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Report STO1-KKr-130830-E

Liaison Final Report CEN/TC 128/WG 3

Generated for:

European Solar Thermal Industry Federation, A.I.S.B.L. (ESTIF)
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August 30, 2013

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This report consists of 8 pages. Results may only be published wholly and not in a content distorting manner.

Fraunhofer-Institute for Solar Energy Systems ISE
Division Solar Thermal and Optics

Freiburg, August 30, 2013

Kramer

Korbinian Kramer Konstantin Geimer

1 Subject

Mr. Korbinian Kramer was commissioned to report the activities across from CEN/TC 128/WG 3 to CEN TC 312 as the corresponding liaison officer. In this role the object was to work on the following tasks:

- Keep track with the development of on-going work in the CEN/TC 128[1] regarding solar thermal installations
- Inform the CEN/TC 312/WG 1[1] about requirements, changes and so on which are influencing regulations for the solar thermal installation
- Explain and implement the requirements and possibilities from the point of view of solar thermal to CEN/TC 128/WG 3[1]

2 Implementation

Through a participation in all CEN/TC 128/WG 3 meetings the necessary information were aggregated by Fraunhofer ISE (Mr. Kramer, Mr. Erban, see annex A). The results of the on-going work were reported regularly in interim reports to TC 312/WG 1 in form of presentations, which were distributed by the CEN secretary (see annex B). Furthermore the results were reported to the ESTIF standardization and certification group as well as to the Solar Keymark Network.

The requirements and possibilities to contribute to CEN/TC 128/WG 3 from the point of view of solar thermal, were gathered in two workshops. The first workshop was hold in 2010 at Fraunhofer ISE and brought together seven companies (see annex C) and discussed the way companies handled mechanical load tests at this time and their needs for future development.

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[1] CEN/TC 128: Roof covering products for discontinuous laying and products for wall cladding - Standards under development; WG 1: Mandates – Preparation; WG3: Renewable energy systems for roofs CEN/TC 312: Thermal solar systems and components; WG 1: Solar collectors

The second "expert workshop mechanical loads" was held in 2012 in conjunction with the last meeting of TC 128. Thereby it was possible to inform in detail about the work in TC 128 and connected work (see annex C). A coordination meeting of the German industry group "wind and snow loads" and the project team from Fraunhofer ISE "MechTest" took place at Wagner & Co. Solar GmbH, Cölbe on August 24th 2011. Within the project QAiST in work package WP 2 through several telephone conferences and meetings hosted by ESTIF a working paper was developed (see annex D).

Since the collector test standard (EN 12975-2:2006) does not include a qualification of the fixing- and mounting equipment calculation and test methods for these were developed in CEN/TC 128/WG 3. The draft of the technical report (CEN-TC128-WG3-N0047) is a proposal on requirements for structural connections to solar panels for solar energy systems for roofs (see annex E). The objective is to consider all relevant cases (wind, snow, earth quake) and implement best practices of calculation by using the standards EN 1990 - EN 1999 and others. The actual version also includes some calculation examples. To approve that mounting equipment fulfills these requirements the report proposes design by calculation and if not applicable or suitable design by testing.

3 Status quo

The new construction products regulation (EU) 305/2011 is valid since July 2013. The corresponding requirements thereby cover also solar panels and their structural connection to the roof. Therefore a CE-marking according to (EU) 305/2011 is also mandatory for selling these products within the EU. The declaration of performance criteria is normally provided by a test report based on a harmonized EN standard (hEN). At the moment there is neither a harmonized standard available for solar thermal collectors nor for fixing- and mounting equipment.

This is also showing the importance of the activities of CEN/TC 128/WG 3 and the corresponding draft version (CEN-TC128-WG3-N0047). The faster the draft version is worked out, the earlier it can become a harmonized standard to close the gap between the qualification of solar panels and their structural connections to roofs. Since there is no general solution now structural connections need to go for the European Technical Approval (ETA) which should be avoided because it will raise compliance costs and time needed. For example in Germany the DIBt is organizing the ETA for such products for the time being.

At the Fraunhofer ISE in Freiburg, Germany additional research and development is performed in the field of mechanical load tests for solar thermal collectors (and photovoltaic modules) and their structural connections. Since 23.11.2012 a new testing facility is available, making it possible to test complete systems including there fixing- and mounting systems at a range of realistic load cases as well as different climatic conditions (see annex F).

The new test facility was developed within the project “MechTest” (funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in Germany). The project was completed in January 2013. Amongst others, the results showed that parts of the fixing and mounting system are in most cases the weakest point, which is in good compliance with the outcomes of the analysis of damage reports within the project. The new test method has proven itself to be well suited to determine weakest points up to breakage within the system of collector, fixings and mountings experimentally. The final report (German language) is available at Fraunhofer ISE upon request (see annex G).

