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Issue 14

Electrochemical noise during stress-corrosion cracking

ZAG

The direct cost of the corrosion of metals in developed countries has been estimated to be between 3% and 5% of the gross national product. The use of corrosion-resistant metals (various types of stainless steel, titanium and nickel alloys, etc.) could, in general, reduce the damage caused by corrosion. However, these materials are sensitive to localised corrosion processes: i.e. pitting and crevice corrosion, stress-corrosion cracking and corrosion fatigue. The most dangerous localised corrosion process, stress-corrosion cracking, can cause delayed failures of structures without any previously visible outward damage. In recent years much research work has been directed towards the development of a system which would be able to detect stress-corrosion cracking, since conventional monitoring methods do not provide reliable information about localised corrosion.

Electrochemical current and voltage noise (electrochemical noise – EN) is spontaneously generated by corrosion reactions. This means that the characteristics of EN are influenced only by the nature and intensity of corrosion processes. In the last few years, in order to detect localised corrosion processes, the research team from the Laboratory for Metals, Corrosion and Anti-Corrosion Protection at ZAG has carried out numerous investigations based on measurements of EN, with the emphasis on the detection of stress-corrosion cracking. They have proved the reliability of stress-corrosion cracking detection by means of the EN technique with simultaneous measurements of micro-changes in elongation of the specimen while subjected to a tensile load. No characteristic EN fluctuation was observed without a sudden coincident 'jump' in elongation (see figure 1).

The main aim of their recent and present studies is the characterisation of EN signals generated by cracking processes and to correlate these signals with the initiation and/or propagation of a single crack. Characteristic electrochemical current and voltage transients, as well as a simultaneous crack velocity transient (obtained by time differentiation of elongation), are shown in figure 2. By means of a comparison between the measured electrochemical conditions and the simultaneous cracking kinetics, several new assumptions concerning the phenomenon of cracking processes, from the initiation of a crack to the arrest of its development, have been obtained:

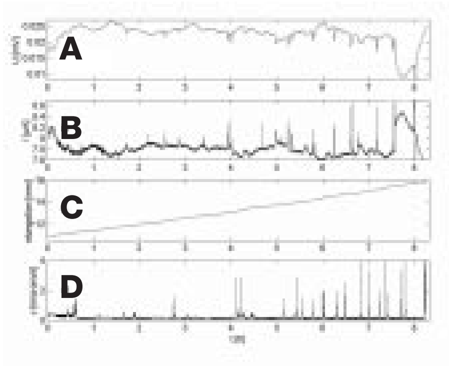


Figure 1 Characteristic time series of: a) electrochemical voltage noise, b) electrochemical current noise, c) elongation, and d) crack velocity

- the time evolution of the current depends strongly upon the rate of formation of bare metal (in one of the related studies it was confirmed that the amplitudes of current transients are linearly dependent upon the amplitudes of crack velocity transients)

- due to the fact that the voltage transient does not wholly follow the transients of current and crack velocity (the discrepancy between the times when the described transients reached their maximums was observed – see figure 2), it can be assumed that voltage transient evolution is driven not only by current (which is, for example, common during metastable pitting), but also by a second process, probably due to a temporary change in the electrochemical double layer characteristics influenced by crack growth.

In future work, it is planned that this research be extended to environments simulating the conditions in pre-stressed concrete structures (high-strength steel in a high pH-environment), nuclear power stations (a low conductivity environment), and littoral structures (stainless steel and aluminium alloys in brine). Corrosion fatigue will also be included in these investigations. It is believed that the knowledge obtained will help us to clarify and to model mechanisms of these complex corrosion processes. Additionally, it is hoped that the EN technique will be developed to such an extent that it will be possible to perform reliable in-situ monitoring of dangerous corrosion processes on different structures.

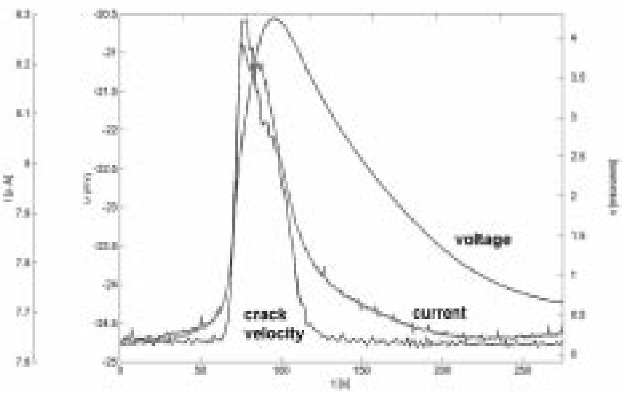


Figure 2 Characteristic transients of electrochemical voltage and current, and simultaneous crack velocity transient – all of them generated by the same cracking event

For further information please contact:
Andraz Legat
ZAG Ljubljana
Tel: +386 1 588 8295
Fax: +386 1 436 7749
E-mail: andraz.legat@zag.si

in brief

Towards the European Research Area

At the beginning of October the European Commission issued a Communication (COM (2000) 612) relating to the development of the European Research Area (ERA) and its impact on plans for the Sixth Framework programme (FP6).

