Work Package E – Snow and Ice Load

Newsletter August 2006

Background

The project «EURopean performance requirements and guidance for ACTIVE ROOFERs» (Eur-Active Roofer for short) has its origin in the increasing variety of new products being introduced in roofing, such as photovoltaic (PV) systems, solar collectors, roof lights, ventilation devices, insulation and safety devices. These products change the roof into an *active roof*, a roof supplying electricity and hot water while providing daylight and ventilation. An active roof may contribute significantly to the quality of the living space underneath it.

When installed in a roof system, the quality of these products, as well as the quality of safety equipment for installation and maintenance, is in many cases insufficient. There are no standards or legislation to assess their performance. Also, inexperienced roofers often fail to install these products adequately. This leads to a significant number of (preventable) failures from rain and snow water ingress, wind damage and condensation. In the EU, such failures cost a total of approx. € 2 000 million each year. The secondary damage to the interior of the building is, at least, of the same order of magnitude. (See Eur-Active Roofer, Description of Work.)

Active roofs

The definition *active roofs* covers all roofs that in one way or another contributes beyond the traditional task of protecting the building's inside from various climate exposure factors. Several installations typical of active roofs are depicted in figs. 1 and 2.

The increased attention to active roofs is due to:
- New types of installations
- Increased use of installations
- Change in climate and climate loads
- Increased focus on moisture problems and the indoor environment

Project objectives

The main strategic aim of the Eur-Active Roofer project is to supply tools for the European roofing trade. The tools will enable the European roofers to:

1. Respond to the new demands for integration of roof accessories and fittings
2. Upgrade from delivering just roof tiles to delivering total (active) roofs

Eur-Active Roofer aims at both newly built active roofs and existing roofs which will be upgraded (retrofitted) towards active roofs. This will be achieved through the following specific objectives for the project:

