CIDB MALAYSIA

TECHNICAL OPINION

SUBMITTED TO CIDB MALAYSIA | FEBRUARY 2012

TECHNICAL OPINION REPORT

PRODUCT
WG Tunnel Sealing (WGTS) System

APPLICANT
Atlas Hall Sdn. Bhd.

CIDB MALAYSIA

CONSTRUCTION INDUSTRY DEVELOPMENT BOARD
7th Floor, CIDB Headquarters,
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No. 72, Jalan Pahang, 53000 Kuala Lumpur

CREAM
Construction Research Institute of Malaysia

CONSTRUCTION RESEARCH INSTITUTE OF MALAYSIA
Makmal Kerja Raya Maysia (MKRM),
IBS Centre, 1st Floor, Block E, Lot 8,
Jalan Chan Sow Lin, 55200 Kuala Lumpur

FOREWORD

Construction Industry Development Board (CIDB Malaysia) is a statutory body enacted under the Act 520 in 1994. Its mission is to develop Malaysian Construction Industry towards global competitiveness. To support that mission, a number of functions were formulated and one of them is to encourage the improvement of construction techniques and materials. Under that function, CIDB is to carry out assessment and appraisal of innovations of any kind of product and technology related to construction and to publish its finding, in the form of Technical Opinion.

This Technical Opinion will provide a reference to the relevant / interested parties in the construction industry. CIDB assess innovation based on application and evaluation by its Technical Opinion. Applicants may use it as a supporting document for regulatory and approving authorities, architects, engineers and others in dealing with the new products and technologies.

This Technical Opinion is prepared on behalf of CIDB by The Technical Expert Panel on construction products, construction material and technology in Construction Industry. The Technical Expert Panel was set-up by CIDB and its members are drawn from experts that represent relevant sectors in the construction industry.

This Technical Opinion has been modelled based on international recommended practice.

CIDB Technical Expert Panel Committee for Giertsen Tunnel – WG Tunnel Sealing system

Technical Expert Panel

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Ir Poobalan a/l V. Chidambaram	(Technical Expert Panel)	Department of Irrigation and Drainage Malaysia (DID)
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Ahmad Hazim bin Abdul Rahim	CREAM
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Rohani binti Mokhtar	CREAM
Suhaila binti Abdul Halim	CREAM

GENERAL PROVISIONS

The purposes of this report are to assist respective parties concerned both applicant and granting approval authority, includes specification and also use of the subject. This report shall not be considered as approval.

Special note should be taken of the provisions and limitations set out and the period of validity of the Technical Opinion.

Technical Opinion is initially given a term of validity of three (3) years from the date of issue in the expectation that, after that period, the subject will no longer be an innovation. They can be reviewed within the first (12) twelve months and again as necessary during the life of the products or system described in the document. The limitation on the validity of the opinions should not be interpreted as implying a similarly limited life expectancy of the products or system described in the Technical Opinion. However, if experience shows poor overall standard of quality or performance, the Technical Opinion will be withdrawn.

The legitimacy and validity of the Technical Opinion can be verified at office of CIDB Head Office.

CIDB, the Technical Expert Panel shall accept no responsibility for the quality and performance of the products.

Disclaimer

While every effort is made to ensure accuracy of the information presented in this report, neither the Technical Expert Panel nor its Secretariats or CIDB can accept responsibility for any loss or damage incurred in connection with the use of the contents.

Definition

Technical Opinion Programme:	A programme that initiated by CIDB with the aim to evaluate products, materials, components or system with regard to, but not limited to IBS. It normally covers wide range of innovative products to be used in local construction industry
Technical Expert Panel:	Individuals selected based on their expertise in tunnel construction as well as polymeric material.
WG Tunnel Sealing System:	A system that provides water leakage control, humidity protection and frost insulation for humid rock surface in rock caverns, shafts and tunnels.
Polymer fabric:	Roofing fabric made of pliable PVC with a core of woven polyester.

Abbreviation

AHSB	Atlas Hall Sdn Bhd
BS	British Standard
CIDB	Construction Industry Development Board
CREAM	Construction Research Institute of Malaysia
DID	Department of Irrigation and Drainage Malaysia
EN	European Standard
ISO	International Standards Organisation
NS-EN	Norwegian Standard adopted as European Standard
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance / Quality Control
SINTEF	The Foundation for Scientific and Industrial Research
SIS	Swedish Standards Institute
SMART	Storm water Management and Road Tunnel
UM	Universiti Malaya
UPNM	Universiti Pertahanan dan Nasional Malaysia
WGTS	WG Tunnel Sealing

Symbols

%	percentage
cm	centimetre
CO_2	carbon dioxide
g	gram
K	kelvin
kg	kilogram
km	kilometre
kWh	kilo Watt per hour
m	meter
m^2	meter square
mm	millimetre
MPa	mega Pascal
N	Newton
^oC	degree Celsius

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1.0 IDENTIFICATION

1.1 Title of Product

WG Tunnel Sealing (WGTS) system

1.2 Country of Origin

Norway

1.3 Dates of Evaluation

24th October 2011, 2nd December 2011, 28th December 2011

1.4 Purpose

The purpose and application of WGTS is to provide a complete system for water leakage control, humidity protection and frost insulation for humid rock surface in rock caverns, shafts and tunnels.

1.5 Applicant & Address

Atlas Hall Sdn Bhd
Suite 18-6, 18th floor, Wisma UOA II,
No 21 Jalan Pinang,
50540 Kuala Lumpur, Malaysia.
Contact:
Telephone: 03 7490 8861
Website : www.atlashall.com.my

1.6 Supplier / Distributor / Contractor & Address

Giertsen Tunnel AS
PO Box 78 Laksevaag – NO 5847,
Bergen, Norway
Contact:
Telephone: 47 5594 3030
Website : www.tunnelsealing.com

1.7 Fabric Manufacturer & Address

PROTAN AS
P.O Box 420 Brakerøya – N- 3002,
Drammen, Norway.
Contact:
Telephone: 47 3222 1600
Website : www.protan.com

2.0 DESCRIPTIONS

2.1 General Descriptions of Product

WGTS is a complete system for water leakage control, humidity protection and frost insulation for humid rock surface in shafts, tunnels and rock caverns. The product is made of roofing fabrics made of pliable PVC with a core of woven polyester with tubular steel pipes. Additional accessories include rock bolts and hot weld machine are required. The product is supplied and installed by Giertsen Tunnel AS in Norway and the fabric is manufactured by PROTAN AS in Norway, while other accessories could be obtained locally. Atlas Hall Sdn Bhd is the local counterpart of Giertsen Tunnel AS in Malaysia.

2.2 Element of Product

2.2.1. Fabric

The fabric is roofing fabrics made of pliable PVC with a core of woven polyester. Stabilizers have been added to make the roofing resistant to high and low temperatures, ultra violet radiation, and to limit the spread of flames. The fabric types are Protan SE, EX and EXG. Protan EX has a layer of polyester felt and can be laid directly on old roofing underlay of bitumen. The fabric may also be used under turf roofing. Protan SE can be used as roofing on all types of underlay, but needs a separate migration barrier / levelling layer on polystyrene underlay and for re-roofing applications. Protan EXG has a layer of glass felt, fixed to the underside. It can be laid directly to the polystyrene

2.2.2. Composition of fabric

The compositions of the fabric are polyester textile, PVC, plasticizers, pigments, fire retardants and stabilizers.

(Note: Refer to Appendix A - Environmental Product Declaration ISO 14025 and ISO 21930)

2.2.3. Other accessories for WGTS

a) Bolts : (e.g.: J-Bolts, M&E Bolts, Foundation Bolts, K500TS Hot-Dipped Galvanised J-Bolts with diameter 16 mm, Hot-Dipped Galvanised M&E Bolts with diameter 16 mm)
b) Chemical adhesive – (e.g.: Hilti HY-150)
c) Galvanised steel wire: diameter 5.4 mm.
d) Wire clamps.
e) Rope stitch
f) Washer and Nut
g) Coupling Sleeve
h) PVC Bar

2.3 Usage Application

WGTS is used for water leakage control, humidity protection and frost insulation for humid rock surface in rock caverns, shafts and tunnels. Some examples of the applications are:

a) Hydroelectric power plant
b) Public fresh water supply
c) Sewage water purification plant
d) Military facilities
e) Underground storage area
f) Civil defence shelter
g) Storage of nuclear waste
h) Oil and gas pipeline
i) Underground car park

2.4 Usage Limitation

In the event when the tunnel has relative humidity above 50%, dehumidifier is recommended to be installed to prevent corrosion and fungus growth.

2.5 Installation Method

2.5.1 *Method Statement of WGTS supplied by Giertsen Tunnel AS:*

The method statement outlined the step-by-step installation methods for WGTS. Some of the main methods are:

i) Marking or Setting out for Drilling of Foundation and Suspended J-Bolts.
ii) Drilling
iii) Bolting
iv) Wire
v) Lining
vi) M&E Bolt Penetration
vii) Welding of Lining
viii) Fixing of Lining to Ground

(Note: Refer to Appendix B – Method Statement for WGTS.)

2.6 Technology / Skill Required

WGTS is from Norway and supplied by Giertsen Tunnel A.S. It has been widely used by other countries such as Denmark, Norway, India, Philippines, Scotland, Zimbabwe, Italy, Singapore, etc. This product has never been applied in Malaysia. The installation process can utilize local labours under full supervision of experts from Giertsen Tunnel AS.

2.7 Special Conditions for Usage and Installation

2.7.1. *Storage*

Protan roofing fabrics should be stored in a dry place, with the rolls placed on pellets at the building site and protected by a cavern.