In relation to future European research activities the Communication proposes, amongst other issues, to:

- increase networking of national research activities and of centres of excellence
- promote large-scale targeted research projects (about 10M€ each) particularly in the field of industrial research.

Specific priorities the Communication mentions are:

- Post-genome research
- Nanotechnologies
- Information society research
- Aeronautics and space
- Support for EU policy
- Sustainable development

Results of last GROWTH Call

Construction and infrastructure-related proposals did well in the last call in the GROWTH programme. In KA1 (Innovative Products Processes and Organisation) 102 of the 373 proposals were successful. Of this 102, 25 were from the 'Infrastructure' TRA. Additionally there were 4 successful Thematic Network proposals from the 9 submitted. Of this 4, 3 were from the construction sector.

"ENBRI brings together the principal Building Research Institutes of the European Union (EU) and of the wider European Economic Space (EES), for the benefit of the world of construction."

Executive Secretariat ENBRI
c/o WTCB-CSTC
rue de la Violette, 21-23
B-1000 BRUSSELS, Belgium

Tel: +32 2 716 42 11
Fax: +32 2 725 32 12
www.enbri.org

Developing an environmental performance standard for the Dutch Building Decree

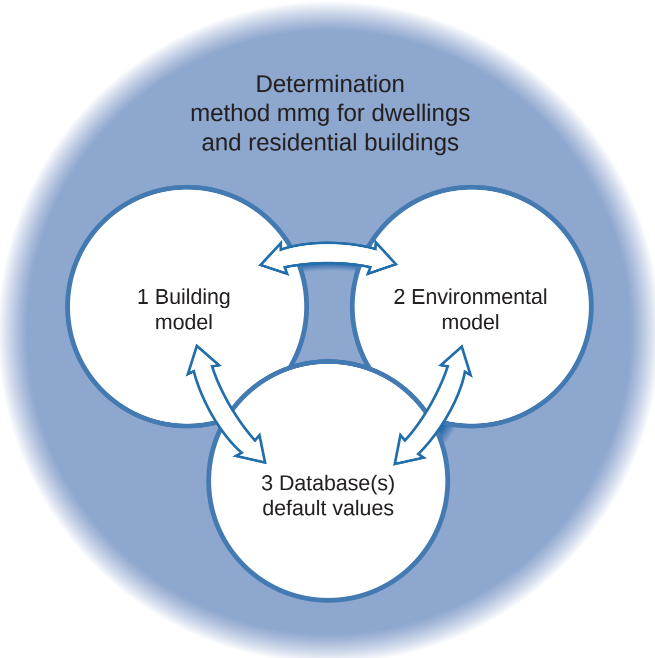
After consulting the building industry, the Dutch government decided in February 1998 to incorporate sustainability requirements into the Dutch Building Decree by the year 2001. Part of the requirements will be a material-related environmental performance requirement for buildings (Dutch acronym – mmg). An energy performance requirement for buildings is already part of the Dutch Building Decree.

At the request of the Ministry of Housing, Physical Planning and Environment, a consortium of TNO, IVAM, CML. INTRON and W/E, developed a prototype for the determination methodology for the mmg. This comprised the first phase of the work. In the second phase, to be completed by mid-2001, the methodology will form the basis for a standard.

In the methodology a solution will be given for three elements of the determination method (see diagram):

- modelling dwellings and residential buildings, using material specifications available at the stage of a building permit, when not all decisions about specifications of materials have been taken
- developing a model to calculate the environmental effects of the materials used during the lifetime of a building; the LCA (life cycle analysis) method will be the basis for the method
- developing databases (with the building industry) outlining the environmental performance of building products.

For further information, please contact:
Erica Waller
Tel: +46 33 16 56 06
Fax:+46 33 13 45 16
E-mail: erica.waller@sp.se



Elements of the model for the determination method

Preventing disorders
Mastering the terrible trio: water, heat and mechanical stresses

Symphonie software simulates the behaviour of structures under combined effects of water, heat and differential movements. It opens the way for a rational means of predicting pathology in a sector in which empiricism reign.