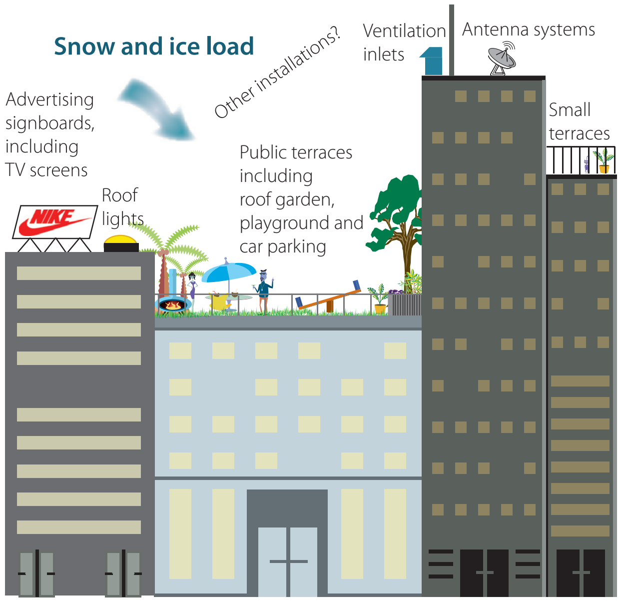


Figure 1. Various active roof installations for flat roofs

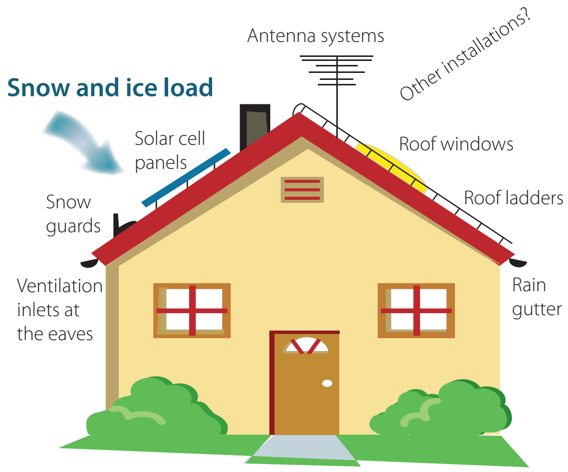


Figure 2. Various active roof installations for pitched roofs

1. Develop conceptual solutions and best practice recommendations for integrated active roofs
2. Identify typologies to describe different European roofs. The roofing industry can use the typologies, and they will also be used as input in the different work packages on environmental actions, i.e. development of a central data base.
3. Develop performance criteria and assessment methods for environmental actions on different types of roofs, including wind uplift, driving rain, snow and ice load, condensation risks, and seismic effects. This will result in guidelines and pre-standardisation documents as a basis for subsequent standardisation within CEN and EOTA.
4. Develop guidelines for the installing of new roof accessories. The aim is to reduce the number of reported roof failures from the current level of approx. 20 % to no more than 5 % within five years.
5. Develop best practice examples of roof maintenance and safety devices. The aim is to promote safe working practices on active roofs and reduce deaths and injuries caused by falls from height.
6. Develop national training programs to train the SMEs (small and medium enterprises) on:
   - the application of the pre-standards developed under (3)
   - the application of the guidelines developed under (4) and (5)

Work packages

The Eur-Active Roofer project is divided into ten work packages (WPs) as shown in table1 (see also tab. 2, Participants).

As shown in table1, SINTEF Building and Infrastructure leads the WP E-project – Snow and Ice Load, while TNO is main project leader and coordinator.

Table1. Work packages (WPs) with corresponding names and project leaders (PLs) (participant list in tab. 2).

WP	Name	PL
A	New Concepts for Active Roofs	Cenergia
B	Wind and Seismic Effects	TNO
C	Rain and Wind Driven Rain Effects	BRE
D	Condensation	BTI
E	Snow and Ice Load	SINTEF Building and Infrastructure
F	Safety, Installation, Maintenance and Repair	EMI
G	Guidance and Dissemination	IFD
H	Pre-Standardisation and Labelling	TNO
I	Training Activities	ZVDH
J	Management	TNO

WP E – Snow and ice load

In this context, snow and ice load includes:

- Snow and ice load problems
  - Weight, structure strain, freezing and thawing cycles
- Snowdrift problems
  - Snow accumulation at leeward side
  - Blocking of entrances etc.
- Ventilation inlet (and outlet) problems
- Downfall of snow and ice
  - Snow and ice avalanches – snow and ice friction
  - Formation and downfall of icicles

Snow and ice related problems

Typical problems related to installations on roofs exposed to snow and ice loads are:

- Snow and ice
  - Snow accumulation
  - Ice formation (e.g. freezing/thawing)
  - Icicles (e.g. downfall)
  - Snow and ice avalanches
  - Etc.
- Snow intake through ventilation inlet (and outlet)
- Snow intake through air gap opening at the eaves of air ventilated cold attics
- Increased use of active roof installations
  - ⇒ increased traffic on the roofs and
  - ⇒ increased demand for safety systems
- Detailed design of installations

Proposed work tasks in WP E

Proposed work tasks in WP E are:

WT A. Friction between snow/ice and roofing/active roof installation surfaces

WT B. Prevention of snow intake in ventilation inlets

WT C. Insulated, naturally ventilated pitched roofs and problems associated with solar cell installations

Most emphasis will be on WT A.

WT A – Friction

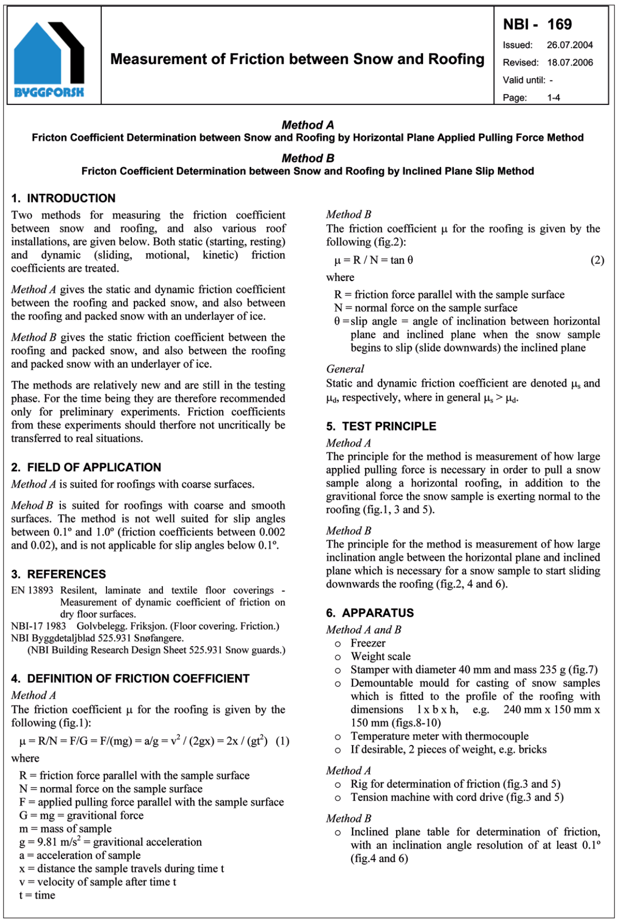
Traditionally, roofs have been designed to keep the snow in place on top of the roofs. However, solar cell roofs should ideally have no snow at all covering the cells, in order to maximize the energy production. Other active roofs may also require as little snow as