4 Annex A-E

Annex A:

- 10th and 11th May 2011, BBRI Brussels; Workshop on “roof integration of renewable energies
- 5th of October 2011, BBRI Brussels; CEN TC 128 WG 3
- 1st November 2011, Renewable Energy House, Brussels; ESTIF C&S group meeting
- 12th January 2012, BBRI Brussels; TC 128 WG3 meeting
- 6th June 2012, BBRI Brussels; TC 128 WG3 meeting
- 22nd and 23rd November 2012, Fraunhofer ISE; TC 128 WG3 meeting and Industry workshop

Annex B:

- Liaison Report on liaisons with TC 128 and TC 254, October 2010, see attached PDF
- Liaison Report on TC 128 (incl. TC 254) for TC 312, May 2012, see attached PDF
- Liaison Report on TC 128 (incl. TC 254) for TC 312, January 2013, see attached PDF

Annex C:

- First workshop on mechanical loads, Fraunhofer ISE, Freiburg
  Participating Companies: Bosch, Ritter, Schüco, Vaillant, Viessman, Wagner, PSE

- Second "Expert workshop mechanical loads ST and PV components and their mounting systems", November 23rd, 2012
  Participating companies: Vaillant Group, Monier Technical Centre Ltd, Mounting Systems, Creotecc GmbH, Viessmann Faulquemont S.A.S., ELCO Shared Services GmbH, PV-plan, KBB Kollektorbau GmbH, Ernst Schweizer AG, airwasol GmbH & Co. KG, General Solar Systems GmbH, BDA Dakadvies B.V., Wolf GmbH, Stiebel Eltron GmbH & Co. KG, BL Solar Roof Systems
  Agenda: See attached PDF

Annex D: Working paper for mechanical load test, see attached file / http://www.qaist.eu/

Annex E: Proposed CEN technical report CEN-TC128-WG3-N0047 Draft, November 14th, 2012, "Technical Report on solar energy systems for roofs – requirements for structural connections to solar panels", see attached PDF
Scope: This Technical Report provides guidance on the principles and requirements of structural design for the safety and serviceability of the structural connection between solar energy panels (thermal or photovoltaic) that are mounted on flat or pitched roofs.

Annex F: Press Release November 23rd, 2012, Fraunhofer ISE Freiburg, "Fraunhofer ISE Inaugurates New Test Stand for Solar Thermal Collectors", see attached PDF

Annex G: Final report project "MechTest" September 2013, Fraunhofer ISE Freiburg, "Characterization of the mechanical load cases caused by wind and snow on solar thermal collectors and their fixing- and mounting systems", available at the Fraunhofer ISE upon request and soon at http://mechtest.de in german language
Abstract: In recent years in Europe shortcomings have been determined regarding standardization and certification in the field of mechanical safety for solar thermal systems. This is visible through insufficient mechanical

requirements in the relevant testing standards, as well as the fact that fixing- and mounting systems are not considered. Therefore manufacturers are forced to investigate themselves the mechanical safety for their own products.

The project “MechTest” (funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in Germany) was initiated to analyze the situation and find solutions. The purpose of the project “MechTest” was to characterize the mechanical load cases caused by wind and snow on solar thermal collectors and their fixing- and mounting systems. As part of the project reported cases of damage and their causes were analyzed, a new test facility was developed and commissioned, a series of mechanical load tests (also at different climatic conditions) and two field tests at locations with extreme weather conditions were performed.

One of the most important results is a new testing method, making it possible to test the combination of the collector including fixings and mountings under realistic load cases. The results of the test series also showed that parts of the fixing and mounting system are in most cases the weakest point, which is in good compliance with the outcomes of the analysis of the damage reports. The new test method has shown itself to be well suited to determine these weakest points up to breakage within the system of collector, fixings and mountings experimentally.

Additionally the new testing method was compared to the corresponding standards with the aim to determine the potential to reduce compliance costs and the time needed.