2.7.2. *Installation*

The joints of Protan SE, EX and EXG are welded by the use of hot air and the fabrics shall be installed in accordance with the manufacturer's instructions.

(Note: Refer to Appendix C – Technical Approval prepared by SINTEF)

2.8 Inspection and Maintenance

The roofing fabrics must be cleaned locally before starting any welding of joints as a part of repair work.

(Note: Refer to Appendix C – Technical Approval prepared by SINTEF)

3.0 BASIS OF APPRAISAL

3.1 Check on Document Received from Atlas Hall Sdn. Bhd.

A copy of the following documents was received to confirm appraisal of the products.

3.1.1. *Test report on the material:*

The test reports on the material can be referred in section 4.2.

3.1.2. *Illustration of WGTS.*

Detailed illustration of WGTS are attached in Appendix D.

4.0 MATERIAL: STANDARDS, SPECIFICATIONS AND TESTS.

4.1 Material Standards and Specifications

4.1.1. Measures and tolerances for Protan SE,EX and EXG are attached in Appendix C – Technical Approval (Table 1)

4.1.2. Product properties for fresh material of Protan SE, EX and EXG roofing fabrics are attached in Appendix C – Technical Approval (Table 2)

4.2 Type of Tests

The following type of tests has been carried out in accordance with acceptable International Standards. These tests include material, mechanical, physical, chemical resistance, and fire resistance tests as follows:

i. Foldability at Low Temperature
ii. Dimensional Stability
iii. Tear Resistance

iv. Tensile Strength

v. Elongation

vi. Average Peel Resistance of Joints

vii. Shear Resistance of Joints

viii. Resistance to Puncture

a) By impact at +23^{o}C

b) By impact at -10^{o}C

c) By static loading

(Note: Test results (i) until (viii) are attached in Appendix C – Technical Approval, Table 2. Certification of Test is not provided by the Applicant)

ix. Ageing Test.

(Note: Test results (ix) are attached in Appendix C – Technical Approval, Table 3. Certification of Test is not provided by the Applicant)

x. Environmental Declaration

a) Global warming

b) Energy use

c) Recycled material

d) Indoor air classification

(Note: Test results (x) are attached in Appendix A – Environmental Declaration)

xi. Fire Testing

a) Minimum Flash-Over Time

b) Maximum Heat Release

c) Average Heat Release

d) Maximum Smoke Production

e) Average Smoke Production

(Note: Claim of fulfilment of testing criteria for test xi (a) until xi (e) is attached in Appendix E Claims on Fire Testing according to ISO 9705 and Appendix F – Quality 554 Data Sheet and Claim. Certification of Test is not provided by the Applicant)

xii. Chemical Resistance Test

(Note: Refer to Appendix G – PROTAN AS Data Sheet. Certification of Test is not provided by the Applicant)

xiii. Smoke and Toxic Test

(Note: Refer to Appendix H (1) – Smoke and Toxic Test Report)

xiv. Water Tightness Test

(Note: Refer to Appendix H (2) – Water Tightness Test Report)

xv. Measurement of Water Vapour Permeance Test

(Note: Refer to Appendix H (3) – Measurement of Water Vapour Permeance Test Report)

4.3 Additional Test Conducted

Atlas Hall Sdn. Bhd. is to notify to the Technical Expert Panel Committee on any additional test conducted (if any) other than those mentioned in 4.2.

4.4 Summary of Test Results Provided by Atlas Hall Sdn Bhd.

The following test results has been summarised from the documents provided by the Applicant.

4.4.1. Ageing Test:

Product properties for aged material of Protan SE, EXG and EX are shown in Table 4.1 below. The test proves that all the three (3) Protan materials pass the foldability test at temperature < -25°C after artificial ageing process:

Table 4.1: Product Properties for Aged Material

Foldability at low temperature (Aging process) :	Standard	Results			Unit
		Protan SE	Protan EXG	Protan EX	
Aged in hot water	EN 495 – 5: 2001	≤ - 30	≤ - 30	≤ - 30	°C
Artificial aging		≤ - 25	≤ - 25	≤ - 25	°C

(Note: Refer to Appendix C – Technical Approval prepared by SINTEF, Table 3)

4.4.2. Chemical Resistance test:

The chemical resistance depends upon concentration, duration of contact and temperature. Table 4.2 below indicates the resistance of Protan fabric to various common substance.

Table 4.2: Chemical Resistance Properties

Well suited	Conditional	Not Resistance
Aluminium	Carbon tetrachloride	Asphalt
Caustic potash	Salt of Potassium	Bitumen
Carbon monoxide	Diesel oil and fuel oil	Ethyl ether
Common salt	Formaldehyde	Fats (animal and vegetable)

Copper and ferrous materials	Iron residues	Oils (animal and vegetable)
Detergents	Motor oils	Petrol
Steam	Nitric Acid	Turpentine oil
Salt of Calcium	Non-aromatic mineral oils	Softeners
Sea water	Paraffin	Solvent
Soaps	Wood preservatives	Tar

(Note: For further details, refer to Appendix G – PROTAN AS Datasheet)

4.4.3. *Environmental declaration:*

The declaration has been prepared by SINTEF. It has been carried out according to ISO 14044, ISO 14025 and ISO 21930. This report does not include the release of any hazardous gases in the case of fire except for the nine (9) specimens reported in Appendix H(1) for the product of WG Tunnelduk 556. The results provided are shown in Table 4.3 below:

Table 4.3: Environmental Declaration Results.

Indicators	Result	Unit
Global warming	2.2	kg CO_2 equivalent.
Energy use	11.0	kWh
Recycled materials	0	%
Indoor air classification (According to CR 1752:1999)	Not relevant	-

Functional Unit (FU) – m^2 installed tunnel membrane.

(Note: Refer to Appendix A – Environmental Declaration of Product)

4.4.4. *Product Properties:*

Product properties of the fabric have been tested by SINTEF Building and Infrastructure. The results are shown at the table 4.4

Table 4.4: Product Properties for Fresh Material of Protan SE, EX and EXG.

Property	Test Method EN	Control limit [1)]			Unit
		Protan SE (Thickness: 1.2 mm, 1.6 mm, 1.8 mm)	Protan EXG (Thickness: 1.2 mm w/felt, 1.6 mm w/felt)	Protan EX (Thickness: 1.2 mm w/felt,1.6 mm w/felt, 1.8 mm w/felt)	
Foldability at low temperature	495-5:2001	≤ -30	≤ -30	≤ -30	^{o}C
Dimensional stability	1107-2:2001	± 0.5	± 0.5	± 0.5	%
Water tightness (10 kPa)	1928:2000 (A)	Tett	Tett	Tett	-
Tear resistance	12310-2:2000	≥ 210	≥ 210	≥ 300	N
Tensile strength	12311-2:2000 (A)	≥ 1050	≥ 1050	≥ 1100	N/50 mm
Elongation	12311-2:2000 (A)	≥ 15	≥ 15	≥ 15	%
Average peel resistance of joints	12316-2:2000	≥ 150	≥ 150	≥ 150	N/50 mm
Shear resistance of joints	12317-2:2000	≥ 1000	≥ 1000	≥ 1000	N/50 mm
Resistance to puncture • By impact at +23^{o}C • By impact at -10^{o}C • By static loading	12691:2006 (A) 12691:2001 12730:2001 (A)	≥ 400 ≤ 8 ≥ 20	≥ 400 ≤ 10 ≥ 20	≥ 400 ≤ 8 ≥ 20	mm mm diam. kg

[1)] The stated values are the existing control limits for internal control at the producer and supervising control.

(Note: Refer to Appendix C – Technical Approval, Table 2)

5.0 DESIGN

5.1 Illustration of WGTS

Detailed illustration of WGTS is attached in Appendix D.

5.2 Structural Design Analysis

Design analysis and calculation is not provided by Applicant.

Please contact Applicant for further details.

5.3 Design Capacities

Design capacities at ultimate limit state for mechanical fasteners in Protan SE, EX and EXG 1.2 mm and 1.6 mm are as shown in Table 5.1 below:

Table 5.1: Design Capacities at Ultimate State for Mechanical Fasteners.

Fastening system / Fastener	Capacity, N per fastener
Placed at lane edge, Protan SE, EXG	
• Roofing nail 2, 8 – 25	100
• Staples (2 x 20 mm)	130
• ECOtek 40 washer	650
• Teleskop 40 washer	650
• Iso-Tak 40 washer	650
• Teleskop 42 fastener	700
• ECOtek 45 fastener	700
• Iso-Tak 45 fastener	700
• SK Isofest Y40 fastener	700
• SK Isofest Ø 50 Croco without studs	750
• SFS IT-C 40 x 82 washer	1000
• Iso-Tak Plus 48-3N fastener	1000
• Teleskopo Dracula TPD 50 fastener	1000
• Iso-Tak Twin Peak Plus fastener	1100
• SK Isofest Ø 50 Croco with studs	1100
Placed at the edge, Protan EX	
• Teleskop 42 fastener	850
• Teleskop 40 washer	900
• Iso-Tak 40 washer	900
• Teleskopo Dracula TPD 50 fastener	1100
• SFS IT-C 40 x 82 washer	1100
• SK Isofest Ø 50 Croco with studs	1100

Placed in roll flip X-335	
• Teleskop 42 fastener	1000
• SFS IT-C 40 x 82 washer	1100
• Teleskopo Dracula TPD 50 fastener	1100
• Iso-Tak Twin Peak Plus fastener	1100
• SK Isofest Ø 50 Croco with studs	1100
Pull through resistance	
• Teleskop 40 washer	1100
• Iso-Tak 40 washer	1100
• Iso-Tak 45 washer	1000
• Teleskop 42 fastener	1000
• SFS IT-C 40 x 82 washer	1200

