miami Tunnel
facetted panel anchor layout

Port of Miami Tunnel
facetted panel backer strip

Thermal justification of the system

Existing test data provided sufficient thermal information on system performance of the proposed system, apart from some very project specific parameters, which are the tunnel radius and the specific anchor type. The radius has an effect on the dimensions of the gap behind the main panel and therefore the volume of air that will absorb the heat. Due to the "Buy America Act" for steel components, the application of European anchors that had already been fire tested for previous projects was not feasible. The intended anchors had not been fire tested to RWS time-temperature curve prior to this project. Both the radius and anchor issues were addressed by means of an independent fire test at Efectis Netherlands, which completed the total technical offer. The aim was for the test specimen to survive 120 minutes RWS exposure, whereas it achieved 180 minutes.

Joint detail between the main panels

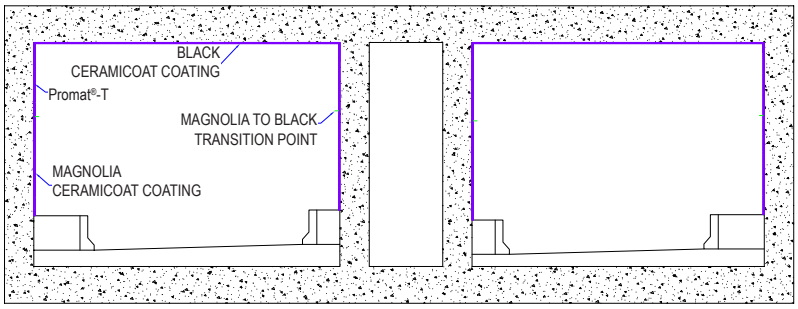
The Port Of Miami Tunnel has 900 feet radius horizontal curves and 1500 feet radius vertical curves; at some locations these were compounded. The tunnel internal diameter is 37 feet. These parameters, along with tolerances on the segment installation, dimensional tolerances on the fire protection boards and installer error posed the question of the maximum allowable gap between the main panels, such that the thermal criteria as listed in paragraph 4b are not exceeded. Through additional finite element calculations concluded that a maximum gap of 19mm (3/4") could be allowed. It was expected by the installation crew that the maximum gap between the main panels would not be over a 1/4". This made the facetted board system a forgiving system to install and would allow for an acceptable degree of installer error without jeopardizing the thermal performance of the system.

Final judgment by Efectis Netherlands

The main contractor had commissioned Efectis Netherlands to judge the proposed passive fire protection systems and analyze the test data from previous fire tests, mechanical tests, material properties tests and accessories. The conclusion was drawn that the above detailed facetted system met all the requirements and was suitable for application in the Port Of Miami Tunnel. Efectis has concluded this in their letter with reference 2012-Efectis-B0195: A.J. Breunese and M. Vermeer.

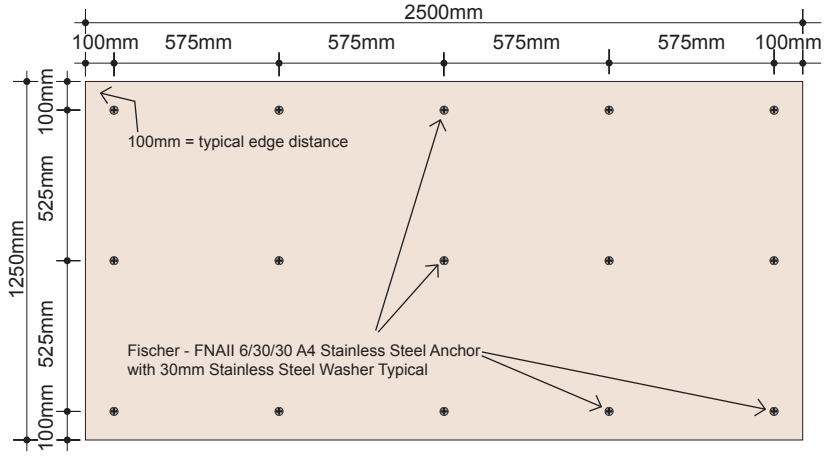
Promat Technical Offer, Approaches – Cut and cover areas

The approaches of the Port Of Miami Tunnel have been constructed using cast-in-situ concrete. The thermal criteria, as per NFPA502-2008 edition, are listed in paragraph 3 of this document. Test data and finite element calculations using conservative values lead to the required material thickness of 22mm using the Promat®-T board. These boards were installed butt jointed using 6mm (1/4") mechanical expansion anchors (non-cut back anchors).