Combined transfers of heat and water, in all their forms, associated with differential structural movement, are the causes of numerous disorders in buildings. Materials dilate under the effect of heat, bloat by absorbing water or retract in cold. These differential movements create tensions, especially in heterogeneous assemblies such as thin coatings on insulating materials, and ultimately generate cracks. In case of fire, they provoke shattering of new high resistance concrete.

Reproducing these phenomena simultaneously in a laboratory, on a beam measuring several meters or on a 12 metre high wall, is almost impossible. Similarly, it is difficult to reproduce different climatic stress to which building structures are subjected throughout their life cycle. At best we can subject a reduced-scale model to extreme stress, supposedly the equivalent of real-life ageing.

Symphonie software, developed as part of the Mocadi unit by CSTB researchers, represents progress by enabling users to foresee phenomena and thus master potential risks of disorder. This software relies on modelling interactions between thermal, hydric and mechanical phenomena and simulates the behaviour of building structures for all scenarios that one could hope to study such as climate, duration and stress.

Symphonie software can help optimise the design of heated floor systems, among others

This modelling of fundamental physical phenomena stems from characterising intrinsic properties of materials, a process which is only possible in advanced metrology laboratories, such as those at CSTB.

Once the physical characteristics of material are entered, *Symphonie* software enables researchers to:

- study the behaviour of all types of composite assemblies such as envelope panels (sandwich panels), constructive systems consisting of successive varied layers (thin coatings over insulating material, coverings, etc)
- optimise the design of heating/cooling floors while determining the position of pipes to assure a constant temperature and also to avoid phenomena of condensation and thus corrosion
- perfect new formulae for high resistance concrete to increase the safety of structures in relation to fire risk
- study the resistance to fire of very tall walls.

Besides a vast field of applications, *Symphonie* software opens the way to computer-assisted design and optimisation of building components.

For further information, please contact:
Ghassan Mounajed
Tel: 33 (0)1 64 68 84 15
Fax: 33 (0)1 64 68 84 99
E-mail: mounajed@cstb.fr

A virtual evaluation tool for systems and components

A platform of multi-discipline development, *Symphonie* software is a finite element general calculation code specifically developed for the virtual analysis of building problems. Most currently marketed calculation codes do not feature a sufficiently open architecture to include, simply and quickly, new possibilities or to test new laws of behaviour.

Symphonie most notably features a library of uni-, bi- and tri-dimensional elements to analyse linear and non-linear problems in the following areas:

- mechanics (static and dynamic)
- thermal transfer (stationary and transitory)
- thermo-mechanic coupling
- thermo-hydric coupling
- thermo-hygro-mechanic coupling in saturated and non-saturated areas (thesis with the Ecole Centrale de Paris, the Ecole Nationale des Ponts et Chaussées and the Laboratoire Central des Ponts et Chaussées)
- under-structuring and modal analysis techniques in thermal transfer (thesis with the INSA Lyon).

It also features a graphic and interactive pre- and post-processor developed in Windows (object-oriented, event-driven programming) and allows users to have a rapid definition of a problem and a complete analysis of calculation results in graphic form.

The Building Research Institute

The Building Research Institute (Instytut Techniki Budowlanej – ITB), the largest and oldest research centre in Polish construction, works for the building industry, conducting science and research works, with the aim of:

- developing science in the construction industry, in the specialities represented at the Institute, particularly in the area of research and analytical works regarding models of phenomena affecting the buildings, construction works, their elements and products and their behaviour resulting from these phenomena – enabling the improvement of calculation methods and research procedures
- establishing scientific foundations for formulating technical specifications and Polish standards, specially their harmonisation with European requirements (UEAtc, EOTA), national settlements to the standards and technical approvals, adjustment of them to European and international standards (EN and ISO respectively)
- scientific substructure of technical guidelines including individual tests, synthesises of outside tests and verifications for presentation that Essential Requirements were performed, guidelines on this scale and model solutions for the construction works
- studies and research works for the development of construction research service – modernisation and enlargement of laboratories base, methods of activities, testing procedures and calculation techniques concerning quality assurance systems.

Other activities

- Diagnose causes of catastrophes and breakdowns.
- Assess technical state of constructions works.
- Give guidance for preserving threatened buildings or repairing them.
- Provide expertise statements and technical opinions.
- Issue technical approvals for construction products.
- Deliver certificates of conformity.
- Issue quality systems certificates of the construction users.