(Note: Refer to Appendix C – Technical Approval prepared by SINTEF, Table 5)

6.0 COMPLIANCE TO INTERNATIONAL STANDARDS

6.1 Material Tests Standard

A series of tests performed by WGTS was adopted with International Standards or equivalent. The standards are shown as per Table 6.1 below:

Table 6.1: Standards for All Type of Tests Reported

Type of tests reported	**Standard** *(Reference from the Applicant)*
Foldability at low temperature - aged in hot water - artificial aging	**EN 495-5:2001** Flexible sheets for waterproofing. Determination of foldability at low temperature. Plastic and rubber sheets for roof waterproofing.
Dimensional stability	**EN 1107-2:2001** Flexible sheets for waterproofing. Determination of dimensional stability. Plastic and rubber sheets for roof waterproofing
Water tightness (10 kPa)	**EN 1928:2000 (A)** Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water tightness

Tear resistance	**EN 12310-2:2000** Flexible sheets for waterproofing. Determination of resistance to tearing (nail shank). Plastic and rubber sheets for roof waterproofing.
Tensile strength	**EN 12311-2:2000 (A)** Flexible sheets for waterproofing. Determination of tensile properties. Plastic and rubber sheets for roof waterproofing
Elongation	**EN 12311-2:2000 (A)** Flexible sheets for waterproofing. Determination of tensile properties. Plastic and rubber sheets for roof waterproofing
Average peel resistance of joints	**EN 12316-2:2000** Flexible sheets for waterproofing. Determination of peel resistance of joints. Plastic and rubber sheets for roof waterproofing
Shear resistance of joints	**EN 12317-2:2000** Flexible sheets for waterproofing. Plastic and rubber sheets for roof waterproofing
Resistance to puncture – by impact at +23°C – by impact at – 10°C – by static loading	**EN 12691:2006 (A)** Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to impact **EN 12691:2001** Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to impact **EN 12730:2001 (A)** Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to static loading
Water vapour permeability	**ISO 12572:2001** Hygrothermal performance of building materials and products. Determination of water vapour transmission properties

Water vapour resistance as equivalent air layer thickness	**ISO 12572:2001** Hygrothermal performance of building materials and products. Determination of water vapour transmission properties
Environmental declaration tests	**ISO 14044** Environmental management. Life cycle assessment. Requirements and guidelines **ISO 14025** Environmental labels and declarations. Type III environmental declarations. Principles and procedures **ISO 21930.** Sustainability in building construction. Environmental declaration of building products
Smoke and Toxicity Test	**ISO 5659-2: 1994** Plastics - Smoke generation – Part 2: Determination of optical density by a single-chamber test
Fire test	**SIS 6500 82** Textiles – Determination of flameproofness of fabric **BS 3119: 1959** Specification for method of test for flameproof material. **NS-EN 13501-1** Fire classification of construction products and building elements. Classification using test data from reaction to fire tests **BS 476-7** Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products

7.0 RELEVANT DOCUMENTS

7.1. QA / QC plan

This document is important to ensure quality in production is observed at all time during process of installing the components. QA/QC plan is attached in Appendix I – Quality Assurance Plan.

7.2. Installation Checklist

This document is attached in Appendix J – WGTS Installation Checklist

8.0 VALIDITY OF OPINION

8.1. Condition

The Technical Opinion Report given here was based on the European, Norway and ISO Standard. All results and test reports were issued from Accredited Laboratories in Norway. The assessment is only focusing on the performance and quality of the Protan Fabric and not on the structural performance of the WG Tunnel Sealing System.

The recommendations are based on and limited to available information provided by the applicant.

8.2. Recommendations from Technical Expert Panel

1. Critical test such as fatigue and dynamic test to be conducted.
2. Suitability and options for localised repair of tunnel leakages.
3. The usage of local product in design and construction of structural frame.
4. All design submission to approving authorities must be certified by local Professional Engineers.
5. Design calculations to be verified by local Professional Engineers.
6. The user is encouraged to perform additional tests to confirm the mechanical properties of the product.
7. Suitability of using the fabric on specific local condition (i.e. acidic or alkaline environment) must be tested and confirmed at any Accredited Laboratory.

8.3. Withdrawal

In the event of non-compliance to International Standards or any other equivalent standards will lead to withdrawal of this opinion.

8.4. Term of Validity

The recommendation is valid for three (3) years from the issuance of this Technical Opinion Report subject to the validity of the existing Test Certificates. This report is valid from February 2012 to January 2015.

9.0 APPROVED OPINION ABSTRACT

WGTS System is supplied and installed by Giertsen Tunnel,Norway. The fabric Protan EX, EXG and SE which are manufactured in PROTAN, Norway complies with the Specification of European and International Standards.

The Technical Expert Panel is in the opinion that this WGTS system generally is suitable to be used in Malaysia provided that it complies with the terms and conditions mentioned in this report. A dehumidifier is recommended to be installed when the relative humidity is above 50% to prevent corrosion and fungus growth.

Any additional tests required by the client have to meet the International Standards and specification.

Ir. Dr Zuhairi Abd. Hamid
Chairman
Technical Expert Panel

Ir. Poobalan a/l V. Chidambaram
Technical Expert Panel

Kol. Prof. Madya Ir. Dr. Norazman Mohamad Nor
Technical Expert Panel

Dr. Nur Awanis Hashim
Technical Expert Panel

February 2012

10.0 REFERENCES

Internet

1. http://www.atlashall.com.my/ (19 August 2011)
2. http://tunnelsealing.com/home.aspx (22 August 2011)
3. http://www.Protan.com/thecompany/pages/default.aspx (13 September 2011)
4. http://www.sintef.no/home/ (15 September 2011)

11.0 BIBLIOGRAPHY

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2. AHSB. (2011 b). EC Certificate of Conformity for Protan SE, EX and EXG from Norwegian Building Research Institute
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15. AHSB. (2011 o). Test Report: Water Vapour Permeance
16. AHSB. (2011 p). Quality Assurance Plan
17. AHSB. (2011 q). Fire Test Quality 554
18. AHSB. (2011 r). Illustration of WGTS

APPENDIX A

ENVIRONMENTAL PRODUCT DECLARATION ISO 14025 and ISO 21930

PROTAN

Membrane for tunnels

EPD
Foundation for Environmental Declarations in Industry

NEPD no.: **100**
Approved 01.10.2007
Valid until 29.09.2012

Independent verification of conformity

We confirm that this environmental declaration has been carried out according to ISO 14044, ISO 14025 and ISO 21930, and Product category rules (PCR) for "Mechanical fixed single ply roof waterproofing membranes (EN 13956)". The documentation has been carried out with the EcoDec-tool.

The declaration has been prepared by:
SINTEF Byggforsk SINTEF

Oslo : 01.10.2007

Independent verifier

Manufacturer

PROTAN AS
Postboks 420 Brakerøya N-3002 Drammen Norway
Organisation no. NO 91 569 809 MVA
ISO 14001: : NS-EN ISO 14001:NO 97-OSL-SYMI-8015
Market area: Europa

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Product information

Scope	Cradle to grave
Year of study	2007
Expected service life of building	50 years
Service life of product	50 years
Functional unit (FU)	m² installed tunnel membrane and 50 years

Product description

This product is a plastic coated technical textile. It consists of plasticised PVC and a polyester reinforcement. It is intended to be use in tunnels.

Product specification

	Part %	Quantity (kg/FU)
PVC	33,5 %	0,23
Polyester textile	28,6 %	0,20
Plasticiser (DINP)	22,6 %	0,16
Fire-, heat- and UV-stabiliser	15,3 %	0,11
SUM	100,0 %	0,70

Environmental Indicators		
Global warming	2,2	kg CO2 equiv.
Energy use	11,0	kWh
Recycled materials	0	%
Indoor air classification (Classification according to CR 1752:1999)	Not relevant	

APPENDIX B

GIERTSEN Tunnel AS

METHOD STATEMENT FOR WG-TUNNEL SEALING

1. **Marking/Setting-out for Drilling of Foundation & Suspended J-Bolts**
   a) Measurement to determine the As-Built rock cavern structure is in accordance to approved Construction Drawings.

   b) Datum reference axis would be marked at ground level.

   c) Foundation Bolts are drilled to min. depth of 250mm at drain-side floor kerb and installed using Hilti HY-150 chemical adhesive.

   d) Position of Suspended J-Bolts at datum reference axis is, translated from ground to rock cavern wall using laser.

   e) Suspended J-Bolts are drilled to min. depth of 250mm into secured rock at face of cavern and 5installed using Hilti HY-150 chemical adhesive.

   f) Ø5,4mm Galvanized Steel Wire is pulled through the 'eye' of each Bolt for individual datum reference axis and tightened using WG stretching device to achieve the theoretical profile.

2. **Drilling**
   a) Foundation Bolts are drilled to min. depth of 250mm at side of floor kerb.

   b) Suspended J-Bolts and M&E Bolts are drilled to min. depth of 250mm into secured rock at face of cavern.

3. **Bolting**
   a) Ø16mm K500TS Hot-dipped Galvanised J-Bolts are used for all Foundation and Suspended Bolts.

   b) All Bolts, including that of M&E, are installed using Hilti HY-150 chemical adhesive in accordance to the Manufacturer's recommended application.

   c) Fine tune adjustment would be made using the Plumb and Tracking Cord to ascertain the correctness of position as each Bolt is inserted into the adhesive.