Figure 3. Snow from roof effectively covering the glass facade of a school building. (Photo: SINTEF Building and Infrastructure)

Figure 4. Large icicles in front of a school building's glass facade, representing a hazard to the children. (Photo: SINTEF Building and Infrastructure)

Figure 5. Large icicles covering a shopping centre's glass facade. To the right there is complete ice coverage. (Photo: SINTEF Building and Infrastructure)

Figure 6. Snow friction experiments, method A at the top and method B at the bottom (Photo: SINTEF Building and Infrastructure)



BYGGFORSK	**Measurement of Friction between Snow and Roofing**	**NBI - 169** Issued: 26.07.2004 Revised: 18.07.2006 Valid until: - Page: 1-4

Method A
Fricton Coefficient Determination between Snow and Roofing by Horizontal Plane Applied Pulling Force Method

Method B
Fricton Coefficient Determination between Snow and Roofing by Inclined Plane Slip Method

1. INTRODUCTION

Two methods for measuring the friction coefficient between snow and roofing, and also various roof installations, are given below. Both static (starting, resting) and dynamic (sliding, motional, kinetic) friction coefficients are treated.

Method A gives the static and dynamic friction coefficient between the roofing and packed snow, and also between the roofing and packed snow with an underlayer of ice.

Method B gives the static friction coefficient between the roofing and packed snow, and also between the roofing and packed snow with an underlayer of ice.

The methods are relatively new and are still in the testing phase. For the time being they are therefore recommended only for preliminary experiments. Friction coefficients from these experiments should therfore not uncritically be transferred to real situations.

2. FIELD OF APPLICATION

Method A is suited for roofings with coarse surfaces.

Mehod B is suited for roofings with coarse and smooth surfaces. The method is not well suited for slip angles between 0.1° and 1.0° (friction coefficients between 0.002 and 0.02), and is not applicable for slip angles below 0.1°.

3. REFERENCES

EN 13893 Resilent, laminate and textile floor coverings - Measurement of dynamic coefficient of friction on dry floor surfaces.
NBI-17 1983 Golvbelegg. Friksjon. (Floor covering. Friction.)
NBI Byggdetaljblad 525.931 Snøfangere.
(NBI Building Research Design Sheet 525.931 Snow guards.)

4. DEFINITION OF FRICTION COEFFICIENT

Method A
The friction coefficient μ for the roofing is given by the following (fig.1):

$$\mu = R/N = F/G = F/(mg) = a/g = v^2 / (2gx) = 2x / (gt^2) \quad (1)$$

where

R = friction force parallel with the sample surface
N = normal force on the sample surface
F = applied pulling force parallel with the sample surface
G = mg = gravitional force
m = mass of sample
g = 9.81 m/s^2 = gravitional acceleration
a = acceleration of sample
x = distance the sample travels during time t
v = velocity of sample after time t
t = time

Method B
The friction coefficient μ for the roofing is given by the following (fig.2):

$$\mu = R / N = \tan \theta \quad (2)$$

where

R = friction force parallel with the sample surface
N = normal force on the sample surface
θ = slip angle = angle of inclination between horizontal plane and inclined plane when the snow sample begins to slip (slide downwards) the inclined plane

General
Static and dynamic friction coefficient are denoted μ_s and μ_d, respectively, where in general $\mu_s > \mu_d$.

5. TEST PRINCIPLE

Method A
The principle for the method is measurement of how large applied pulling force is necessary in order to pull a snow sample along a horizontal roofing, in addition to the gravitional force the snow sample is exerting normal to the roofing (fig.1, 3 and 5).