Port of Miami Tunnel post fixed cut and cover

A typical distribution of the anchors on a full size panel looks as depicted below:

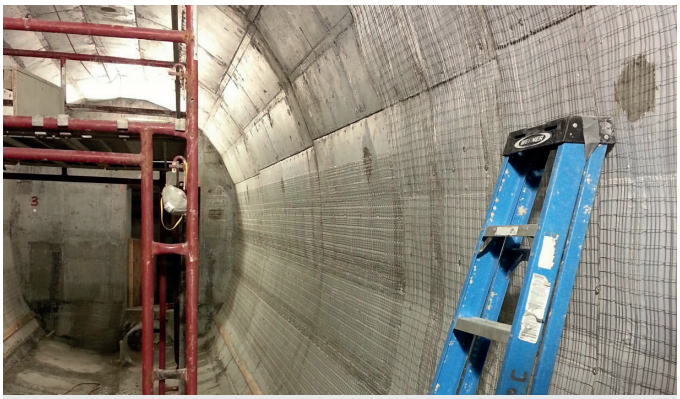


Port of Miami Tunnel anchor layout - cut and cover

Port of Miami Tunnel typical anchor

Promat Technical Offer, Cross Passages

The cross passages of the Port of Miami tunnels were constructed using cast-in-situ concrete. The thermal criteria, as per NFPA-502 2008 edition is listed in paragraph 3 of this document. Test data and finite element calculations using conservative properties lead to the required material of 40mm using the PROMASPRAY®-F5, which is high density cement based wet mix spray mortar fire protection. The PROMASPRAY®-F5 was reinforced with Stainless Steel 316/A4 Profiled Mesh – 2" x 2" – Profile Depth 5/8". The Stainless Steel Mesh was fixed with Promat® Mesh Retaining Anchors Stainless Steel 316 Anchors at 24" centers. Prior to the installation of the profiled mesh, a Promat® SBR Keycoat is required. The function of the Keycoat is to provide a tough, textured and strongly adhering mechanical key under ambient conditions for subsequent coats of PROMASPRAY®-F5. Surfaces must be free of contamination and release agents before application.



Port of Miami Tunnel
cross passage stainless steel profiled mesh

Port of Miami Tunnel PROMASPRAY®-F5 applied with a semi textured finish

Installation Guide and Experiences

Method of installation

Preparation of the works

Storage: boards shall be stored in a dry and protected area.

Material Check: check the board surface and edges for damages and imperfection. Check anchors, washers and nuts for right dimensions.

Initial centerline crown installation

Installation procedure

The installation sequence was to be a top and down installation, which provides the advantage to prevent damage to the boards during handling and securing. The sequence of installation can be summarized as follows:

Sequence summary:

1. Assess tunnel liner conditions at the locations prior to installing boards,
2. Mark center line crown of tunnel, by chalk line,
3. Mark drill holes on board with a template (wooden strip, drywall screw hammer), as per the installation drawings,
4. Bevel edges with hand held rasp to create small flat area where panels edges meet,
5. Pre-drill holes,
6. Fix all 4 backing strips to the board with staples,
7. Bring 1st board into exact position,
8. Fix board with wall jacks (2 per board),
9. Drill 10 holes for anchors,
10. Set the anchors with pneumatic hammer until washer touches board then tighten stainless steel nut with nylon insert with battery driver,
11. Bring the 2nd board into position (without backing strip), butt jointed to 1st board,
12. Check that butt joint with adjacent boards and use hammer and wood strip to tighten the joints as much as possible without damaging the board edges. In case of gap greater than recommended by manufacturer, cut the board to fit or change the board,
13. Drill (*) 5 holes next to the upper adjacent board already installed,
14. Set the anchors with pneumatic hammer until the washer touches board then tighten stainless steel 316 nylon nut with battery driver,
15. Slide in the 2 backing strips and bring in position,
16. Drill 5 holes for anchors on the lower edge of board,
17. Set the anchors with pneumatic hammer until washer touches board
18. Tighten the stainless steel nut with nylon insert with battery driver,
19. Repeat steps 11-18 for adjacent boards,
20. The last board in a ring needs to be cut to fit leaving a gap > 1'' to the walkway and jersey barriers.