Liaison Report on liaisons with TC 128 and TC 254

TestLab
Solar Thermal
Systems

Korbinian Kramer

Fraunhofer Institute for
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CEN / TC 312
Graz, October 2010
www.ise.fraunhofer.de

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TC 128 and TC 254:

- 9 Sub-Committees, separated by different materials, and ways of mounting
- Dealing with roofing materials and products
- About to harmonize their standards to meet EU directives
- Planning to establish a TaskForce for renewable energies
- Up-comming dates important for us:
  - General Meeting, 9th-10th of May 2011
  - Planning a work-shop on integration of renewables on:

    Antwerpen, 11th of May 2011
  - Meeting with TC 254 on 12th -13th
- Problem is the ESTIF group on standardization right now has a „gap“ for some person caring about the issue
- There is strong interest of industry in the issues, but not much commitment to join forces, that is easy to understand but somehow hindering

Liaison Report on TC 128 (incl. TC 254) for TC 312

TestLab
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Systems

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TC 128 und TC 254:

- New Technical Report on how to design the interphase between roofing and Solar Panel, excluding from the scope:
    - Products which are taken into account by any other fitting regulation
    - in-roof panels
    - Fassade panels

“**1.0 Scope**

This Technical Report provides guidance on the principles and requirements of structural design for the safety and serviceability **of the structural connection between rigid solar energy panels (thermal or photovoltaic) that are mounted on flat or pitched roofs**.

This Technical Report does **not include** requirements for:

Solar panels which are made as part of the roof covering; Weather tightness of the roof, solar panels and connections; Electrical or thermal characteristics of the solar panels; Precautions against fire of the installation.”

TC 128 und TC 254:

- Some empirical experiments using wind tunnel testing suggest significant higher values for proper design for roofing interphases as were calculated nowadays…
- Design by calculation is limited as a tool for any optimisation or conformity checks.
- It is important for the system overall safety to know the performance of all parts in the chain of forces.
- High potential for cost reduction by optimisation through better understanding.
- *Lessons learned* from PV branch should not be redone from solar thermal.
- Expansions and forces induced by cuts are one of the important load profiles (Fraunhofer ISE internal results).
- Önorm as published recently gives nice hints for the installer, it is neither a design standard nor a test standard.
- Netherlands standard (old version was basisi for Önorm) is under reviosn will be published soon
- MCS published a draft on how to design by test
- Proposal of ad hoc WG in TC 128 WG 3 to prepare a CEN/TS

Liaison Report on TC 128 (incl. TC 254) for TC 312

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Recent version of the TR including different example calculations. More wind tunnel tests will bring more clear results on forces necessary to asume.

Pre-Standard for the Netherlands NVN 7250:2007 available (roof-integration, revision expected).

Last meeting in Freiburg (hosted by Fraunhofer ISE) to get to know a little bit more the solar branch/R&D -> quite impressed by the possibilities of testing and R&D

Workshop on „Mechanical loads“ organised at Fraunhofer ISE, including speakers from the TC 128 (42 attendences), new test facility inaugurated at the occasion of the workshop.

Next meeting:

14./15. March, Netherlands

Scope of the TR:

- New Technical Report on how to design the interphase between roofing and Solar Panel, excluding from the scope:
  - Products which are taken into account by any other fitting regulation
  - in-roof panels
  - Fassade panels

“**1.0 Scope**

This Technical Report provides guidance on the principles and requirements of structural design for the safety and serviceability **of the structural connection between rigid solar energy panels (thermal or photovoltaic) that are mounted on flat or pitched roofs**.

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Solar panels which are made as part of the roof covering; Weather tightness of the roof, solar panels and connections; Electrical or thermal characteristics of the solar panels; Precautions against fire of the installation.”

Discussed issues:

- Some empirical experiments using wind tunnel testing suggest significant higher values for proper design for roofing interphases as were calculated nowadays...
- Design by calculation is limited as a tool for any optimisation or conformity checks.
- It is important for the system overall safety to know the performance of all parts in the chain of forces.
- High potential for cost reduction by optimisation through better understanding.
- *Lessons learned* from PV branch should not be redone from solar thermal.
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Friday November 23rd, 2012 – 9:00-16:00, Freiburg

Expert workshop mechanical loads ST and PV components and their mounting systems

Aim: Simplify, qualify and harmonize mechanical load tests, raise standardization of mounting systems

Location: Fraunhofer ISE, Berliner Allee 29, 79110 Freiburg
Room T-601

Agenda

• **9:00 Welcome and moderation**	**K. Kramer** Fraunhofer ISE
• **9:15 – 12:00 lectures (20 min presentation, 10 min dialog)**	
o Requirements for structural connections to solar panels (TC128 WG3)	**Dr. B. Chan**
o Mounting systems for PV in view of structural engineering (precise title will be specified soon)	**Dr. F. Zapfe** Dr. Zapfe GmbH
o Extended investigations (load cases, temperature) of the mechanical stability of ST collectors	**K. Geimer** Fraunhofer ISE
o Wind loads of ST and PV (precise title will be specified soon)	**Prof. H. Ruscheweyh** Ruscheweyh Consult GmbH
o Situation of snow loads for ST collectors (precise title to be specified soon)	**C. Stadler** Sonnenkraft Deutschland GmbH
o Mechanical connection and safety status of solar facade technologies	**C. Erban** Fraunhofer ISE

