

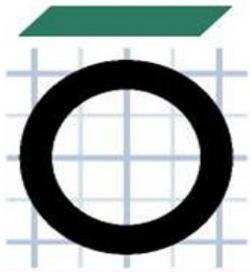
Activity Group Lining & Waterproofing

Progress Report

Tom Melbye



- The first topic this AG tackled has been best practice guidance on the use of spray applied waterproofing membranes
- Spray membranes are a relatively new technology and there are no international standards or specifications
- The AG formed a team of cross-industry experts and suppliers of membrane technologies
- During 2012 and 2013 the team has produced, through regular meetings, and design review, an harmonised guidance document for the tunnelling industry



ITAttech

The Activity Group Team

Tom MELBYE (Chair)	Normet Group
Tim BABENDERERDE	Babendererde Engineers GmbH
Klaus BONIN	Wacker Chemie AG
Ross DIMMOCK	Normet UK
Simon GREENSTED	Stirling Lloyd Polychem Ltd.
Bethan HAIG	Normet UK
Thomas KOTHE	BASF Construction Chemicals Europe AG
Stefan LEMKE	Sika Services AG
Kiril MASLEV	Hydromat Ltd
Matthias REINHOLD	Hagerbach Test Gallery Ltd.
Ernando SARAIVA	BASF Construction Chemicals Europe AG
Giorgio TANSINI	MAPEI S.p.A.
Volker WETZIG	Hagerbach Test Gallery Ltd.

- The UK BTS-ICE Specification is too broad, but a good start
- The project based specifications are too project specific
- The key membrane suppliers guidance and method statements are too product specific
- The tunnelling industry needed a better document with the latest requirements and test methods
- We needed to harmonise and give good advice to the industry if we could!



ice
Specification for tunnelling
Third edition

British The Inst

Section KW20

Materials and Workmanship Specification-
Spray Applied Waterproofing Membrane
Systems for SCL Works

Document Number: C121-MMD-Z4-RSP-CR001-00003

Document History

Revision	Date	Prepared by	Checked by	Approved by	Reason for Issue
7.0	16-09-10	B Haig	A Digne	M Murray	For acceptance

CROSSRAIL CENTRAL (PDP) REVIEW AND ACCEPTANCE STATUS
This deal is to be used for submitted documents requiring acceptance by Crossrail Central.

<input type="checkbox"/>	Code 1. Accepted. Work May Proceed
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<input type="checkbox"/>	Code 4. Received for information only. Receipt is confirmed
Reviewed/Accepted by (signature)	
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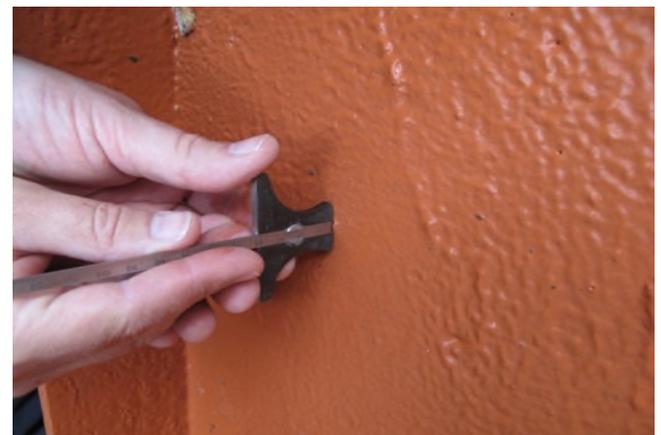
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- The team has developed an international document with key sections providing current best practice guidance on:
 - Design aspects
 - Model specification
 - Accreditation and training approach
 - Quality control records
 - Example detail drawings
 - Reference projects
- The document also highlights potential suitable applications for spray membranes



- Addresses drained and un-drained tunnel design options
- Interfaces with other membrane systems
- Technical properties of membranes
- Dealing with water ingress during construction to allow successful installation
- Trials and testing for assured performance
- Application guidance and quality control during construction
- Design concepts such as composite action for further efficiencies