Co-operation expectations

The Institute is particularly interested in the opportunity of undertaking co-operation within the EU's Fifth Framework Programme for Technical Development. The work currently being undertaken in the Institute regarding the issue of adapting existing large-panel buildings to contemporary requirements is particularly relevant to the City of Tomorrow and Cultural Heritage Key Action.

For further information please contact:
Dr Roman Gajownik
Tel: +48 22 825 15 75 or 825 77 60
Fax: +48 22 825 77 30
E-mail: rgajownik@pro.onet.pl

The Building Research Institute conducts research work in the following areas:

- the bases of structure safety
- fire safety in buildings
- evaluation of the carrying capacity and deformation ability of soil
- building of landfill sites
- building works on mining excavation areas
- concrete, masonry and wooden structures
- lightweight partitions and envelope of buildings and building woodwork
- finishing works, materials and technologies
- indoor environment, hygiene
- noise protection
- rational energy use in buildings
- durability of buildings and structural elements
- moisture, biological and chemical corrosion protection
- maintenance and modernisation of housing resources.

ENBRI Members

France – CSTB
+33 1 40 50 28 28
+33 1 45 25 61 51
www.cstb.fr

UK – BRE
+44 1923 664000
+44 1923 664010
www.bre.co.uk

Ireland – Enterprise Ireland
+353 1 808 2000
+353 1 808 2020
www.enterprise-ireland.com

Belgium – CSTC / WTCB
+32 2 716 4211
+32 2 725 3212
www.bbri.be

Netherlands – TNO-Bouw
+31 15 284 2000
+31 15 284 3990
www.bouw.tno.nl

Spain – I.E.T.c.c.-CSIC
+34 91 302 0440
+34 91 302 0700
www.csic.es/torroja/

Portugal – LNEC
+351 1 848 2131
+351 1 849 7660
www.lnec.pt/LNEC/portug

Italy – ICITE
+39 02 98061
+39 02 98 28 00 88
www.icite.cnr.it

Germany – BAM
+49 30 81 04 17 00
+49 30 81 04 17 07
www.bam.de

Denmark – SBI
+45 45 86 55 33
+45 45 86 75 35
www.sbi.dk

Finland – VTT
+358 9 4561
+358 9 456 7031
www.vtt.fi/rte/bldtech.html

Norway – NBI
+47 22 96 55 55
+47 22 96 55 42
www.byggforsk.no/english.htm

Iceland – IBRI
+354 5 70 7300
+354 5 70 7311
www.rabygg.is

Sweden – SP
+46 33 16 50 00
+46 33 13 55 02
www.sp.se

Slovenia – ZAG
+386 61 188 8100
+386 61 188 8484
www.zag.si/

Hungary – EMI
+36 1 466 9105
+36 1 386 8123
www.emi.hu

Poland – ITB
+48 22 825 04 71
+48 22 825 5286
itb@wa.onet.pl

Definition and evaluation of the architectural residential quality

Residential space characteristics influence the daily life of users and so helps determine their quality of life. Therefore, the quality of housing is an important objective to all the those involved in its promotion, financing, design, construction, inspection, use and management.

In order to help improve and ensure the architectural quality of housing and residential areas, a study *Definition and Evaluation of Architectural Residential Quality* was developed at LNEC. This study was presented at the Architecture Faculty of Oporto University (FAUP) as a PhD thesis.

Two major outputs were obtained:

- an architectural housing program defining a set of performance requirements
- a method to evaluate the fulfilment of these requirements.

Program of performance requirements

The knowledge of user needs and wishes, expressed by the performance requirements and specifications, is necessary for housing design, analysis and evaluation.

Sometimes, this knowledge is not easy to obtain because, during the design phase, the users may not be known; user needs evolve and users may vary during the service life of the building. Therefore, a program was developed which can be used as a reference to design new buildings or to rehabilitate existing ones. It may also support the development of new instruments for quality analysis and evaluation.

The program is organised in four physical levels: dwelling spaces, dwellings, buildings and neighbourhoods, and defines three performance levels (minimum, recommended and optimum) referring to different satisfaction levels of user needs (Figure 1).

The program was based on the synthesis and harmonisation of Portuguese and other information sources (regulations, standards, enquiries to users, housing development analysis, etc). The development of more than 100 models that fulfil the proposed requirements, tested the coherence of the program.