4. **Wire**
   a) Ø5,4mm Galvanized Steel Wire is pulled through the 'eye' of each Bolt for individual datum reference axis and tightened using WG stretching device to achieve the theoretical profile.

   b) Frog Clamp is used to tighten the wire.

   c) Each end of the wire is finally secured by 2 nos. of wire clamps.

METHOD STATEMENT FOR WG-TUNNEL SEALING

5. Lining

a) Lining is installed from the Pitch of each axis and rolled-off to stretch to one side of axis.

b) Temporary ties are used to secure the stretched lining to the Ø5,4mm Galvanized Steel Wire.

c) Returning to the Pitch, the same process is repeated for the other side of the axis.

d) The lining between 2 subsequent bays is than threaded using Ø6mm ulstron through the 'eyelets' and rope stitched to the Ø5,4mm Galvanized Steel Wire.

e) Lining is then stretched to achieve the required tautness.

6. M&E Bolt Penetration

a) Ø16mm Hot-dipped Galvanised M&E Bolts, typically, penetrates through the lining at the stitched joints between 2 bays.

b) At the interface between the Bolt and Lining, 2 pieces of Special WG Packing encompass the Bolt and 'sandwich' the Lining (1 on each side of the Lining).

c) The 2 pieces of Special WG Packing 'sandwiching' the Lining is, in turn, held in place by a Washer and Nut on each side.

d) A Coupling Sleeve would be finally threaded to the end of the M&E Bolt (within the Lining) for future extension.

e) The above-mentioned connection detail is shown in the Shopdrawing.

7. Welding of Lining

a) The overlaps along the stitched joint of the Lining would be heat fused to a waterproof connection.

8. Fixing of Lining to Ground

a) Along the perimeter at ground level, the Lining is secured along the drain-side floor kerb using a PVC Bar and Stainless Steel Concrete Nails.

Bergen Norway
11.08.2011
Alv Hanstvedt

Technical Approval

No. 2010

Issued: 15.02.1995
Revised: 25.04.2007
Valid until: 25.04.2012
Page: 1 of 4

SINTEF Building and Infrastructure

Norwegian member of European Organisation for Technical Approvals, EOTA, and European Union of Agrément, UEAtc

Protan SE, EX and EXG roofing membranes

is approved by SINTEF Building and Infrastructure with properties, fields of application and conditions as stated in this document

1. Holder of the approval

Protan AS
P.O.Box 420
NO-3002 DRAMMEN
Tel.: +47 32 22 16 00 Fax: + 47 32 22 17 00
www.protan.com

2. Manufacturer

Protan AS, Drammen.

3. Product description

Protan SE, EX and EXG are roofing membranes made of pliable PVC with a core of woven polyester. Stabilizers have been added to make the roofing resistant to high and low temperatures, ultra violet radiation, and to limit spread of flames. Installation is carried out by using hot air welding.

Protan SE, EX and EXG are available in several thicknesses, and with specifications as shown in Table 1. Protan EX has a layer of polyester felt, and Protan EXG a layer of glass felt, fixed to the underside.

Standard widths are 1 m and 2 m. Standard length is 20 m per roll. Other dimensions are available on request.

The membranes are manufactured with several standard surface colours. The underside is dark grey.

4. Field of application

Protan SE, EX and EXG are used as exposed, mechanically fastened roofing membranes on flat and sloping roofs, see Fig. 1.

Protan SE can be used as roofing on all types of underlay, but needs a separate migration barrier/levelling layer on polystyrene underlay and for re-roofing applications.

Protan EX has a laminated felt, and can be laid directly on old roofing underlay of bitumen. The membrane may also be used under turf roofing. An additional loose felt must be used on liquid applied asphalt roofing.

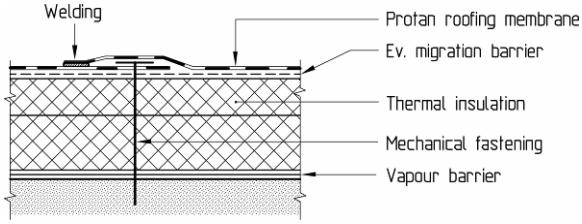


Fig. 1
Protan SE, EX and EXG roofing, mechanically fastened at the edge

Protan EXG is laminated with glass felt and can be laid directly on polystyrene.

Roofs must have adequate slope to drain water from rain and melting snow. SINTEF Building and Infrastructure recommends that all roofs have an inclination of minimum 1:40.

5. Properties

Material properties

Product properties for fresh material are shown in Table 2.

Safety in case of fire

Protan SE fulfils the requirements of class B_{ROOF} (t2) according to EN 13501-5 for all underlay except EPS/XPS-insulation. When using a migration barrier of at least 120 g/m^2 and 50 g/m² glass felt respectively, Protan SE fulfils class B_{ROOF} (t1) and (t2) also on EPS/XPS-insulation.

Protan EX satisfies the requirements of class B_{ROOF} (t2) on underlay of old roofing membranes.

Protan EXG fulfils class B_{ROOF} (t2) according to EN 13501-5 for all underlay.

Durability

Some properties after artificial ageing are given in Table 3. The products have shown satisfying properties after artificial ageing in connection with type-testing and audit testing performed by SINTEF Building and Infrastructure.

Table 1
Measures and tolerances for Protan SE, EX and EXG roofing membranes

Property	Protan SE			Protan EXG		Protan EX		
Thickness (mm)	1.2 +0.2/-0.1	1.6 +0.2/-0.15	1.8 +0.2/-0.15	1.2 +0.2/-0.10	1.6 +0.2/-0.15	1.2 +0.2/-0.1	1.6 +0.2/-0.15	1.8 +0.2/-0.15
Weight (kg/m^2)	1.4 +0.2/-0.1	1.75 +0.2/-0.1	2.1 +0.2/-0.1	1.4 +0.2/-0.1	1.75 +0.2/-0.1	1.4 +0.2/-0.1	1.75 +0.2/-0.1	2.1 +0.2/-0.1
Width	1 m / 2 m ± 2 %	1 m / 2 m ± 2 %	1 m / 2 m ± 2 %	1 m / 2 m ± 2 %	1 m / 2 m ± 2 %	1 m / 2 m ± 2 %	1 m / 2 m ± 2 %	1 m / 2 m ± 2 %
Roll length	20 m + 2 %/-0 %	20 m +2 %/-0 %	20 m +2 %/-0 %	20 m +2 %/-0 %	20 m +2 %/-0 %	20 m +2 %/-0 %	20 m +2 %/-0 %	20 m +2 %/-0 %
Weight. Polyester core (impr.)	80 g/m^2	80 g/m^2	80 g/m^2	80 g/m^2	80 g/m^2	80 g/m^2	80 g/m^2	80 g/m^2
Weight. Polyester felt						180 g/m^2	180 g/m^2	180 g/m^2
Weight. Glass felt				55 g/m^2	55 g/m^2			

Table 2
Product properties for fresh material of Protan SE, EX and EXG roofing membranes

Property	Test method EN	Control limit[1]								Unit
		Protan SE			Protan EXG		Protan EX			
		1.2 mm	1.6 mm	1.8 mm	1.2 mm w/felt	1.6 mm w/felt	1.2 mm w/felt	1.6 mm w/felt	1.8 mm w/felt	
Foldability at low temperature	495-5:2001	≤ -30	≤ -30	≤ -30	≤ -30	≤ -30	≤ -30	≤ -30	≤ -30	°C
Dimensional stability	1107-2:2001	± 0,5	± 0,5	± 0,5	± 0,5	± 0,5	± 0,5	± 0,5	± 0,5	%
Water tightness (10 kPa)	1928:2000 (A)	Tett	Tett	Tett	Tett	Tett	Tett	Tett	Tett	-
Tear resistance	12310-2:2000	≥ 210	≥ 210	≥ 210	≥ 210	≥ 210	≥ 300	≥ 300	≥ 300	N
Tensile strength	12311-2:2000 (A)	≥ 1050	≥ 1050	≥ 1050	≥ 1050	≥ 1050	≥ 1100	≥ 1100	≥ 1100	N/50 mm
Elongation	12311-2:2000 (A)	≥ 15	≥ 15	≥ 15	≥ 15	≥ 15	≥ 15	≥ 15	≥ 15	%
Average peel resistance of joints	12316-2:2000	≥ 150	≥ 150	≥ 150	≥ 150	≥ 150	≥ 150	≥ 150	≥ 150	N/50 mm
Shear resistance of joints	12317-2:2000	≥ 1000	≥ 1000	≥ 1000	≥ 1000	≥ 1000	≥ 1000	≥1000	≥ 1000	N/50 mm
Resistance to puncture										
- by impact at +23°C	12691:2006 (A)	≥ 400	≥ 400	≥ 400	≥ 400	≥ 400	≥ 400	≥ 400	≥ 400	mm
- by impact at -10°C	12691:2001	≤ 8	≤ 8	≤ 8	≤ 10	≤ 10	≤ 8	≤ 8	≤ 8	mm diam
- by static loading	12730:2001(A)	≥ 20	≥ 20	≥ 20	≥ 20	≥ 20	≥ 20	≥ 20	≥ 20	kg
Water vapour permeability	ISO 12572:2001	$12 \cdot 10^{-12}$	$9 \cdot 10^{-12}$	$8 \cdot 10^{-12}$	$12 \cdot 10^{-12}$	$9 \cdot 10^{-12}$	$12 \cdot 10^{-12}$	$9 \cdot 10^{-12}$	$8 \cdot 10^{-12}$	kg/m²sPa
Water vapour resistance as equivalent air layer thickness	ISO 12572:2001	16	22	24,5	16	22	16	22	24,5	m

[1] The stated values are existing control limits for internal control at the producer and supervising control

Table 3
Product properties for aged material of Protan SE, EX and EXG roofing membranes

Property	Test method EN	Measured value								Unit
		Protan SE			Protan EXG		Protan EX			
		1.2	1.6	1.8	1.2	1.6	1.2	1.6	1.8	mm
Foldability at low temperature										
- Aged in hot water[1]	495-5:2001	≤ -30			≤ -30		≤ -30			°C
- Artificial ageing[2]		≤ -25			≤ -25		≤ -25			°C

[1] Aged according to method NS-EN 1847 (NS 3531) for 8 weeks at 60 °C

[2] Aged according to method NS-EN 1297 with specimen exposed to UV light, heat radiation, water and laboratory climate

Calculation of fasteners

Load capacities for fastening the roofing membrane with various types of fasteners are shown in Table 5. The capacities relate to the fastening of the membrane itself. The strength of the hold to weak underlay may limit the overall capacity of the fixing points.