- Enhanced pre-works material performance requirements and test methods compared to earlier specifications
- Workmanship requirements for successful installation focusing on:
 - Substrates
 - Water ingress management
 - Dealing with defects and repairs
- Quality control regime, records and test methods
- Supervision regime requirements

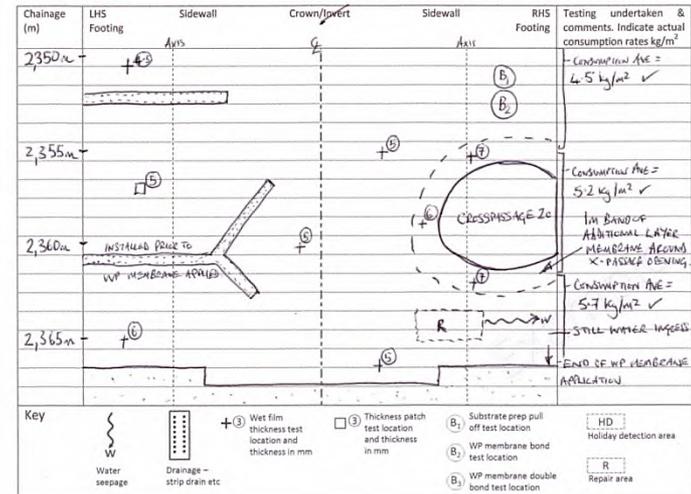
Spray Applied Waterproofing Membrane – Quality Control Check Sheet

Project: Metrosub 10, UK



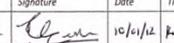
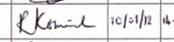
Tunnel/Structure	SOUTHBOUND RUNNING TUNNEL		Date/Time	10/01/12 14:30			
Regulating Layer	<input type="checkbox"/>	Required thickness	mm		Shift/Team	SHIFT B	
Waterproofing membrane	<input checked="" type="checkbox"/>	Required thickness	4 mm	Approved Applicator Name	A. N. OTHER		
		Req'd consump' rate	4 kg/m ²	Certificate No.	95765		
Secondary lining	<input type="checkbox"/>	Required thickness	mm		Ambient Temp.	17°C	
				Substrate Temp.	15°C	Rel. Humidity %	75%

Plan of structure

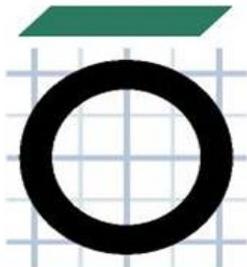


Inspection & Approvals

<input checked="" type="checkbox"/>	Regulating layer approved
<input checked="" type="checkbox"/>	Spray wp membrane approved CH 2350 to CH 2363m
<input type="checkbox"/>	Secondary lining approved
<input checked="" type="checkbox"/>	Section not approved CH 2363 to CH 2364m
Re-inspection date/time: 11/01/12 @ 14:00	

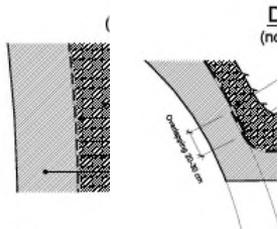
Representative	Name	Signature	Date	Time
Contractor Representative	T. EYBLEM		10/01/12	14:30
Supervisor Representative	R. KEMMIS		10/01/12	14:38
Client Representative	B. GINN		10/01/12	14:40

Details of re-work to permit approval:
WATER INGRESS AT CH 2364 NEEDS ADDRESSING.