For each physical level the program:

- organises the general data of the problem (classification of spaces and use functions, definition and characterisation of the most frequent typologies)
- defines a set of performance requirements and specifications (concerning environmental comfort, safety, space-functionality adequacy, articulation, personalization and economy)
- exemplifies the application of the performance requirements and specifications with models of the most frequent typologies.

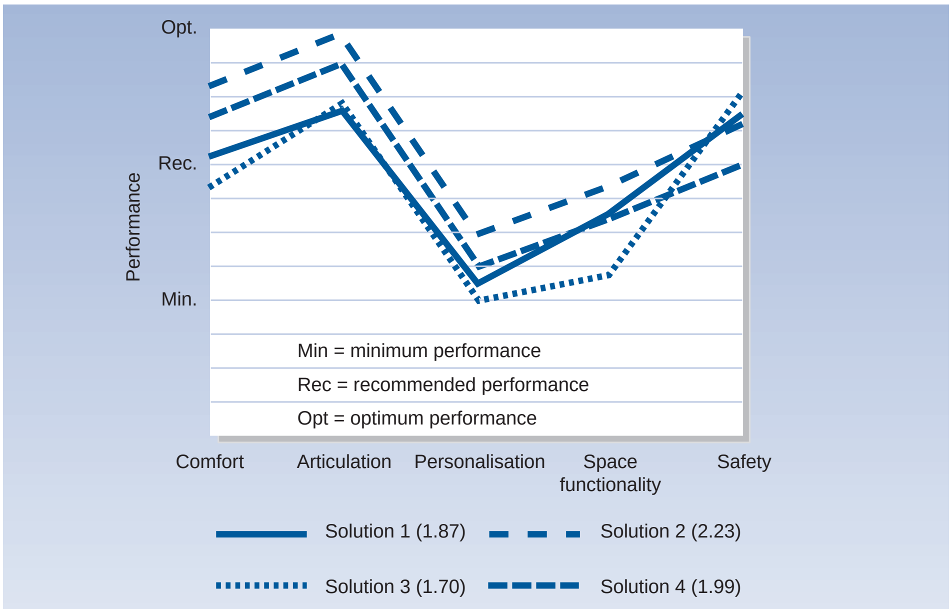


Figure 1 Performance profile

Evaluation method

Housing promotion, use and management processes often require the choice between different solutions for a problem.

Sometimes, this decision is not simple, due to the multiple aspects of the architectural residential quality and the different objectives of the entities involved.

To support the formulation, justification and/or transformation of such decisions, an evaluation method that organises and quantifies the most important aspects of architectural housing quality was developed.

This evaluation method included:

- a decision tree with the quality objectives
- the indicators to evaluate each objective performance
- the preferred criteria for each objective
- the methodology that combines indicator results and preferential criteria in a global result.

The objective is to develop a simple and practical methodology. To achieve this the use of the method is modular. The input data can be collected from the design drawings or observed in situ. A fixed vocabulary is used and the required technical concepts are explained in a glossary.

Since the evaluation method can be used in different situations, the preferred criteria, which determines the relative importance of each objective in a global evaluation, was defined in order to express the priorities of the general users. It is expected that the preferred criteria are customised in each application.

In order to make the application of the evaluation method easier, a computer program was developed. This manages the solution's description data, performs the solution's evaluation and presents the results (figure 1 is an example of the performance profile produced by the computer program).

For further information please contact:
João Branco Pedro
Tel: + 351 21 8443782
Fax: +352 21 8443028
E-mail: jpedro@lnec.pt

Evaluation and laboratory testing of roofs with combined sheathing and wind barrier

BYGGFORSK
Norwegian Building Research Institute

Construction principle

In Norway it has become common to use products which combine the functions of sheathing and wind proofing in inclined, thermally insulated and ventilated roofs. The construction principle is an alternative to those where the sheathing and wind barrier are separate layers with a ventilated gap in between, see figures 1 and 2. Roofs combined the sheathing and wind barrier elements which are ventilated under the roofing material (e.g. roofing tiles) only. The sheathing material must simultaneously have adequate water tightness, air tightness and vapour permeability. Special attention is paid to the provision of tight joints.

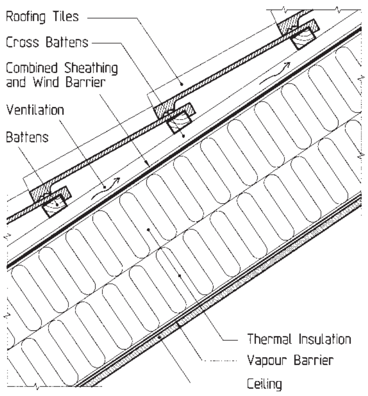


Figure 1 Combined sheathing and wind barrier

Special products which fulfil these requirements are available in the form of sheet material or felt.