Note: (*) when anchors are found to be falling either into bolt or lift recesses, or near a segment joint, move the anchors position in order to guarantee at least 3" to the edge of concrete. Add the necessary anchors to guarantee a maximum spacing of 575mm as per plan.

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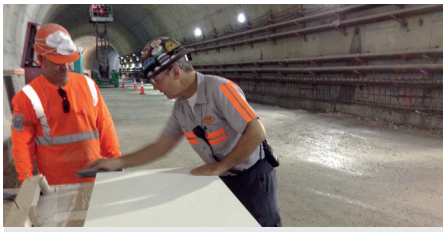
Port of Miami tunnel fire protection
A post-fixed facetted system, Promat®-T

Template for marking holes



Beveling edge

Pre-drill hole

Setting anchor with pneumatic hammer

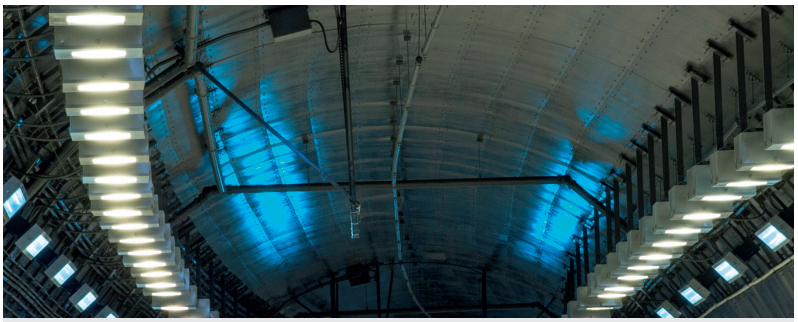
Tighten stainless steel nut with battery driver

Installing 2nd board to adjacent

Slide backing strips into position

Side view of panels with leading backer strip for adjacent panel installation

Installation of panels through curve



Finished tunnel lining

Finished tunnel

Project References Promat Tunnel Fire Protection

The Promat®-T Fireboard system has been designed specifically for underground transport systems.