- **12:15 – 13:00 service tour**
    - TestLab Solar Thermal Systems: Collector test area, hail stone test facility
    - TestLab PV Modules: Classical mechanical load test facility
- **12:45 opening of the new mechanical load test facility** (project “MechTest” funded by the Federal Ministry for the Environment, Nature Conservation and Nuclar safety)
    - Short opening speech: **Prof. E. Weber** director of the Fraunhofer ISE in Freiburg
    - Champagne and fingerfood / lunch
- **14:00 – 16:00 teamwork in four groups**
    - Definition of common aims (Development of calculation methods, standardization of mounting systems, “CErtification” of components and mounting systems)
    - Setting priorities from different point of view (industry, planers, testlabs, etc.)
    - Discussing the results and defining work packages to succeed
    - Idea to apply for a (EU) project to harmonize certification and mechanical load tests (Partner constellation, competencies, time table, letter of intent)

Working paper for mechanical load test

Content

1. Introduction

Mechanical load induced by wind or Snow/Ice is one of the severe influences on the long time durability of collector installations. Especially the consecutive forces resulting from wind are not easy to calculate. Over all the resulting forces for the collector components, the fixings, the mounting equipment and the roof fixings are strongly influenced by the mounting angle, surroundings the weather and climate and the mounting situation. The standards provide assumptions and equations to calculate snow/ice loads (part 5) and wind loads (part 4). Most of the above mentioned influences can be taken into account within the standard. The assumptions on the other hand are not provided for the case of *Solar Thermal collectors and Applications,* so one has to “translate” the standard to these situations. This is to some extend possible, especially for snow loads. For wind loads it is much more vague.

The process of harmonizing the standard EN 12975 towards EU regulations (“construction products”, = dt. Bauproduktenrichtlinie 89/106/EWG) includes the aspect of structural safety. This process is paving the way to base a CE marking for solar thermal applications on the CPD. For this an Annex ZA will be prepared to reference all necessary documents, which define how the relevant aspects are dealt with within the harmonized EN 12975. For this reason it is important to fulfil the requirements of state of the art structural safety. The recent way to deal with this is to improve the methodology within EN 12975.

TC 312 is not the only TC working on these issues. As well TC 128 and TC 254 and maybe others are dealing with this topic. From their view the topic is summarized in “Roof and Façade integration of Renewable energies”. The mentioned TC 128 accepted a liaison with TC 312 and is holding meetings on the topic within a 2011 founded ad-hoc working group. This group is called WG3 and is located within TC 128. The group holds several official liaisons with other related TCs (as TC 82, TC 312, TC 254). Within this working group a draft document was developed, which is recently send to the CEN board as a proposal for placing an official work item for mechanical load testing and calculation rules for building integrated renewable energies to TC 128 WG3. From this process a TS may result which later is possibly suggested to become an EN.

Experiences from the mass market of PV in regards of problems/failures as well as the benefits of standardisation are available. This information should be taken into account when improving the requirements and methodologies for solar thermal products.

There are other branches as well, dealing with similar problems, as roof-integrated windows manufacturer.

Last but not least there is some diffuse pressure resulting out of the insurance branch, which is at least in some EU countries asking for more safety and regulation on the issue of wind and snow/ice load.

The following working paper summarizes and guides the recent discussion on this topic within CEN/TC 312 WG1 and QAiST.

2. EN 12975

The recent standard EN 12975 gives the following information regarding mechanical load tests:

2.1. Part 1:

“EN 12975-1:2006, 5.3.8. Mechanical load test

When tested in accordance with 5.9 of EN 12975-2:2006 **the cover, the collector box and the fixings between collector box and mounting system** shall not show any major failure as defined in 5.3.1 and 5.9.1.3 of EN 12975-2:2006. The **permissible** and the **maximum positive and negative pressure shall be recorded in the installer manual**.

NOTE Individual country’s safety requirements may prevail.”

2.2. Part 2:

“EN 12975-2:2006, 5.9 Mechanical load test

5.9.1. Positive pressure test of the collector

5.9.1.1. Objective

This test is intended to assess the extent to which the transparent cover of the collector and the collector box are able to resist the positive pressure load due to the effect of wind and snow.

5.9.1.2. Apparatus and procedure

The collector shall be placed horizontally on an even ground. On the collector a foil shall be laid and on the collector frame a wooden or metallic frame shall be placed, high enough to contain the required amount of gravel or similar material (see Figure A.12).