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Example Drawing Details



Note 1:
The receiving substrate membrane. It shall be according to the m

Note 2:
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Note 3:
Dimpled sheet strip the tunnel crown a the groundwater a drainage level with to membrane appli

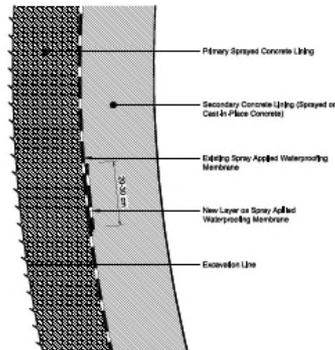
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Note 1:
The receiving substrate shall be appropriate for application of the spray applied waterproofing membrane. It shall be treated (smoothing layer and/or primer) prior to membrane application according to the membrane supplier's instructions and/or to the Work Specification.

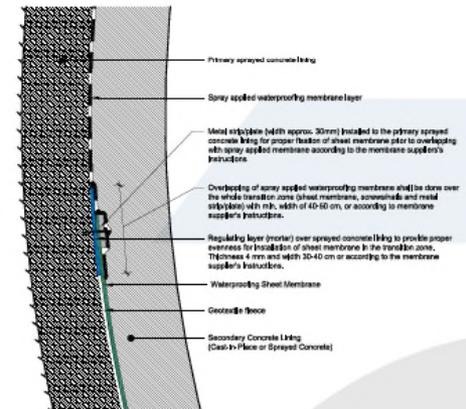
Note 2:
Overlapping shall be done according to supplier's instructions, the existing membrane shall be properly cleaned and inspected prior to application of the new membrane to build and overlap, according to supplier's instructions.

Note 3:
This drawing and all included details are only illustrative. Detailed design shall be done by the design engineer based on the specific project requirements.



Sprayed concrete Lining with Spray Applied Waterproofing Membrane			
Detail of Cross Section with Membrane Overlapping			
NO.	REVISION	DATE	BY
1			
		CBL-WP Detail_100	

(not to scale)



Note 1:
The receiving substrate shall be appropriate for application of the spray applied waterproofing membrane. It shall be treated (smoothing layer and/or primer) prior to membrane application according to the membrane supplier's instructions and/or to the Work Specification.

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This drawing and all included details are only illustrative. Detailed design shall be done by the design engineer based on the specific project requirements.

Sprayed concrete Lining with Spray Applied Waterproofing Membrane			
Detail of Cross Section, Insertion with a Waterproofing Sheet Membrane			
NO.	REVISION	DATE	BY
1			
		CBL-WP Detail_110	

Project details Design approach Application approach & control Benefits



1 >> GISWIL ROAD ESCAPE TUNNEL, SWITZERLAND



6 >> CROYDON CABLE TUNNEL, UNITED KINGDOM



3 >> TORONTO TRANSIT SHEPARD LINE EXTENSION, CANADA



1.1. PROJECT DETAILS

The 2,066 m long Giswil road tunnel in the Canton of Obwalden, Switzerland, was opened in 2004. It provides a bypass for the town of Giswil. The project consists of a two-lane road tunnel and an emergency escape tunnel running approx. 20 m parallel to the main tunnel. Connections between the main tunnel and the emergency escape tunnel are provided every 300 m. The tunnel was excavated in rock by the cut-and-blast method. The portal zone were built as cut-and-cover sections. The emergency escape tunnel was excavated by a 4 m diameter hard-rock TBM and partly by the cut-and-blast method. The project owner is the Canton of Obwalden and the total project cost is approx. CHF 150 million.

1.2. DESIGN APPROACH ADOPTED

The spray applied waterproofing membrane MASTERSEAL 345 was installed as a fully-linited (non-oriented) waterproofing system in between two sprayed concrete linings in the southern part of the emergency escape tunnel (area of approx. 2,000 m²).

1.3. APPLICATION APPROACH AND CONTROL

MASTERSEAL 345 application was done by manual handhold nozzle, as described in the following:

- 1- Treatment of water seepages through the substrate with PU and acrylic injection
- 2- Cleaning of the substrate with water and air
- 3- Application of MASTERSEAL 345 (min. 3 mm) on the tunnel bench and crown (70-80 m²/hr)
- 4- Installation of the secondary (inner) lining one day after membrane application
- 5- Installation of the primary lining in the invert
- 6- Cleaning of the substrate in the invert



7- Application of MASTERSEAL 345 (min. 3 mm) onto the substrate in the invert (70-80 m²/hr)
 8- Installation of the secondary lining in the invert one day after membrane application.
 Quality control was done mainly by measuring the membrane curing status and achieved membrane thickness, as well as thorough inspection of the cured membrane surface before application of the secondary (inner) concrete layer. Furthermore, groundwater pressure has been monitored since 2004.