Year	Country	City	Tunnel Project	Type of Tunnel	Details
2012	Netherlands	Amsterdam	IJ Tunnel Renovatie phase:2	Road Tunnel	Fire Curve: RWS 2 hours
2012	Great Britain	Newcastle	Tyne tunnel Refurbishement	Road Tunnel	Fire curve : RWS 2 hours
2011	Netherlands	Leiden	A4 Stalen Aquaduct	Road Tunnel	Fire Curve: RWS 2 hours
2011	Germany	Hamburg	Elb Tunnel	Road Tunnel	Fire Curve: ZTV 30 ceiling Promat®-T On subframe
2011	Netherlands	Amsterdam	IJ Tunnel Renovatie phase:1	Road Tunnel	Fire Curve: RWS 2 hours
2011	Norway	Trondheim	Vaernestunellen	Road Tunnel	Fire Curve: RWS 2 hours
2010	France	Paris	A14 Bretelle de La Défense	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2010	France	Marne	Nogent-sur-Marne	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2010	France	Paris	Porte d'Italie	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2010	France	Lyon	Broteaux	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2010	Great Britain	Dartford	M25 Dartford Crossing West Bore Refurbishment	Road Tunnel	Fire Curve: RWS 2 hours
2010	Great Britain	Newcastle	New Tyne Crossing (TT2)	Road Tunnel	Fire Curve: HCM 2hrs
2010	France	Paris	A6b	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2010	France	Paris	Bretelles Nanterre	Road Tunnel	Fire Curve: HCM 2hr + ISO834 4hr
2010	France	Paris	Parc des Princes	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2009	France	Paris	A14-86 La Defense Paris	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2009	France	Nanterre	Gare De Nanterre	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2009	France	Lyon	Lyon	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2009	France	Fouragere	Fouragere	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2009	France	Yvelines	Saint Germaine	Road Tunnel	Fire Curve: HCM 2hr + ISO834 4hr
2009	France	Marseille	Parette Tunnel	Road Tunnel	Fire Curve: HCM 4hr + ISO834 4hr
2009	France	Marseille	Joliette Tunnel	Road Tunnel	Fire Curve: HCM 2hr + ISO834 4hr
2009	France	Paris	Picasso Tunnel	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2009	Great Britain	Birmingham	Holoway Circus Phase1	Road Tunnel	Fire curve : RWS 2 hours
2008	France	Saint Germain	A14 Saint Germain-en-Laye	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2008	Monaco	Monaco	A500 Tunnel	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2007	France	Orelle	Orelle	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2007	France	Orly	Orly	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2007	Scotland	Glasgow	Clyde tunnel	Road Tunnel	Fire curve : RWS 2 hours, 2 layers 15mm Post Curved
2006	France	Mont Sion	Mont Sion	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2006	France	Monaco	Monaco	Road Tunnel	Fire curve : RWS 2 hours, 2 layers 15mm Post Curved
2006	France	Monaco	Monaco	Road Tunnel	Fire curve : RWS 2 hours, 2 layers 15mm Post Curved
2005	France	Lioran	Lioran	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2004	France	Chamioise	Chamoise	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2004	France	La Parette	La Parette	Road Tunnel	Fire curve : RWS 2 hours, 2 layers 15mm Post Curved
2004	France	Porte des Lilas	Porte des Lilas	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2004	France	Puymorens	Puymorens	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2004	France	Siaix	Siaix	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs
2004	France	Toulon	Toulon	Road Tunnel	Fire Curve: HCM 2hrs + ISO834 4hrs

Reference List

RWS Fire Test:

- 2000-BVC-R02482 RWS 120 minutes fire test: Dr. Ir. C. Both and Ing R.D. Scheepe - TNO Building and Construction Research, Centre for Fire Research, Delft/Rifswik, The Netherlands
  - Thermal performance of Promat®-T when exposed to 120 minutes RWS fire curve, tested in accordance with 1998-CVB-R1661 rev.1 as per NFPA requirements. These tests demonstrate the performance of the Promat®-T Board against RWS with the maximum edge distance of anchors of 100mm and the maximum span between anchors of 575mm.
  - These tests have been performed on two thicknesses of Promat®-T Panels (15mm and 30mm), and have allowed Efectis to develop a software to determine the required thickness of Promat®-T board based on the targeted interface temperature.
- 2000-CVB-R02482 English Summary STUVA
  - A summary of the test setup, test regime and test results by independent engineering office for underground facilities STUVA, Germany
- 2012-Efectis-R9440b: A.J. Breunese and M. Vermeer Efectis Nederland BV Centre for Fire Safety, Rijswijk, The Netherlands
  - Assessment of structural integrity of 22mm Promat®-T boards when mounted as a facetted lining - 180 min RWS duration