Calculation of fastener spacing is carried out according to SINTEF Building Research Design Sheet 544.206 and "TPF Informs No. 5". The capacities apply to Norwegian conditions, with load coefficient 0.9 x 1.5 according to NS 3490. Factor 0.9 is reduction factor k_L regarding reliability class 1, and factor 1.5 is load factor.

Environmental declaration

Specific environmental declaration has been worked out for Protan SE. Environmental indicators are given in Table 4. For complete documentation see environmental declaration document NEPD No. 0032 on http://www.nho.no (search for "PCR"). No environmental declarations have been worked out for the other membranes. The products contain no chemical substances listed on the Norwegian authorities' observation list of compounds being harmful to human health or the environment.

Table 4
Environmental declaration for Protan SE, 1,2 mm

Environmental indicators	
Global warming	6,1 kg CO_2 ekv.
Energy use	29,55 kWh
Recycled materials	0 %
Indoor air classification (Classification according to CR 1752:1999)	Not relevant

Waste treatment/recycling

The materials in Protan SE, EX and EXG can be recycled, and a system for recycling has been established. Energy can be retrieved by delivering the membranes to a waste combustion plant.

6. Special conditions for use and installation

Storage

Protan roofing membranes should be stored in a dry place, with the rolls placed on pallets at the building site and protected by a covering.

Installation

The joints of Protan SE, EX and EXG are welded by the use of hot air, and the membranes shall be installed in accordance with the manufacturer's instructions. The products shall otherwise be used in accordance with the principles shown in SINTEF Building Research Design Sheet 544.202, 544.204 and 544.206, as well as in "TPF Informs No. 5".

Widths over 1 m should only be used at the mid-section of the roof, and where the dimensioning peak velocity pressure is ≤ 40 m/s. Maximum spacing between fasteners shall be 1 m.

Table 5
Design capacities at ultimate limit state for mechanical fasteners in Protan SE, EX and EXG 1.2 mm and 1.6 mm

Fastening system/Fastener	Capacity, N per fastener
Placed at lane edge, Protan SE, EXG	
Roofing nail 2,8–25	100
Staples (2 x 20 mm)	130
ECOtek 40 washer	650
Teleskop 40 washer	650
Iso-Tak 40 washer	650
Teleskop 42 fastener	700
ECOtek 45 fastener	700
Iso-Tak 45 fastener	700
SK Isofest Y40 fastener	700
SK Isofest Ø 50 Croco without studs	750
SFS IT-C 40 x 82 washer	1000
Iso-Tak Plus 48-3N fastener	1000
Teleskop Dracula TPD 50 fastener	1000
Iso-Tak Twin Peak Plus fastener	1100
SK Isofest Ø 50 Croco with studs	1100
Placed at the edge, Protan EX	
Teleskop 42 fastener	850
Teleskop 40 washer	900
Iso-Tak 40 washer	900
Teleskop Dracula TPD 50 fastener	1100
SFS IT-C 40 x 82 washer	1100
SK Isofest Ø 50 Croco with studs	1100
Placed in roll flip X-335	
Teleskop 42 fastener	1000
SFS IT-C 40 x 82 washer	1100
Teleskop Dracula TPD 50 fastener	1100
Iso-Tak Twin Peak Plus fastener	1100
SK Isofest Ø 50 Croco with studs	1100
Pull through resistance	
Teleskop 40 washer	1100
Iso-Tak 40 washer	1100
Iso-Tak 45 washer	1000
Teleskop 42 fastener	1000
SFS IT-C 40 x 82 washer	1200

Fasteners

Fastening with normal steel washers can be used in longitudinal overlap joints on stiff underlay, i.e. on wood-based roof sheathing or on concrete.

On underlay of insulation material with good compression strength, such as EPS 20 kg/m^3 or similar, plastic fasteners with integrated sleeve are preferably used. When roofing membranes are installed on insulation material with lower compression strength, the tightening of the fasteners must be controlled and fasteners with good telescopic action must be used.

Fasteners with studs must always be used on the roll width of 2 m for Protan SE and EXG. Some suitable fasteners are:

a) Teleskop Dracula TPD 50
b) Iso-Tak Twin Peak Plus
c) Iso-Tak Plus 48-3N
d) Croco Ø 50 mm with studs

Underlay

When a fire classification is required the underlay must be in accordance with the provisions stated in section 5 "Safety in case of fire".

To avoid migration, Protan EXG or a separate migration barrier must be used when the roofing is installed directly on old, aged PVC, or on EPS or XPS insulation.

When the membrane is installed on old asphalt roofing without additional insulation, Protan SE with a separate barrier or Protan EX shall be used.

Protan EX is recommended for installation on wood-based roof sheathing.

Inspections and maintenance

The roofing membranes must be cleaned locally before starting any welding of joints as a part of repair work.

Roof traffic

When it should be expected that roof traffic may exceed what is required for normal inspection visits and maintenance, special measures should be taken to protect the roofing membrane.

7. Factory production control

Protan SE, EX and EXG are subject to supervisory factory production control and product control according to contract between SINTEF Building and Infrastructure and Protan AS concerning SINTEF Technical Approval.

The manufacturer Protan AS has a quality system which is certified by Det Norske Veritas according to ISO 9001:2000, certificate no. 95-OSL-AQ-6343.

8. Basis for the approval

Material- and design data have been verified by type testing and audit testing performed by SINTEF Building and Infrastructure during the years 1975–2006.

Resistance against spread of flames have been verified by type testing and audit testing performed by the Norwegian Fire Research Laboratory during the years 1975–2006.
The data in Table 5 is based on system tests in accordance with the test methods NT Build 307 and NBI 162/90, supplemented by comparable results from simplified tests in accordance with NBI 163/91.

The durability of Protan PVC roofing membranes against humus attacks from roots in the turf roofing has been verified according to DIN 16734 par. 5.16, see report 31224/96 and 33354/97 from Süddeutsches Kunststoff-Zentrum, and in accordance with FLL-Verfahren (1999), see report dated 12.10.1999 from Institut für Bodenkunde und Pflanzenernährung.

9. Marking

All rolls/packages shall be marked with the manufacturer's product code, product name and date of production. The approval mark for SINTEF Technical Approval No. 2010 may also be used.

Approval mark

10. Liability

The holder/manufacturer has sole product responsibility according to existing law. Claims resulting from the use of the product cannot be brought against SINTEF beyond the provisions of Norwegian Standard NS 8402.

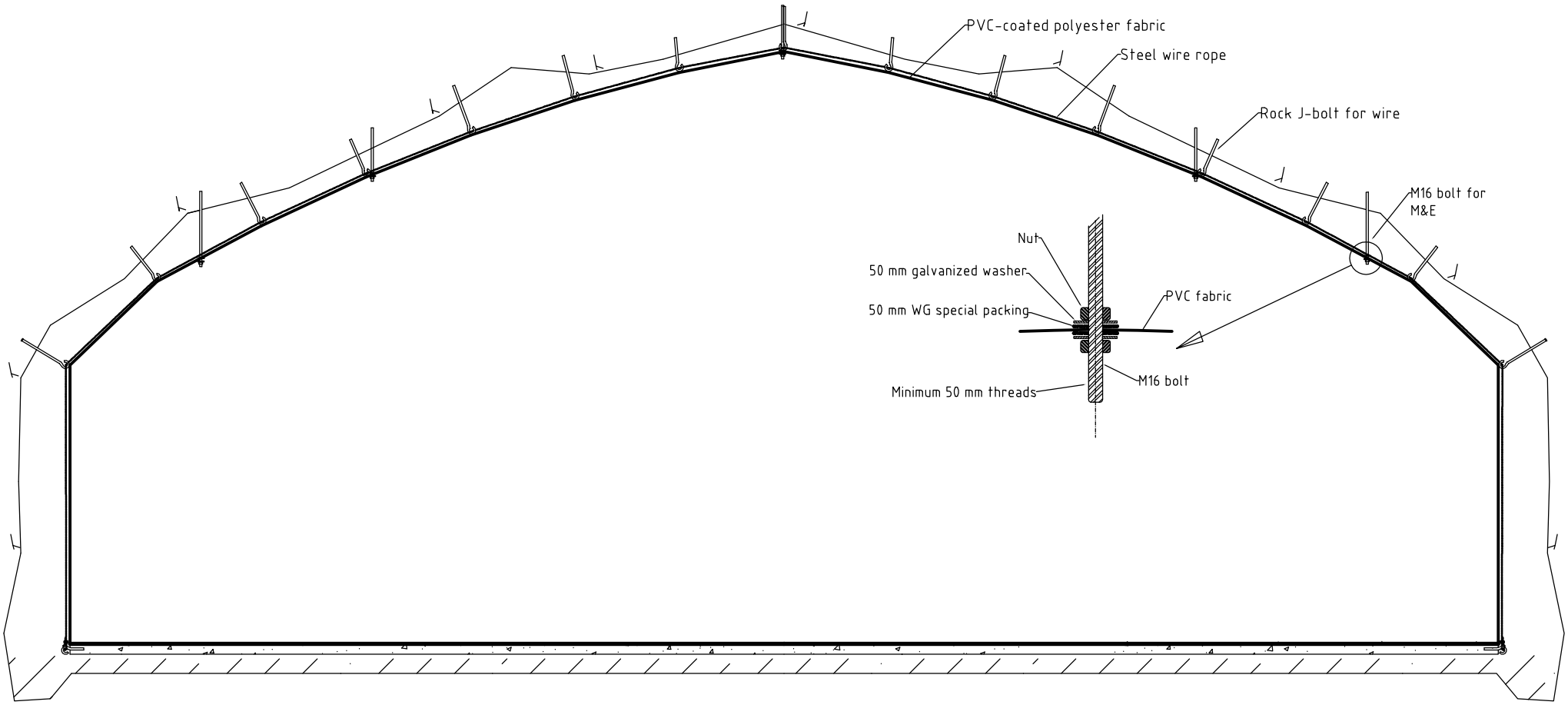
11. Technical management

Project manager for this approval is Knut Noreng, SINTEF Building and Infrastructure, Trondheim.