1.4. PROJECT BENEFITS

- The related project benefits include:
- No water ingress since installation in 2004.
 - Continuous membrane application with full membrane coverage.
 - Compatibility with other sealing systems.
 - Continuous waterproofing from the bored tunnel to the cut-and-cover tunnel section.
 - Faster installation of the waterproofing system and the inner sprayed concrete lining.
 - Reduced construction time.



6.1. PROJECT DETAILS

As part of the expansion its high voltage power distribution in SE England, National Grid plc contractor Morgan Tunneling to build a air diameter cable tunnel to carry heavy duty power cables. Construction was by TBM, with the linings of the front and back shafts being formed by primary and secondary sprayed concrete with an effective waterproofing membrane sandwiched between the two layers.

6.2. DESIGN APPROACH ADOPTED

The chosen waterproofing system needed to be capable of forming a tenacious bond to both layers of sprayed concrete as well as being tough enough to withstand the spray application of the second concrete lining. Following extensive testing and evaluation, Morgan Tunneling selected Siling Lloyd's Integritank HF: a spray-applied, seamless methacrylate resin based membrane system.

6.3. APPLICATION APPROACH AND CONTROL

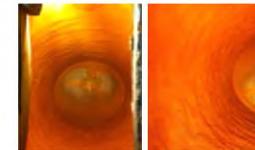
The application, by Siling Lloyd Construction Ltd, consisted of Integritank HF Primer followed by two coats of Integritank HF membrane. Two coats and quality control, and the thickness of each coat was checked every 2 m² using wet film techniques. The final quality check was the use of high voltage holiday detection testing to confirm the 100% integrity of the waterproofing.



6.4. PROJECT BENEFITS

By using the Integritank HF spray-applied system, Morgan Tunneling was able to construct a tunnel not only with effective long term protection to the assets within, but also to achieve it in a very cost-effective manner with both decreased build time and cost. Additionally, Integritank HF's tolerance of difficult site and weather conditions enabled application in February in a northern winter when the temperature varied between 0°C and 4°C, which would preclude the application of membranes based on other resins. The use of a liquid sprayed system that could follow the contours of the tunnel meant no line consuming and costly scaffolding or outlying associates with steel membranes was necessary. Integritank HF's unique project benefits included:

- Non-destructive testing of the waterproofing membrane enabled confirmation of its 100% integrity prior to secondary lining installation.
- Rapid application and cure of the membrane, assisting in shortening the construction programme.
- High durability and adhesion: Integritank HF minimized potential physical damage to the waterproofing from other site activities.



3.1. PROJECT DETAILS

The Sheppard Line Extension of the Toronto Light Rail project, that had been cancelled by the Mayor in 2007, started a re-proposal in 2012 and work on the project recommenced to increase the scope of Toronto's public transport system. The project is being constructed by the McMillan/Kiewit/Atcon JV (MKA JV). It was decided to use Tamseal 800 spray applied waterproofing membranes in the cross passages.

3.2. DESIGN APPROACH ADOPTED

The project designers -arch Matt MacDonato (iRMA) have opted to use Tamseal 800 spray applied waterproofing membranes in conjunction with a drainage fleece. The membrane will bond to the primary lining, but should water breach the membrane in any location it will travel through the fleece applied to the back into the drainage system.