- 2012-Efectis-B0195: A.J. Breunese and M. Vermeer
  - Justification letter of Promat®-T Facetted System for POMT in regards to POMT-BF-2380-00020-00-FSB – Bouygues-Civil-Works-Florida
- IBS 14854 Water Saturated RWS 180 minutes fire test: IBS-Institut fur Brandschutztecnik und Sicherheitsforshung, GmbH, Linz, Austria
  - This test demonstrates the integrity of Promat®-T when water saturated and exposed to 180 minutes RWS fire, as the Promat®-T boards do not spall under these saturated conditions.
- IBS 14854 Water Saturated RWS 180 minutes fire test – English summary STUVA
  - A summary of the test setup, test regime and test results by independent engineering office for underground facilities STUVA, Germany.
- 2012 – Efectis-R4011 Facetted System: A.J. Breunese and T.B. van der Waart van Gulik, Efectis Nederland BV Centre for Fire Safety, Rijswijk, The Netherlands
  - Efectis statement related to the applicability of the Efectis validated software for determining the material thickness for the facetted system.
  - Evaluation for the suitability of the software for facetted system and the use of Promat®-T and Promat®-H as cover strips in the facetted system.
- Efectis reports 2010 – Efectis-R0437 and 2008-Efectis-R0045
  - This report demonstrate the stability of the Promat®-T boards under RWs fire conditions without taking advantage of the concrete cooling effect. It clearly shows that the Promat®-T boards do not melt nor deform under RWS fire conditions.
- Efectis Nederland-Report 2012-Efectis-R9102.131: A.J. Breunese and T.B. van der Waart van Gulik, Efectis Nederland BV Centre for Fire Safety, Rijswijk, The Netherlands
  - Computational Fluid Dynamic report for Promat®-T 21mm with Promat®-T 15mm cover strips and allowable maximum gap
- Efectis reports 2007 – Efectis-R0459 and 2008-Efectis-R0045 (reference only - proprietary to Promat)
  - These reports were for the development and validation of the Efectis Finite Element software owned by Promat Intl. These reports are not made publicly available. The outcome of the finite element calculations provided can be cross checked by Efectis. Promat is willing to get the Efectis approval of the finite element calculations provided.
  - FEM Calculation – Promat®-T 19.0mm – Average Values
  - FEM Calculation – Promat®-T 21.7mm – Conservative Values
- NFPA-502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways Edition 2008, NFPA, 1 Batterymarch Park, Quincy, MA – An International codes and Standards Organization

General tests

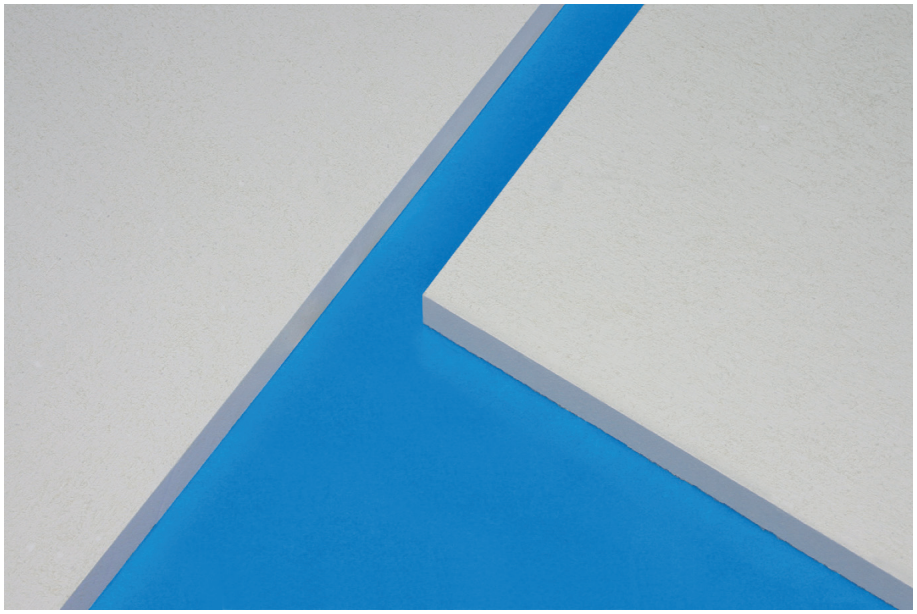
- Non-Combustibility in accordance to ASTM E-136 or equivalent - 2012-Efectis-R9101.149b: S.D Nieuwendijk and C.C.M. Steinhage, Efectis Nederland BV Centre for Fire Safety, Rijswijk, The Netherlands
  - Assessment of the non-combustibility of Promat®-T, tested according to the EN ISO 1182:2010 compared to the ASTME E-136-12 - Non-combustibility in accordance with ASTM E 136 or equivalent
  - Promat®-T is non-combustible (A1) in accordance with EN13501-1.
  - Promat®-T is non combustible in accordance with ASTM E 136
- Flame Spread – ASTM E84 or equivalent - 2012-Efectis-R9101.149c: S.D Nieuwendijk and C.C.M. Steinhage
  - Assessment of the performance of Promat®-T, according to the ASTM E-84-12b according to the EN ISO 1181:2010
- Melting temperature above 1350°
  - TNO – November 2000 (2000-CVB-R02482), IBS 14854 – September 2002
- Water resistance
  - AT040909 Water Erosion Test – May 23, 2005
  - AT050601 Water Impermeability Test – May 23, 2005
  - IBS 14854 – September 2002
- Pressure and suction loading test (fatigue)
  - AT041208 – Dynamic load test 15mm Promat®-T on strips – April 28, 2005
- Abrasion resistance
  - DIN 53778 T2, edition 1983, with 800 abrasion cycles directly on the board surface: MPA 220003473-03 – April 2004
- Wear resistance
  - REDCO – R200418615 – December 2004 – According to ASTM C501-80
- Impact resistance
  - Resistance to impact as following Swiss regulation RdT 31-a-1.1 – July 2005