Documentation

The technical regulations to the Norwegian Planning and Building Act require that relevant product properties are documented (e.g. through a NBI Technical Approval). There are specific product requirements with regard to air tightness, water tightness and vapour permeability associated with the issuing of a NBI Technical Approval for a combined sheathing and wind barrier. Additionally, documentation of construction characteristics for air tightness and rain tightness is required.

Vulnerable solution

A combined sheathing and wind barrier has several advantages. The insulation material can be placed directly under the sheathing which means that one ventilation gap may be omitted. The solution also saves material and volume, giving lower building height. However, the construction is more vulnerable to air and water leakage. For this reason NBI requires laboratory testing of each individual system.

Testing of materials

Vapour permeability, water tightness and air permeability for materials may be tested in the NBI laboratories in Trondheim. The characteristics are tested according to NBR F 217/97 (ISO/DIS 12 572) – 'Building Materials – Determination of Characteristics by Water Permeation', NS 3530, chapter 7.1 'Tightness' and NS 3261 'Determination of Air Permeation'.

Testing of constructions

Construction testing of combined sheathing and wind barrier systems is also carried out in Trondheim. The system is mounted on a test panel, 2.5 x 2.5 m^2, with a realistic number of joints, roof ridge and other details.

Air tightness

Air tightness is tested according to the NBI-94 method. The test specimen is mounted in a 'cupboard' with the 'cold' side (towards the roof) on the specimen facing inwards. Inside the 'cupboard' the desired pressure is established and the air leakage at a given pressure is determined. With the aid of smoke, the leakage areas may be detected on the warm side of the test panel.

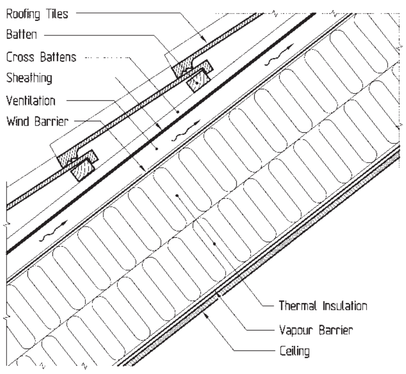


Figure 2 Separate sheathing and wind barrier

Rain tightness

The rain tightness of a construction is tested according to NT BUILD 421 Roofs: 'Water tightness under Pulsating Air Pressure'. The test panel is mounted in the test rig, also called the RAWI Box (Rain and Wind), see figure 3. The test equipment has been developed by NBI and simulates the simultaneous action of wind and rain on a construction (the equipment is also used for glass roofs, façades and roofing products). The test rig can be tilted from 0 to 90°. According to the test method, pulsating wind pressure is applied with a gradually increasing maximum pressure. Water leakage is detected on the warm side (inside) of the construction.

Test results

Fitness for use is well documented. This type of testing is also eminently suited for developing new systems. Any weakness in the products is easily detected. The critical roof angle with regard to rain tightness may be determined along with the pressure differences at which leakages occur. The air permeability of a construction may be calculated.

More information

For more information about guidelines for NBI Technical Approval for wind barriers, combined sheathing and wind barriers and other sheathing products please contact NBI, Building Technology Department, Trondheim.

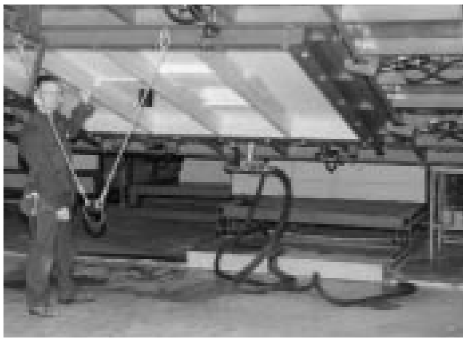


Figure 3 Testing of a construction in the RAWI-box

For further information please contact:
Dr.ing Berit Time
Tel: +47 73 59 33 90
Fax: +47 73 59 33 80
E-mail: Berit.Time@Byggforsk.no

BRE

Published on behalf of the European Network of Building Research Institutes (ENBRI) by BRE,
Garston, Watford, Herts, WD25 9XX
Telephone: +44 (0)1923 664312 Fax: +44 (0)1923 664795
email: hughesd@bre.co.uk

ENBRI