for SINTEF Building and Infrastructure

Steinar K. Nilsen
Approval manager

APPENDIX D



Dato	Konstr./Tegnet	Tracet	Målestokk	GIERTSEN Tunnel AS
13/1-12	P. M. Dale		-------	P.O.Box 78 Laksevåg N-5847 Bergen / Norway
Kontr.	Stand.kontr.	Godkjent		

WG TUNNEL SEALING SYSTEM

SYSTEM DRAWING

Erstatning for:	Erstattet av:
Tegnings nr.: 04	
Henvisning:	Beregning:
Bedr.int registrering:	

APPENDIX E

New claims of fire

Products to Norwegian road tunnels
Testing according to ISO 9705

Criteria	Unit	New criteria Tunnelclass A - B	New criteria Tunnelclass C - F
Minimum flash-over time	min	20	20
Maximum heat relase	kW	500	300
Average heat relase	kW	100	50
Maximum smokeproduction	m^2/s	2,3	2,3
Average smokeproduction	m^2/s	1,4	0,7

WG Tunnel Sealing 556 fulfill all this claims!

APPENDIX F

GIERTSEN TUNNEL AS

Date 08.2007

Quality No.	**554**	
Base fabric		Polyester, 100 dtex
Coating		PVC
Width		204 cm
Weigth	DIN 53352	ca. 700 g/m2
Tear resistance	DIN 53356	ca. 500 / 450 N
Tensile strength	DIN 53354	ca. 3000 / 2900 N/5 cm
Adhesjon		ca. 100 N/5cm
Flame retardancy	SIS 650082	Satisfactory
Temperature resistance	DIN 53361	+ 70 °C - 30 °C

Subject to modifications without notice

Giertsen Tunnel AS
P.B. 78 Laksevåg
N-5847 Bergen

Drammen 16 mai 2007

Fire test, quality 554

Our quality 554 are fire tested by Protan`s own laboratory.
The laboratory is approved according to the ISO 9001 standard. (Norske Veritas)

Test method is SIS 6500 82 (BS 3119: 1959)
SIS 6500 82 is a vertical fire test and is a relevant fire test for our pvc coated qualities.

In addition to Protan`s own laboratory test, quality 554 each year are tested by SINTEF and SITAC according to standard SIS 6500 82.

Quality 554 also satisfactory the requirement to NS-EN 13501-1, Fs class B, C and D, tested by SINTEF August 2003.

BS 476-7 is a test for surface spreading of fire (prevent spreading to unforeseen building).

BS 476-7 is not a relevant test method for our pvc coated liners.

Protan can not compare SIS 6500 82 against BS 476-7 because BS 476-7 is a irrelevant test method for Protan`s pvc coated liner 554.

Best regards

Geir Strandenes
Sales Manager, Technical Textile

Protan AS
Postboks 420 Brakerøya, N-3002 Drammen
Tlf.: 32 22 16 00 Faks 32 22 17 00
Foretaksregisteret NO 983 599 060 MVA

Protan SE is the principal material used on exposed roof applications, in vacuum or mechanically attached systems. These roofing systems are suitable for new build and refurbishment applications, flat and pitched roofs.
Protan EX is a Protan SE with a laminated polyester fleece on its reverse side and can be installed directly on old roofing underlay. Protan EXG is a Protan SE with a laminated glass fleece on its reverse side and can be installed directly on polystyrene thermal insulation. We recommend that all roofs have an inclination of minimum 1:40 to provide positive drainage.

Protan SE

Manufactured from pliable PVC with a reinforcement of woven polyester. The PVC contains stabilisers, which make the product resistant to high and low temperatures, UV-resistant and makes it flame retardant. Protan SE, EX and EXG are available in the thicknesses and specifications as shown below.

	Protan SE, EX, EXG		Protan EX	Protan EXG
Thickness	1,2 mm	1,6 mm	Weight of polyester fleece on side = 180 g/m²	Weight of glass fleece reverse side = 50 g/m²
Weight	≥1,4 kg/m²	≥1,75 kg/m²		

Low temperature flexibility – weather conditions

Protan SE is designed in Norway for the low temperature conditions in Scandinavia during winter months. The material remains flexible at low temperatures, during installation and use, without fracturing. The material can be installed in all kinds of weather conditions, even when it is raining.

	Protan SE, EX, EXG 1,2 mm - 1,6 mm
Flexibility at low temperatures EN 495-5	- 30 °C

Water vapour permeability

Protan SE, EX and EXG are vapour permeable materials. When used as a mechanically attached system, the membrane provides an ideal design solution for roof constructions with limited risks of interstitial condensation.

Solar reflection

A relative light coloured roofing material can reduce surface temperatures during warm weather and heat gain within the interior of the building. Where air conditioning is in use, cost savings may be significant.

Tensile strength and tear strength

Tensile strength is an important property in determining the material's ability to resist wind uplift forces, thermal movements and different movements of the building structure. High tear strength is essential for mechanically attached roofing membrane systems. Tensile and tear strength properties are shown in the table below.

	Protan SE and EXG		Protan EX	
	1,2 mm	1,6 mm	1,2 mm	1,6 mm
Tensile strength EN 12311-2	≥ 1050 N/50 mm	≥ 1050 N/50 mm	> 1200 N/50 mm	> 1200 N/50 mm
Elongation at break EN 12311-2	> 15 %	> 15 %	> 15 %	> 15 %
Tear resistance EN 13210-2	210N	210N	300N	300N

Puncture resistance

Protan SE, EX and EXG are resistant to normal foot traffic during roof maintenance and inspections. At areas where frequent foot traffic is expected, for example on walkways to roof-top plant, a Protan walkway membrane can be attached to the Protan SE material, normally in a contrasting colour. The different thickness and fleece lamination of respectively Protan SE, EX and EXG provide suitable resistance according to substrate. Details of puncture resistance are shown in the following table.

	Protan SE and EXG		Protan EX	
	1,2 mm	1,6 mm	1,2 mm	1,6 mm
Penetration by increasing force on EPS 20 kg/m³ EN 12730	< 350N	> 400 N	> 550 N	> 550 N
Resistance to puncture by impact + 23 °C EN 12691	8 mm	8 mm	6 mm	6 mm
Resistance to puncture by impact -20 °C EN 12691	10 mm	10 mm	8 mm	8 mm

Chemical resistance

The chemical resistance of Protan SE, EX and EXG
depends upon concentration, duration of contact and temperature. The table below indicates the resistance of Protan SE at normal temperature to various common substances. Please contact Protan TS-Department for particular concentrations and other materials.

Material	Resistance	Material	Resistance
Aluminium	Well suited	Paraffin	Conditional
Asphalt	Not resistant	Petrol	Not resistant
Bitumen	Not resistant	Salt of Aluminium	Not resistant
Caustic potash	Well suited	Salt of Ammonium	Well suited
Carbon Monoxide	Well Suited	Salt of Calcium	Well suited
Carbon tetrachloride	Conditional	Salt of Magnesium	Well suited
Common salt	Well suited	Salt of Potassium	Well suited
Copper & ferrous materials	Well suited	Salt of sodium	Well suited
Detergents	Well suited	Sea water	Well suited
Diesel oil & fuel oil	Conditional	Soaps	Well suited
Ethyl ether	Not resistant	Softeners	Not resistant
Fats (animal &vegetable)	Not resistant	Solvent	Not resistant
Formaldehyde	Conditional	Steam	Well suited
Iron residues	Conditional	Tar	Not resistant
Motor oils	Conditional	Turpentine oil	Not resistant
Nitric acid	Conditional	Urea	Well suited
Non-aromatic mineral oils	Conditional	Weed killer (aqueous)	Well suited
Oils (animal & vegetable)	Not resistant	Wood preservatives	Conditional

Ageing

Accelerated weathering tests have indicated that the minimum life expectancy of Protan SE 1,2mm thick membrane is 25 years. The effects of weathering commence at the external surface of the membrane and progress downwards through its thickness. Protan SE 1,6mm membrane thus has an even longer life expectancy. The use of lighter colours helps reduce surface temperature, and may thus improve the membrane's ageing performance.

Fire resistance

According to ENV 1187 part 2.