3.3. APPLICATION APPROACH AND CONTROL

The surface of the primary lining was prepared using a regulating layer, giving a surface finish without fibres and large holes. The membrane was then applied in two layers using hand application with rollers/bushes. The two layers of membrane were in contrasting colours: the first in orange, the second in white/grey. This approach allowed the thickness of the membrane to be controlled and allowed for later quality control checking of the application. Coverage was checked using a combination of visual inspection and frequent depth gauge and patch testing.



3.4. PROJECT BENEFITS

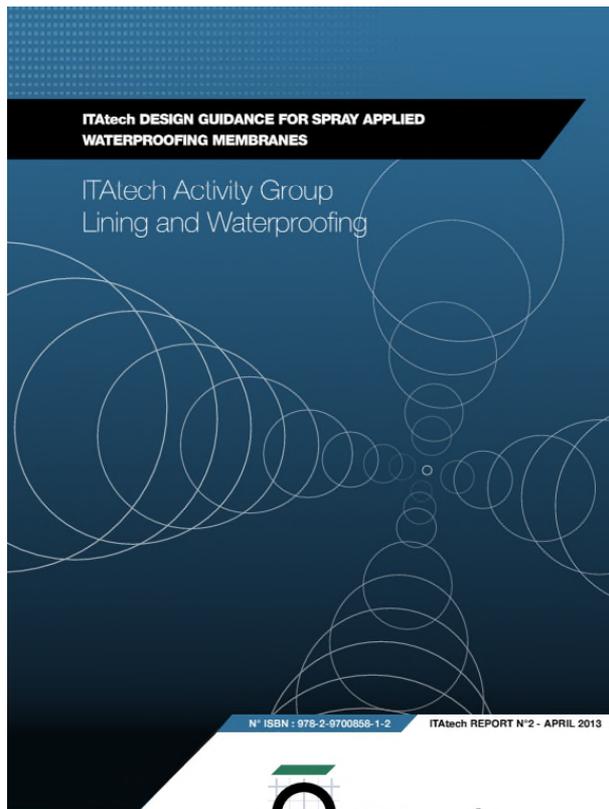
Using Tamseal 800 spray applied waterproofing membrane for the cross-passages allowed the project to install the membrane quickly and easily without the need for additional specialist equipment or the manual handling involved in cutting, welding and testing a sheet membrane to changing profiles.

- Bonded membrane solution with drainage.
- Membrane installed using basic equipment already available on site.
- Cross passages easily integrated into the rest of the tunnel system.
- No requirement for complex secondary lining shutters.
- Easier connection details to running tunnels.



- Training and accreditation similar to EFNARC for sprayed concrete is currently not available for membranes
- ITAttech is preparing a training scheme for:
 - Engineers and Supervisors
 - Applicators
- The certification will be available for Applicators through bodies like ITA-CET and will be based on technical knowledge and practical ability

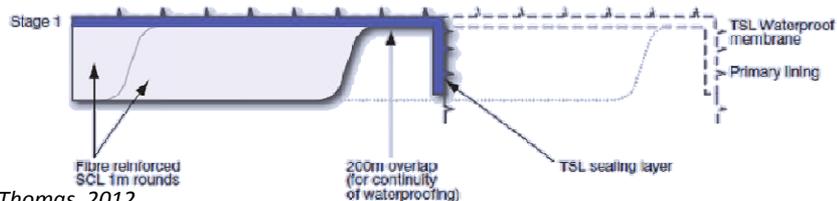




- Revision 1 is now complete
- The ITAttech Design Guidance document is available now:
 - Hard copies at WTC
 - Can be downloaded at ITA website under ITAttech

- Last week we run a successful deminar at the Hagerbach Test Gallery, Switzerland
- 30 plus participants
- Seminar papers based on Design Guidance report
- Practical spraying from three membrane solution providers in real conditions

- Position of spray membranes within tunnel lining section – drive towards single shell
- Understand the load sharing behaviour between concrete shells through the membranes
- Watertight concrete without membranes
 - Crack free solutions
 - Poly-modified concrete
- Sheet membrane development?
- Surface finishes for sprayed concrete linings



Pickett & Thomas, 2012