The gravel, preferably type 2-32 mm, shall be weighed in portions and distributed in the frame so that everywhere the same load is created (pay attention to the bending of the glass), until the desired height is reached.

The test can also be carried out installing the collector in accordance with 5.9.2.2 and loading the cover using suction cups, gravel or other suitable means (e.g. water).

As a further alternative, the necessary load may be created by applying an air pressure on the collector cover.

The load may also be created by applying a negative pressure on the collector cover. In this case, apparatus in accordance to EN 12211 can be used. However this method cannot be applied on all collector types.

5.9.1.3. Test conditions

The test pressure shall be increased at maximum steps of 250 Pa until a failure occurs or up to the value specified by the manufacturer. The test pressure shall be at least 1000 Pa. A failure can be the destruction of the cover and also the permanent deformation of the collector box or the fixings.

NOTE A permanent deformation should be assigned to a load value, while it is completely relieved after every load increment of 250 Pa and the distortion is measured compared to the beginning of the test sequence. The value of an inadmissible permanent deformation amounts to max. 0,5 %. (Example: 10 mm distortions at 2 m length of collector frame).

5.9.1.4. Results

The pressure at which any failure of the collector cover or the box or fixings occurs shall be reported together with details of the failure. If no failure occurs, then the maximum pressure which the collector sustained shall be reported.

The maximum positive pressure is the pressure reached before occurring a failure. The permissible positive pressure is the maximum pressure divided by the safety factor SF+ = 1,5:

$$F_{perm+} = F_{max+} \ / \ SF+ \quad \text{with} \quad SF+ = 1{,}5$$

NOTE When the test is done with an on-roof mounting system the test results are also valid for the roof integrated mounting system.

5.9.2. Negative pressure test of the collector

5.9.2.1. Objective

This test is intended to assess the extent to which the fixings between the collector cover and collector box are able to resist uplift forces caused by the wind.

For the design of the statics of the mounting system the national and European Guidelines for Structural Planning according to EN 1991 have to be applied.

5.9.2.2. Apparatus and procedure

The collector shall be installed horizontally on a stiff frame by means of its mounting fixtures. The frame which secures the cover to the collector box shall not be restricted in any way.

A lifting force which is equivalent to the specified negative pressure load shall be applied evenly over the cover. The load shall be increased in steps up to the final test pressure. If the cover has not been loosened at the final pressure, then the pressure may be stepped up until failure occurs. The time between each pressure step shall be the time needed for the pressure to stabilise.

Either of two alternative methods may be used to apply pressure to the cover:

- Method (a): The load may be applied to the collector cover by means of a uniformly distributed set of suction cups (see Figure A.13).
- Method (b): For collectors which have an almost airtight collector box, the following procedure may be used to create a negative pressure on the cover (see Figure A.14). Two holes are made through the collector box into the airgap between the collector cover and absorber, and an air source and pressure gauge are connected to the collector airgap through these holes. A negative pressure on the cover is created by pressurising the collector box. For safety reasons the collector shall be encased in a transparent box to protect personnel in the event of failure during this test.

During the test, the collector shall be visually inspected and any deformations of the cover and its fixings reported. The collector shall be examined at the end of the test to see if there are any permanent deformations.

5.9.2.3. Test conditions

The test pressure shall be increased in steps of 250 Pa until a failure occurs or up the value specified by the manufacturer. The test pressure shall be at least 1000 Pa. A failure can be the destruction of the cover and also the permanent deformation of the collector box or the fixings.

NOTE A permanent deformation should be assigned to a load value, while it is completely relieved after every load increment of 250 Pa and the distortion is measured compared to the beginning of the test sequence. The value of an inadmissible permanent deformation amounts to max. 0,5 %. (Example: 10 mm distortions at 2 m length of collector frame).

5.9.2.4. Results

The pressure at which any failure of the collector cover or the box or fixings occurs shall be reported together with details of the failure. If no failure occurs, then the maximum pressure which the collector sustained shall be reported.

The maximum negative pressure is the pressure reached before occurring a failure. The permissible negative pressure is the maximum pressure divided by the safety factor SF- = 2:

$$F_{perm-} = F_{max-} \ / \ SF- \text{ with } SF- = 2"$$

3. EN 12976

Because the fact that EN 12976-1,2:2006 references EN 12975-1,2:2006 it is reasonable to consider the relevant section of EN 12976 here as well.