Method B
The principle for the method is measurement of how large inclination angle between the horizontal plane and inclined plane which is necessary for a snow sample to start sliding downwards the roofing (fig.2, 4 and 6).

6. APPARATUS

Method A and B
- Freezer
- Weight scale
- Stamper with diameter 40 mm and mass 235 g (fig.7)
- Demountable mould for casting of snow samples which is fitted to the profile of the roofing with dimensions l x b x h, e.g. 240 mm x 150 mm x 150 mm (figs.8-10)
- Temperature meter with thermocouple
- If desirable, 2 pieces of weight, e.g. bricks

Method A
- Rig for determination of friction (fig.3 and 5)
- Tension machine with cord drive (fig.3 and 5)

Method B
- Inclined plane table for determination of friction, with an inclination angle resolution of at least 0.1° (fig.4 and 6)

Figure 7. Development of NBI Method 169 – Measurement of Friction between Snow and Roofing

possible covering the installations, e.g. roof windows. One may think of both new material surface technology and new architectural roof design in order to accomplish this objective.

In order to gain experience in this field and attempt to achieve parts of this objective, experiments have been started up measuring the friction between snow/ice and roofing/active roof installation surfaces.

Part of the WT A results will be the development of the new NBI Method 169, further divided into two methods, A and B, as follows:

- **NBI Method 169**

Measurement of Friction between Snow and Roofing

- **Method A**

Friction Coefficient Determination between Snow and Roofing by Horizontal Plane Applied Pulling Force Method

- **Method B**

Friction Coefficient Determination between Snow and Roofing by Inclined Plane Slip Method

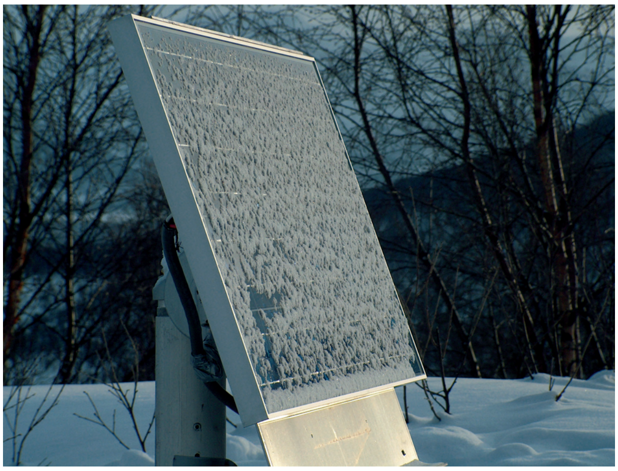


Figure 8. The inclination angle of this solar cell panel is as high as 70°; still the panel is covered by snow. (Photo: NTNU)

Figure 9. Roof windows covered by snow i.e. not fulfilling their purpose of letting daylight into the building. (Photo: SINTEF Building and Infrastructure)

Figure 10. Even at very steep roof inclinations roof windows are covered by snow and ice. (Photo: SINTEF Building and Infrastructure)

Complex Matter – Countless Variations

A vast number of factors may and will influence the snow and ice friction experiments. Hence, care has to be taken by carrying out these experiments and the evaluation of them with respect to real outdoor conditions.

- Very Complex Experimental Method
  - Why?
  - Friction measurements? – No, relatively simple
  - Complex due to:
- The Complex Nature of Snow and Ice
  - Snow and ice in *countless* variations
  - Dependent on a vast number of factors
  - Variable indoor and outdoor climatic conditions
  - Interaction between snow/ice and roofing