General certification

- ISO 9001:2008
- ISO 14001:2004
- OHSAS 18001:2007

Promat

Promat®-T
Matrix Engineered Mineral Board



Introduction

Promat®-T is part of a new generation of high performance board products with multiple advantages for the protection of concrete structures and the protection of escape routes, fire doors, cable systems and ventilation systems.

Designed to provide protection solutions for use within the most severe of fire scenarios; as defined by the RWS fire curve; Promat®-T provides not just a barrier to the passage of fire, but in a way that ensures the substrate being protected is kept cool in a controlled manner.

Advantages

- Easy to install, the application of Promat®-T can be achieved on existing tunnels without total elimination of the traffic.
- The engineered matrix of Promat®-T allows for reduced fire protection thicknesses (by up to 50%) for equivalent concrete interface temperatures.

Applications

- Tunnel lining, concrete floor and wall upgrading
- M&E services enclosure
- Access panels and hatches, fire door

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.

Simple and easy to install, Promat®-T can be applied within existing tunnels without the need to completely close off all traffic lanes.

The engineered matrix of Promat®-T provides a superior performance that allows for a reduction in the required fire protection thickness for equivalent concrete interface temperatures to much thicker competitor products and systems.

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	Calcium silicate-aluminate fire protective board with outstanding performance for protection of concrete and cast iron tunnels.	
Combustibility	EN 13051-1:A1 (Classification Report WFRGent 11536C)	Non-combustible A1
Board format (length x width)	mm	1200 x 2500 - 1250 x 3000 (not for all thickness)
Board thickness	mm	15, 20, 25, 30, 35, 40
Tolerances on length and width	mm	± 0.5
Density (nominal, oven dry)	Kg/m^3	ca. 900
Alkalinity (approximate)	pH	10
Thermal conductivity λ (ASTM C518-75)	W/m°K	ca.0.212 (at 20°C)
Thermal shrinkage	3 hrs 950°C 3 hrs 1250°C	1.7 4.0
Coefficient of expansion α (100 to 20°C)	m/m°K	-8.3×10^{-6}
Water absorption	g/cm^3	0.60
Moisture diffusion resistance	μ	ca. 5
Moisture movement (ambiant to saturated)	mm/m	0.84
Typical moisture content (at EMC*)	%	5
Surface condition	Front face: smooth, sanded Back face: lightly honeycombed textured Colour: greywhish white	
Storage	Store on flat surface, in a dry area.	

*EMC = Equilibrium moisture content

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.