"**4.3 Components and pipework**

4.3.1 Collector

For systems the collector of which can be tested separately, the collector shall conform to EN 12975-1:2000, with the exception of:

- internal pressure tests for absorber (see 5.3.2 of EN 12975-1:2000);

- freeze resistance test (see 5.3.10 of EN 12975-1:2000);

- thermal performance measurement (see 5.3.9 of EN 12975-1:2000).

For systems the collector of which **cannot be tested separately** (for instance integrated collector-store systems),

the whole system shall conform to EN 12975-1:2006, with the exception of:

- internal pressure tests for absorber (see 5.3.2 of EN 12975-1:2000);

- exposure test (see 5.3.4 of EN 12975-1:2000), on the condition that the installation manual for the system

specifies that the empty system shall be protected against prolonged exposure to solar radiation;

- internal thermal shock test (see 5.3.6 of EN 12975-1:2000);

- freeze resistance test (see 5.3.10 of EN 12975-1:2000);

- thermal performance measurement (see 5.3.9 of EN 12975-1:2000).

4.3.2 Supporting frame

Manufacturer shall state the maximum possible loads for their supporting frame, in accordance with EN 1993(Steel) and EN 1999 (Aluminium).

This shall be mentioned in the documents for the installer

Allowance of installing the system is depending on national requirements. Guidelines can be found in new Eurocodes for wind and snowloads."

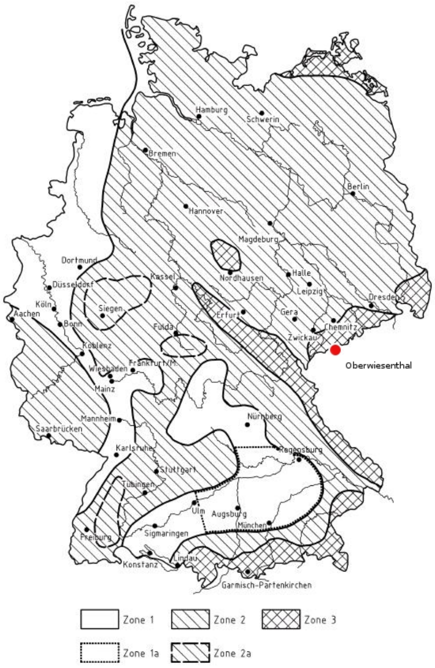
4. Load Classes

4.1. Wind classes and Snow/Ice classes

Eurocodes Wind (Germany)

Windzone	v_{ref}	q_{ref}
WZ 1	22,5 m/s	0,32 kN/m²
WZ 2	25,0 m/s	0,39 kN/m²
WZ 3	27,5 m/s	0,47 kN/m²
WZ 4	30,0 m/s	0,56 kN/m²

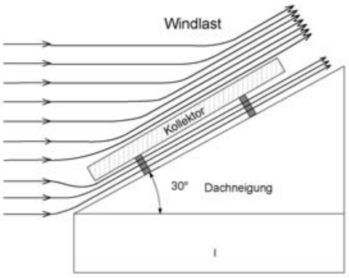
Eurocodes Snow/Ice (Germany)

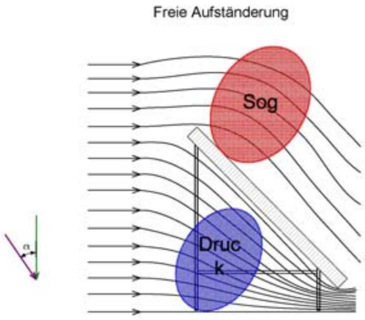


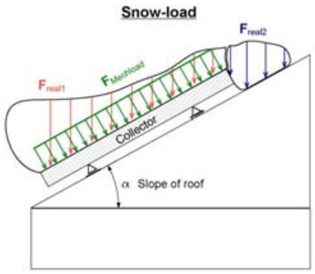
4.2. Boundary conditions and resulting forces/ effects

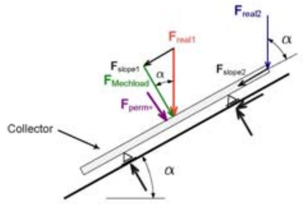
Incident angle

The angle of incidence is influencing the load situation basically. This is true for wind and snow induced loads.









Temperature

The temperature of collector parts is correlated to their strength, adhesion strength, brittleness and stiffness. So it makes a difference if I test the resistance against mechanical forces at elevated or very low temperatures.

The effects of this are very difficult to simulate because many of the used materials and components can not be described with parameters detailed enough. As well the combination of different forces and lots of components along the mounting are limiting the simulation.

Ongoing work is done here at Fraunhofer ISE.