WT B – Snow intake

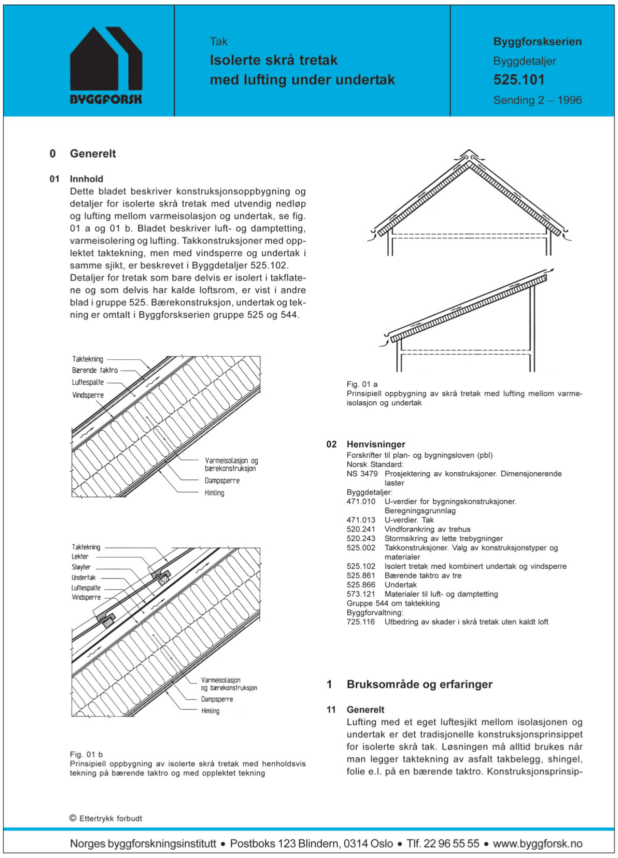
Snow intake in ventilation inlets may lead to moisture problems and subsequent mould growth with increasing health risks.

Ventilation inlet designs will be studied in order to develop designs that reduce the risk of snow and rain inlet.

WT C – Active installations

Mounting of active installations, e.g. solar cell panels, will be studied, and recommendations and design details will be worked out. The results will be incorporated in existing Building Research Design Sheets.

Figure 11. Building with moisture inlet in ventilation inlet on top of the roof, which has encountered large mould growth with following health problems. (Photo: SINTEF Building and Infrastructure)



BYGGFORSK

Tak
Isolerte skrå tretak med lufting under undertak

Byggforskserien
Byggdetaljer
525.101
Sending 2 – 1996

0 Generelt

01 Innhold
Dette bladet beskriver konstruksjonsoppbygning og detaljer for isolerte skrå tretak med utvendig nedløp og lufting mellom varmeisolasjon og undertak, se fig. 01 a og 01 b. Bladet beskriver luft- og damptetting, varmeisolering og lufting. Takkonstruksjoner med opplektet taktekning, men med vindsperre og undertak i samme sjikt, er beskrevet i Byggdetaljer 525.102.
Detaljer for tretak som bare delvis er isolert i takflatene og som delvis har kalde loftsrom, er vist i andre blad i gruppe 525. Bærekonstruksjon, undertak og tekning er omtalt i Byggforskserien gruppe 525 og 544.

Fig. 01 b
Prinsipiell oppbygning av isolerte skrå tretak med henholdsvis tekning på bærende taktro og med opplektet tekning

Fig. 01 a
Prinsipiell oppbygning av skrå tretak med lufting mellom varmeisolasjon og undertak

02 Henvisninger
Forskrifter til plan- og bygningsloven (pbl)
Norsk Standard:
NS 3479 Prosjektering av konstruksjoner. Dimensjonerende laster
Byggdetaljer:
471.010 U-verdier for bygningskonstruksjoner. Beregningsgrunnlag
471.013 U-verdier. Tak
520.241 Vindforankring av trehus
520.243 Stormsikring av lette trebygninger
525.002 Takkonstruksjoner. Valg av konstruksjonstyper og materialer
525.102 Isolert tretak med kombinert undertak og vindsperre
525.861 Bærende taktro av tre
525.866 Undertak
573.121 Materialer til luft- og damptetting
Gruppe 544 om taktekking
Byggforvaltning:
725.116 Utbedring av skader i skrå tretak uten kaldt loft

1 Bruksområde og erfaringer

11 Generelt
Lufting med et eget luftesjikt mellom isolasjonen og undertak er det tradisjonelle konstruksjonsprinsippet for isolerte skrå tak. Løsningen må alltid brukes når man legger taktekning av asfalt takbelegg, shingel, folie e.l. på en bærende taktro. Konstruksjonsprinsip-