Mechanical properties
(based on average product data)

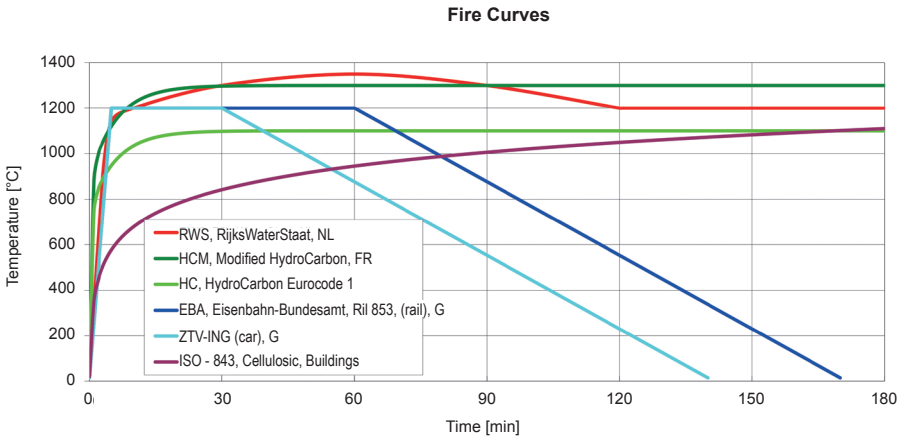
Bending strength (longitudinal direction)	N/mm^2	4.5
Tensile strength (longitudinal direction)	N/mm^2	1.2
Compressive strength (perpendicular to the surface)	1% deformation (N/mm^2)	1.2
	10% deformation (N/mm^2)	7.8
Screw pull out resistance: screw into board surface	quick fix screw - 5.0 x 50	20mm deep airdry: 657N
		20mm deep saturated: 372N
Bolt pull through resistance (board thickness = 25mm)	Bolt M8, washer diameter 30mm	3.220N

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.

Types of fire exposure



In recent years a great deal of research has taken place internationally to ascertain the types of fire which could occur in tunnel and underground spaces. This research has taken place in both real, tunnels and laboratory conditions.

As a consequence of the data obtained from these tests, a series of time/temperature curves for the various exposures have been developed as detailed.

Additional data

Water permeability	The standard board is impermeable according to EN 492 (DIN 492). If the board is continuously exposed to water, a special impregnation has been developed to prevent water absorption and the associated increase in board weight. Accidental exposure to water does not affect the characteristics of the board when dried afterwards.	
Water absorption	g/cm^3	0.6
Moisture Movement	mm/m	Air dry to saturated: 0.84
		Saturated to oven dry: 1.06
		Air dry to oven dry: 0.47
		Oven dry to saturated: 1.19
Coefficient of Thermal Expansion	m/mK	20°C to 105°C 8.3 x 10^{-6}
Thermal shrinkage	%	3 hours at 950°C: 1.5
		3 hours at 1250°C: 4.0
Melting point	°C	>1,400
Abrasion Resistance (taber test – weight loss after 1000 turns)	g/m^2	4,600
Freeze/Thaw Resistance	Using the method for accelerated ageing developed with the STUVA, consisting of 100 cycles of 24 hours per cycle of heat/rain and freeze/thaw, the board does not degrade and retains with its mechanical properties and performance characteristics. A slight flaking of the surface could be possible. If exposed to continuous water soaking and freeze/thaw, Promat recommend the use of impregnated boards. These boards are able to withstand the tests as described in the norm B3303 (designed to testing concrete to freeze/thaw cycles).	

Board weights (Kg/m^3)

Thickness (mm)	Dry Weight	Weight (20°C, 65% RH)
15	ca. 14,8	ca. 15,6
20	ca. 19,8	ca. 20,8
25	ca. 24,7	ca. 25,9
30	ca. 29,7	ca. 31,2
35	ca. 34,6	ca. 36,4
40	ca. 39,6	ca. 41,6


Manitowoc
18000
MERCIANT
OVERSIZE LOAD


DELUGE
ZONE
2

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