Surrounding buildings and collector fields

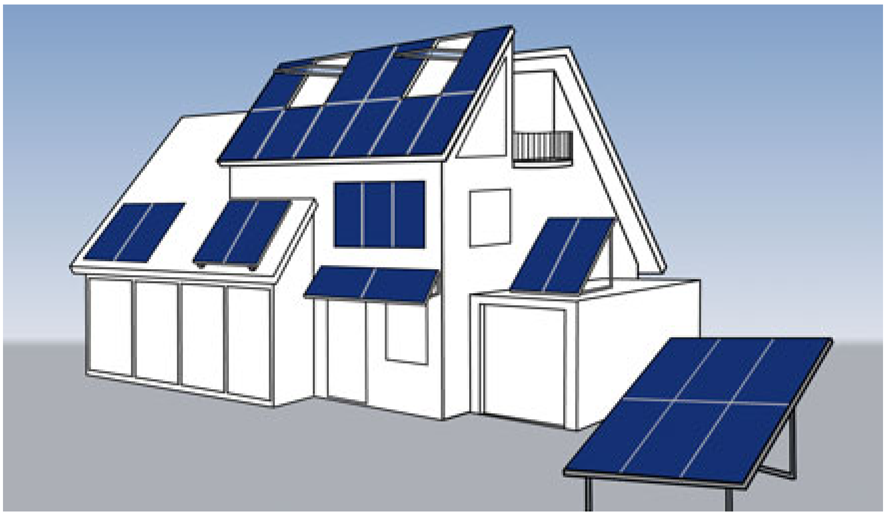
Indeed the wind speeds and snow loads are as well strongly influenced by the surrounding of the location the collector(s) is/are installed. For example collectors can be mounted at a façade of a building and depending on its height they can be exposed to very high wind speeds.

Even rows of collectors in bigger installation effect the load within the field.

Dynamic forces

When installing collectors in areas with lots of wind gusts, there is the possibility of generating dynamic loads at the collector. This is of course a totally different situation which is not represented with the recent test at all.

Mounting situations



4.3. CE-Marking and Classes

One has to take into account that CE will some how “ask” for at least a minimum of mechanical strength or better “structural safety” of the product taken under the regulation for building products. I think we have two possibilities:

1. Define the lowest class to such a level that it is satisfying the requirements of CE-marking.
2. Define a minimum level in Annex ZA which has to be tested and passed to fulfil CE-marking requirements.

Somehow the intention of CE-marking in relation to Solar Keymark (SKM) was that the industry which has SKM on a product does fulfil the CE–

marking requirements automatically. From this point of view only the first solution seems possible.

4.4. Certification and Classes

As wind and snow/ice load is varying extremely around the world and it always an issue of local, national or regional requirements there has to be a very clear levelling up to which forces the collector was tested. The suggestion is not to correlate classes resulting from the outcome of the testing with the wind and snow load classes of existing standards. It would be to complicate to do this worldwide.

One first very simple draft for classes could be:

N/m²	*1000*	*2400*	*5400*	<
Classes	*C*	*B*	*A*	
+				
-				

This draft is really ignoring almost all influences resulting from wind and snow. On the other hand this approach could be introduced even not changing the methodology of testing (at least for flat plate collectors) and bringing a first connection to different wind and snow classes of the Eurocodes.

5. Collector approach

5.1. Mounting equipment and situations

Arguments to include mounting equipment:

- The mounting equipment and fixings are interacting with the collector during test (and in reality).
- As well the mounting equipment is included when testing compact systems.
- Mounting equipment and fixings are not tested anywhere else.
- The customer buys a e.g. Key-marked product and expects that safety things are checked, also of course one can argue that that is in the responsibility of the manufacturer.

- Especially when on-going work will show that sloppy forces are essential to characterise durability of collectors, the fixings and mounting equipment will be in the focus again.
- Different mounting situations need different mounting equipment because different forces result. Testing has to represent this information in an easy way to the customer.

Arguments not to include fixings and mounting equipment:

- It is actually recently not the core competence of solar test labs
- The effort for industry would be increased time and financial wise

5.2. Testing equipment and results

Testing methodology and equipment have to adjust to the “new” situation. The recently used equipment is not suitable to fulfil the intention of the recent standards in many test labs. Doing this one can take an improvement of the equipment into account to develop testing capacities which are prepared for future branch development.

Fraunhofer ISE started activities in this filed with the company PSE AG to develop a new testing equipment and methodology. At the opening workshop especially German speaking industry and AIT took part. More work shops will be organised.