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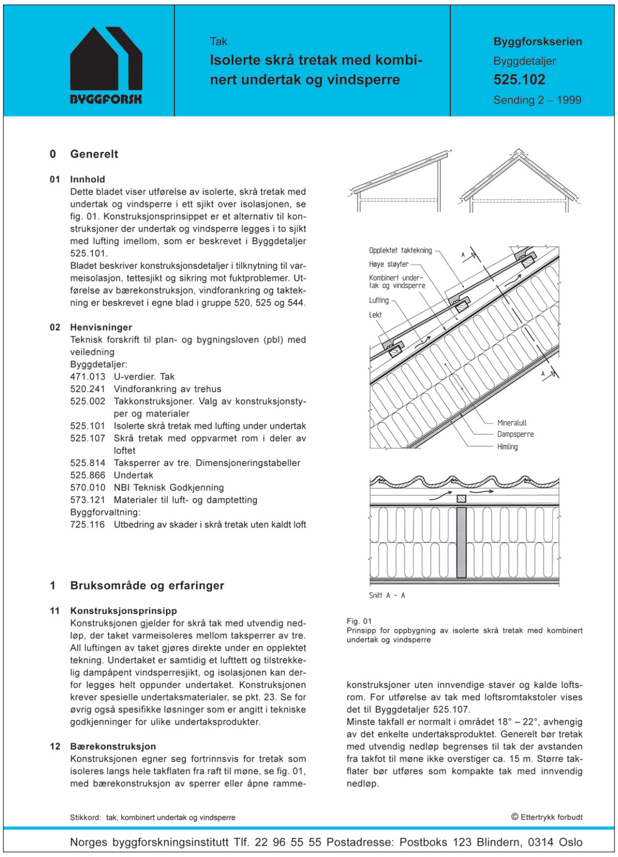

BYGGFORSK

Tak
Isolerte skrå tretak med kombinert undertak og vindsperre

Byggforskserien
Byggdetaljer
525.102
Sending 2 – 1999

0 Generelt

01 Innhold
Dette bladet viser utførelse av isolerte, skrå tretak med undertak og vindsperre i ett sjikt over isolasjonen, se fig. 01. Konstruksjonsprinsippet er et alternativ til konstruksjoner der undertak og vindsperre legges i to sjikt med lufting imellom, som er beskrevet i Byggdetaljer 525.101.
Bladet beskriver konstruksjonsdetaljer i tilknytning til varmeisolasjon, tettesjikt og sikring mot fuktproblemer. Utførelse av bærekonstruksjon, vindforankring og taktekning er beskrevet i egne blad i gruppe 520, 525 og 544.

02 Henvisninger
Teknisk forskrift til plan- og bygningsloven (pbl) med veiledning
Byggdetaljer:
471.013 U-verdier. Tak
520.241 Vindforankring av trehus
525.002 Takkonstruksjoner. Valg av konstruksjonstyper og materialer
525.101 Isolerte skrå tretak med lufting under undertak
525.107 Skrå tretak med oppvarmet rom i deler av loftet
525.814 Taksperrer av tre. Dimensjoneringstabeller
525.866 Undertak
570.010 NBI Teknisk Godkjenning
573.121 Materialer til luft- og damptetting
Byggforvaltning:
725.116 Utbedring av skader i skrå tretak uten kaldt loft

1 Bruksområde og erfaringer

11 Konstruksjonsprinsipp
Konstruksjonen gjelder for skrå tak med utvendig nedløp, der taket varmeisoleres mellom taksperrer av tre. All luftingen av taket gjøres direkte under en opplektet tekning. Undertaket er samtidig et lufttett og tilstrekkelig dampåpent vindsperresjikt, og isolasjonen kan derfor legges helt oppunder undertaket. Konstruksjonen krever spesielle undertaksmaterialer, se pkt. 23. Se for øvrig også spesifikke løsninger som er angitt i tekniske godkjenninger for ulike undertaksprodukter.

12 Bærekonstruksjon
Konstruksjonen egner seg fortrinnsvis for tretak som isoleres langs hele takflaten fra raft til møne, se fig. 01, med bærekonstruksjon av sperrer eller åpne ramme-

Fig. 01
Prinsipp for oppbygning av isolerte skrå tretak med kombinert undertak og vindsperre

konstruksjoner uten innvendige staver og kalde loftsrom. For utførelse av tak med loftsromtakstoler vises det til Byggdetaljer 525.107.
Minste takfall er normalt i området 18° – 22°, avhengig av det enkelte undertaksproduktet. Generelt bør tretak med utvendig nedløp begrenses til tak der avstanden fra takfot til møne ikke overstiger ca. 15 m. Større takflater bør utføres som kompakte tak med innvendig nedløp.