Colours

Protan SE, EX and EXG material are available in the following standard colours:
Dark grey, Light grey, Black, Blue, Red, and Copper green. Depending upon roof area, membrane material can also be produced in special customised colours.

Anti slip surface

Protan SE, EX and EXG have an unique slip resistance surface as standard. Compared with non-textured materials it provides a significant safety factor when walked on in wet weather.

Protan AS
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APPENDIX H

TEST REPORTS

1) **Smoke and Toxic Test**
2) **Water Tightness**
3) **Measurement of Water Vapour Permeance**

SINTEF NBL as
(Norwegian Fire Research Laboratory)

Address: N-7465 Trondheim, Norway
Location: Tiller Bru, Tiller

Telephone: +47 73 59 10 78
Fax: +47 73 59 10 44
E-mail: nbl@nbl.sintef.no
Internet: nbl.sintef.no

Enterprise No.: NO 982 930 057 MVA

TEST REPORT

TITLE / TEST METHOD

Toxic measurements of WG Tunnelduk 556 according to descriptions in IMO FTPC Part 2, ISO 5659-2:1994

PRODUCT NAME

WG Tunnelduk 556

CLIENT(S)

Giertsen Tunnel AS
Postboks 78 Laksevåg
5847 Bergen

CLIENT'S REF.

Mr. Hans-Egil Larsen

PROJECT NO.	TASK MANAGER (NAME, POSITION, SIGN.)	APPROVED BY (NAME, POSITION, SIGN.)
102010.60/05.305	Bjarne Kristoffersen, Discipline Manager	Anne Steen-Hansen, Scientific adviser
ELEKTRONIC FILE CODE		
I:\pro\102010\60\05305\ GiertsenTunnel_report05305_060113.doc		
REPORT DATE	TEST DATE	TOTAL NO. OF PAGES
2006-01-13	2006-01-06	6

ABSTRACT:

Toxic measurements of 9 specimens of the product **WG Tunnelduk 556** was conducted according to descriptions in IMO FTPC Part 2 / ISO 5659-2:1994.

Test results are given in Appendix I.

SINTEF NBL pays attention to the fact that the toxic measurements are conducted on specimens with dimensions 75 mm x 75 mm. 3 tests are conducted at each level of exposure, where the first test was used to find the time period over 2 minutes with the highest smoke production. The toxic measurements were thereafter conducted in this time period at the two remaining tests.

The toxic measurements are not made continuous throughout the tests, but are conducted by the use of Dräger tubes.

PRODUCT DESCRIPTION:

Type of product:	PVC-based foil for use as tunnel covering
Manufacturer:	Protan AS
Place of production:	Drammen, Norway
Sampling:	The tested material was selected by the client. The material subjected for testing arrived SINTEF NBL 2005-12-14. It is not known to NBL if the fire characteristics of the product received is representative of the fire characteristics of the average product.
Test specimens:	9 specimens of tunnel covering with dimensions 75 mm x 75 mm. Nominal values for thickness and square density: approximately 0,54 mm and approximately 600 g/m^2 respectively. Colour: Grey. Measured values for thickness and square density: Density and square density approximately 0,5 mm and 700 kg/m^2 respectively.

TESTING:

Operator:	Erling Stenhaug, engineer
Conditioning of the test material:	The specimens were stored in air with a relative humidity of 50 % and at a temperature of 23 °C until constant mass was obtained.
Number of single tests:	3 at heat flux density 25 kW/m^2, pilot flame present 3 at heat flux density 25 kW/m^2, pilot flame not present 3 at heat flux density 50 kW/m^2, pilot flame not present
Duration of the tests:	Up to 20 minutes

REMARKS / DEVIATIONS:

According to the request from the client, no smoke measurements were recorded or reported.

The wire grid was not used during the test.

The toxicity measurements were performed using Dräger tubes.

According to ISO 5659-2:1994, the following limiting statement shall be given in the test report: *"These results relate only to the behaviour of the specimens of the product under the particular conditions of test; they are not intended to be the sole criterion for assessing the potential smoke obscuration hazard of the product in use."*

This test report is a translation from the original Norwegian version. If any dispute or uncertainty occurs due to interpretation, the text in the original test report is valid.

APPENDICES

Appendix I:	Test results
Appendix II:	Short description of test method and classification criteria.

Appendix I - Test results

Table 1 Average results from toxic measurements of **WG Tunnelduk 556** as described in IMO FTPC Part 2 and ISO 5659-2:1994.

	Test condition		
	25 kW/m^2, pilotflame present	25 kW/m^2, pilotflame not present	50 kW/m^2, pilotflame not present
CO-concentration	100	100	300
HCl-/HBr-concentration (measured with the same Dräger-tube)	300	0	300
HF-concentration	0	0	0
NO_x-concentration	0	40	60
HCN-concentration	0	0	0
SO_2-concentration	0	0	0

The smoke density values are average measurements from three single tests at each test condition.

The fumes for toxicity measurements were sampled during testing of specimen 2 and 3, within 3 minutes after maximum smoke density had been reached. Each measurement from the three exposure levels are reported below.

Table 2 Results from toxic measurements of **WG Tunnelduk 556** as described in IMO FTPC Part 2 and ISO 5659-2:1994.
Test condition: heat flux density 25 kW/m^2, pilotflame present.

	Specimen 1	Specimen 2	Specimen 3
CO-concentration		100	
HCl-/HBr-concentration (measured with the same Dräger-tube)		300	
HF-concentration		0	
NO_x-concentration		0	
HCN-concentration			0
SO_2-concentration			0
Filename	05305004	05305005	05305006

Table 3 Results from toxic measurements of **WG Tunnelduk 556** as described in IMO FTPC Part 2 and ISO 5659-2:1994.
Test condition: heat flux density 25 kW/m^2, pilotflame not present.

	Specimen 1	Specimen 2	Specimen 3
CO-concentration		100	
HCl-/HBr-concentration (measured with the same Dräger-tube)		0	
HF-concentration		0	
NO_x-concentration			40
HCN-concentration			0
SO_2-concentration			0
Filename	0530501	05305002	05305003

Table 4 Results from toxic measurements of **WG Tunnelduk 556** as described in IMO FTPC Part 2 and ISO 5659-2:1994.
Test condition: heat flux density 50 kW/m^2, pilotflame not present.

	Specimen 1	Specimen 2	Specimen 3
CO-concentration		300	
HCl-/HBr-concentration (measured with the same Dräger-tube)		300	
HF-concentration		0	
NO_x-concentration			60
HCN-concentration			0
SO_2-concentration			0
Filename	05305007	05305008	05305009

Appendix II - IMO RESOLUTION MSC 61(67) Fire Test Procedures, Part 2: Smoke and Toxicity test

TEST PRINCIPLE

The test principle is given in international standard ISO 5659-2:1994, with additional measurements and criteria as stated in IMO Res. MSC 61(67). The method is applied to assess smoke production from materials for marine application, and the toxicity of the smoke fumes.

The surface of a specimen with dimensions 75 mm x 75 mm is exposed to heat radiation from above. The test specimen is placed inside a chamber, where the smoke produced from the specimen during the test is collected. Optical smoke density (Ds) is determined by measuring the attenuation of a light beam by the smoke in the chamber. When the smoke density reaches its maximum value, gas samples for measurement of toxic gas concentrations are collected. The toxic gases measured are CO (carbon monoxide), HCl (hydrogen chloride), HF (hydrogen fluoride), NO_x (nitrogen oxides), HBr (hydrogen bromide), HCN (hydrogen cyanide) and SO_2 (sulphur dioxide).

If the correction factor Dc is bigger than 5% of Dm, it shall be subtracted from Dm.

The tests are performed at three different test conditions:
1. heat flux density 25 kW/m^2, pilotflame not present
2. heat flux density 25 kW/m^2, pilotflame present
3. heat flux density 50 kW/m^2, pilotflame not present

Three single tests are carried out at each of these test conditions. The measurements of gas concentrations are only measured once for each test condition.

CLASSIFICATION CRITERIA

The criteria for evaluating a material as not capable of producing excessive quantities of smoke and toxic products or not to give rise to toxic hazards at elevated temperatures are given below.

1. Smoke

An average (Dm) of the maximums of Ds of three tests at each test condition shall be calculated.

.1 for materials used as surface of bulkheads, linings and ceilings, the Dm shall not exceed 200 in any test condition;

.2 for materials used as primary deck covering, the Dm shall not exceed 400 in any test condition;

.3 for materials used as floor covering, the Dm shall not exceed 500 in any test condition and

.4 for plastic pipes and electric cables, the Dm shall not exceed 400 in any test condition.

2. Toxicity

The gas concentrations measured at each test condition shall not exceed the following limits:

CO	1450 ppm	HBr	600 ppm
HCl	600 ppm	HCN	140 ppm
HF	600 ppm	SO_2	120 ppm
NO_x	350 ppm		

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O 14049-1	06.12.2001		2		Confidential	Lars-Ivar Aarseth

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Report

PROTAN TUNNELDUK 554 – WATER TIGHTNESS

Summary

The Norwegian Building Research Institute, NBI, has on order from Protan A/S tested the water tightness of the product "Protan Tunneldug 554"

Test method
The water tightness of samples of the material was tested according to NS-EN 1928, under a water pressure of one meter H_2O.

Result
The material passed the test.

Address of the building	Built (year)

Activity code	Method	Keywords	Filename
3.8 Typeprøving. Godkj. Inspeksjon. Kontr.prøving	Laboratorie-undersøkelse	Kvalitet, Plast, Fukt	Vanntetthet.doc

NORWEGIAN BUILDING RESEARCH INSTITUTE

PROTAN TUNNELDUK 554 – WATER TIGHTNESS

1. INTRODUCTION

The Norwegian Building Research Institute NBI, R&D Department of Building Technology, Trondheim, has on order from Protan A/S carried out a water tightness test of:

Protan tunnelduk 554, 0,57 mm

We received the test material on the 4th of December 2001.