Stikkord: tak, kombinert undertak og vindsperre

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Figure 12. Existing Building Research Design Sheets will be extended to include recommendations and design details from WT C in order to avoid problems associated with for example solar cell installations in insulated, pitched roofs with natural ventilation.

Participants

Table 2. Participant list for Eur-Active Roofer. Project leaders are shown in table1. WP E participants are colour marked in orange, where SINTEF Building and Infrastructure is WP E project leader. TNO is main project leader and coordinator and is colour marked as blue.
IAG = industrial associations and groupings
SME = small and medium enterprise
RTD = research and technology development.
(See Eur-Active Roofer, Description of Work, Collective research project, Sixth framework program.) See also figure13.

List of Participants				
Type	No.	Name	Short Name	Country
IAG	2	Hungarian Federation of Roofing Contractors	ÉMSZ	HU
IAG	3	Het Hellende Dak	HHD	NL
IAG	4	Zentralverband des Deutschen Dachdeckerhandwerks	ZVDH	DE
IAG	5	National Federation of Roofing Contractors	NFRC	UK
IAG	6	British Photovoltaic Association	PV-UK	UK
IAG	7	Construction Industry Federation (Roofing and Cladding Contractors Association)	CIF (RCCA)	IE
IAG	8	Norwegian Roofing Research Association	TPF	NO
IAG	9	Schweizerischer Verband Dach und Wand	SVDW	CH
IAG	10	Polskie Stowarzyszenie Dekarzy	PSD	PL
IAG	23	International Federation of Roofers	IFD	EU
SME	11	Stroomwerk	Stroomwerk	NL
SME	12	Biohaus	Biohaus	DE
SME	13	Bedachungstechnik Manfred Schröder GmbH	Schröder	DE
SME	14	Kuipers Consulting SL	Kuipers	ES
SME	15	Ecovent	ECOvent	DK
SME	16	H and E Costellos roofing	H&E	IE
SME	17	Tectum	Tectum	HU
SME	18	Alukol	Alukol	HU
SME	19	Puskas Muvek	Puskas	HU
SME	20	Schneiderbau	Schneider	HU
SME	21	Energy Equipment Testing Service Ltd	EETS	UK
SME	22	Solarwall Italia	Solarwall	IT
RTD	1	TNO	TNO	NL
RTD	24	Building Research Establishment	BRE	UK
RTD	25	Company for Quality Control and Innovation in Building	ÉMI	HU
RTD	26	SINTEF Building and Infrastructure	SINTEF	NO
RTD	27	Centre for Renewable Energy Sources	CRES	GR
RTD	28	Cenergia	Cenergia	DK
RTD	29	Bautechnisches Institut	BTI	AT
RTD	30	Technische Universität Berlin	TU Berlin	DE
RTD	31	TU Warsaw	WU T	PL
RTD	32	Technische Universiteit Eindhoven	TU/e	NL

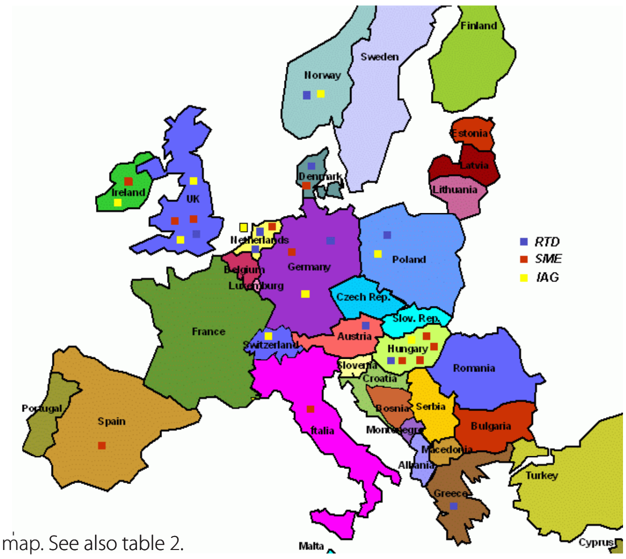

Figure13. Eur-Active Roofer participant map. See also table 2.