2. TEST PROGRAMME

The water tightness was determined according to NS-EN 1928, method A. Three test samples where taken.

The material was tested under a water pressure of one meter H_2O (9,81 kPa).

The test was carried out from December the 4th to December the 7th 2001.

3. RESULTS

The tested material passed the water tightness test for the applied hydraulic pressure of one meter H_2O (9,81 kPa).

Trondheim, 06.12.2001
Norwegian Building Research Institute

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Project/archive no.	Date	Rev. date	No. of pages	Appendixes	Classification	Author(s)
O8340-246 O 14049-1	2002-01-14		3		Restricted	Berit Time

Project leader	Sign.	Responsible manager	Sign.	Quality assurance	Sign.
Berit Time		Terje Jacobsen		Sivert Uvsløkk	

Assignment Report

MEASUREMENT OF WATER VAPOUR PERMEANCE- "PROTAN TUNNELDUK 554"

NORSK AKKREDITERING
TEST 107

Laboratory for Material Testing Trondheim

The results apply to the tested objects only.

Summary

Test method:
The Norwegian Building Research Institute (NBI) has carried out a test in accordance with NS-EN ISO 12572 "Hygrothermal performance of building materials and products. Determination of water vapour transmission properties" on "Protan Tunnelduk 554".

Results:
Water vapour permeance, average of five test specimens was measured to be 32E-12 kg/(m² s Pa).
Water vapour resistance, average of five test specimens was measured to be 32E+9 (m² s Pa)/kg.
This gives an s_d-value of 6,2 m.

Address of the building	Built (year)

Activity code	Keywords	Filename
???	FUKT PLAST	O8340-246 / O14049-1 rapport Protan AS - GD

1. INTRODUCTION

The Norwegian Building Research Institute (NBI) has undertaken water vapour permeance measurement on "Protan Tunnelduk 554". The tests were carried out at NBI's Moisture Laboratory in Trondheim between 10nd of December 2001 and 10th of January 2002.

2. TEST OBJECTS

The tested material was sent to the NBI by the client and received on the 4th of December 2001. (Receipt No. 237/01).

The tested material was "Protan Tunnelduk 554", measured to be 0,57 mm thick.

3. TEST METHOD

The test was carried out by means of a "cup" method **NS-EN ISO 12572 "Hygrothermal performance of building materials and products. Determination of water vapour transmission properties".** The test specimens were installed as lids on boxes that were partially filled with a saturated solution of potassium nitrate, KNO_3, and placed in a room with constant temperature and relative air humidity. The water vapour permeance for the individual test specimens was found by repeated weighing.

4. TESTING

4.1 Preparation of the test pieces

The test pieces were punched out of the supplied material, evenly spaced across the width of the supplied material.

4.2 Conditioning

After cutting, the test pieces were conditioned from the 4th to 10th of December 2001 at 23°C and 50% relative air humidity.

4.3 Test conditions

Table 1. Temperature, relative air humidity and barometric pressure during the test period

	Average during the test period	
Relative air humidity in the box (% RH)	93.9	
Relative air humidity in the room (% RH)	48.9	
Temperature in the box (°C)	24.0	*
Temperature in the room (°C)	24.0	*
Barometric pressure (h Pa)	1011.0	

* Deviation in relation to requirement of standard + 0.5 °C

5. RESULTS

The results apply to the tested objects only.

5.1 Results

Table 2.
Water vapour permeance, equivalent air-layer thickness and water vapour resistance for five test pieces. Individual results are average of five time-intervals with stable moisture transport.

Test no.	Water vapour permeance (kg/m² s Pa)	Equivalent air-layer thickness (m)	Water vapour resistance (m² s Pa/kg)
1	31×10^{-12}	6.2	32×10^{9}
2	31×10^{-12}	6.3	32×10^{9}
3	32×10^{-12}	6.1	31×10^{9}
4	32×10^{-12}	6.1	32×10^{9}
5	32×10^{-12}	6.1	31×10^{9}
Average	32×10^{-12}	6.2	32×10^{9}

5.2 Corrections

The results given in Table 2 have been adjusted for the following parameters:
- Variations in the relative air humidity in the surroundings and in the test box
- Variations in temperature in the surroundings and in the test box
- Variations in barometric pressure
- Transfer resistance at the specimen's upper side
- Vapour transport through the overlap zone at the seal between the specimen and the test box
- Vapour-transport resistance in the air layer in the test boxes.

5.4 Margin of error

Calculated margin of error for every test "cup" carried out is +/- 9.6 %.

NORWEGIAN BUILDING RESEARCH INSTITUTE
TRONDHEIM

Berit Time

APPENDIX I

Quality Assurance Plan.

Project:D2000-00953-060,Mandai **Ref. no TD-1209**
Project Manager: Arne Lærum Assistant Project Manager:Alv Hanstvedt **Date: 10.02.2002**

No	Activity	Control of item	Control Reference	Procedure	Location of control	Control extent	Control conductet by	Final document for control	Type of registration	Remark
01	Contract evaluation	Contract/ Appendix	Check list		Office	100%	Project manager	Contract	Signature	All personell involved in the project must understand the contents of the contract
02	Rig	Rig area	Check list		Site	100 %	Technical manager	Report	Check list	
03	Shipment of equipement,tools	Tools,machines, container etc.	Rig list Freight documents	TP-011	Delivery - site	100 %	Work shop Foreman	Freight letter	Freight documents	
04	Acceptance of delivery	Tools,machines, container etc.	Rig list Freight documents	TP-012	Site	100 %	Foreman	Rig list Freight documents	Rig list	Report any divergence
05	Acceptance of delivery	WGTS order	WGTS order	TP-13	Site	100 %	Foreman Technical manager	Freight documents Purchase document	Check list	Every pallet is marked with section nr.
06	Acceptance of delivery	Bolts and steel	Rig list/steel order	TP-014	WG Norway Site	100 %	Foreman Technical manager	Freight documents Purchase document	Check list	
07	Installation of WGTS	Sealed area	Check list	TP-021	Site	100 %	Foreman Technical manager	Check list	Check list	
08	Installation verification test.	WGTS site	Production report Tender	TP-029 Contract	Site	100 %	Contractor Foreman Technical manager	Production report	Installation documents	
09	Site acceptance verification.	WGTS site	Contract	TP-002 VE-03	Site	100 %	Contractor Project manager Technical manager	Site acceptance document	Site acceptance documents	
10	Invoice.	Invoice documents	Production report Working report	TP-003	WG Norway	100 %	Project manager Office manager Technical manager	Installation documents		
11	Hour consumption Material consumption	Consumption documents	Production report Working report	TP-004	Site WG Norway	100 %	Foreman Technical manager	Production report Working report		
12	Termination rig	Site	Check list	TP-015	Site WG Norway	50 %	Technical manager Foreman Work shop	Rig list Freight documents		Removal of debris
13	Divergence	The whole project	Check list	TP-005	Site WG Norway	100 %	Project manager Technical manager	Divergence report	Divergence list	

APPENDIX J

AH. 04.12.2010 - 01

CHECK LIST

Projectnumber.:	Projectname:
Shaft no.:	Set up by: Alv Hanstvedt
	Approved by:
Date:	Copy to:

POINT	CHECK POINTS	OK	NOT OK	DATE	SIGN.
1.0	**WORKING AREA**				
1.1	Safe Job Analysis				
1.2	Local HSE instructions				
1.3	Storage space for material/tools				
1.4	Cleared working area				
1.5	Floor suitable for use of scaffolding				
1.6	Washroom/Wardrobe/Locker room				
2.0	**MARKING/MEASURING**				
2.1	Is theoretical profile OK (aspect ratio to rock)				
2.2	Longitude/latitude according to sketch				
3.0	**DRILLING**				
3.1	Borehole marked				
3.2	Angle of drill acceptable				
3.3	Drilldepth min. 200mm				
3.4	Rock quality				
4.0	**FIXING BOLTS**				
4.1	All bolts are hot dip galvanized				
4.2	Sufficient Hilti (glue) in the borehole				
4.3	The bolt has correct aspect ratio				
4.4	Endbolts above 0.8m supported with pipes				
4.5	Safety glasses are to be used				
5.0	**WIREROPE**				
5.1	Wirerope sufficient tightened				
5.2	Wire clamps tightened				
5.3	Wire-end secured with tape				
5.4	Wirerope 5,4mm hot dip galvanized				
			NOT		

POINT	CHECK POINTS	OK	OK	DATE	SIGN.
6.0	**DUK.**				
6.1	Tunnelsealing quality 556 as specified.				
6.2	Tunnelsealing sufficient tightened				
6.3	WG packing tightened and correct installed.				
6.5	Welding of Tunnelsealing min. 4cm width				
6.6	All corners are rounded				
6.7	Tunnelsealing delivered at correct place free of damage				
6.8	Fastened to wall, complete with plastic list and warranted tight				
8.0	**GUTTER**				
8.1	Bolts for gutter c/c 2m				
8.2	Aluminiumstrip with double bend fixed to the bolt with connecting plate				
8.4	Hook for gutter c/c 1,0m				
8.5	Gutter installed with sufficient slope				
8.6	Tunnelsealing ensured through gutter edge, and fastened under the aluminiumprofile				
8.7	Gutter is cleaned and free of dirt, etc.				

If extra comments, please note at the other side of the sheet.