5.3. Proposed text for standard revision

The text was changed in this first revisions draft to the following text:

The report sheet in the annex of EN 12975 (formaly annex D) was changed to report the results of the testing using following default:

A.1
Mechanical load test

A.1.1 Positive pressure test of the collector cover

A.1.1.1 Method used to apply pressure:

☐ Loading with gravel or similar material

☐ Loading with water

☐ Suction cups

☐ Pressurisation of collector cover

A.1.1.2 Test conditions

Maximum pressure load:

A.1.1.3 Test results

The results shall be indicated and reported with a “not applied”, + = passed, or - = failed in a table as follows:

Test pressure	+1000 Pa /m²	+2400 Pa / m²	+5400 Pa / m²	Maximum positive mechanical load

Give details of any damage to the collector cover after the test, reporting the value of pressure load which caused the damage and any of the failures denoting “major failure”, defined in **Fehler! Verweisquelle konnte nicht gefunden werden.** of EN 12975-1:2006

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A.1.2 Negative pressure test of fixings between the cover and the collector box

A.1.2.1 Method used to apply pressure:

☐Suction cups ☐ Pressurisation of collector box ☐ Other:

A.1.2.2 Test conditions

Maximum pressure load:

A.1.2.3 Test results

The results shall be indicated and reported with “not applied”, + = passed, or - = failed in a table as follows:

Test pressure	-1000 Pa /m²	-2400 Pa / m²	-5400 Pa / m²	Maximum negative mechanical load

Give details of any damage to the collector cover or cover fixings after the test, reporting the value of pressure load which caused the damage and any of the failures denoting “major failure”, defined in **Fehler! Verweisquelle konnte nicht gefunden werden.** of EN 12975-1:2006

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A.1.3 Negative pressure test of collector mountings

A.1.3.1 Method used to apply pressure:

☐ Suction cups ☐ Air bags

A.1.3.2 Test conditions

Maximum pressure load:

Pa

A.1.3.3 Test results

Give details of any damage to the collector mounting fixtures or fixing points after the test, reporting the value of pressure load which caused the damage and any of the failures denoting “major failure”, defined in **Fehler! Verweisquelle konnte nicht gefunden werden.** of EN 12975-1:2006

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6. Compact systems approach

6.1. Mounting equipment and situations

Boundary conditions for testing according to EN 12975:

Collector to be horizontal, 1000 Pa in steps of 250 Pa.
Problem:

For thermo siphon systems almost always including a mounting device with a tilt angle it is not possible to test the collector following that procedure!

New improved Proposal was prepared for the QAiST Guide for reliability test for EN 12976:

Mechanical load test

Purpose

This test is used to evaluate the carrying capacity of a (thermosiphon) system due to snow and wind loads. The following procedure is for systems comprising a rack with a tilt angle where either the collector is separable or not separable from the tank. In both cases the whole System has to undergo a mechanical load test, not only for systems with not separable collectors as described in EN-12976-1 Chapter 4.3.1. The mechanical load test is adopting the procedure according to EN 12975-2 Chapter 5.9.

Apparatus

plane surface to put the system on

sand sacks (stone plates,…)

measuring tape

stop watch

camera

straps for keeping single weights in position

Safety precaution

safety glasses

safety shoes

gloves

long-sleeved clothing and cap

During the test extreme caution should be exercised at any time since the system may collapse under the weight. Therefore, during the test no other person should stay on or in the immediate vicinity of the test object without proper safety equipment.

Calculation procedure for the mechanical load

The requested pressure on the system is charged with sand sacks (or stone plates) and should be raised in 250 Pa steps until 1000 Pa.

To determine these four weight classes, to charge the system with, first of all the system area **A_{sys}** has to be calculated.

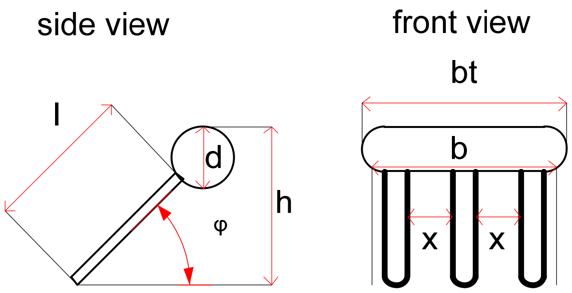


Figure 1: In red the dimensions of the system to be measured

$A_{sys} = A_T + A_{brutt} - A_x$

$A_T = b_t * d$ A_T = area tank

b_t = width tank

d = diameter

$A_{brutt} = l * b$ A_{brutt} = gross collector area

l = length of collector/ length mounting device

b = width collector/ width mounting device for vacuum tube collectors*:

$A_x = l*x*a$ A_x = tube spacing area

x = distance between tubes

a = number of gaps between tubes

**Note:*

In case there is a reflector located behind the tubes, then the tube spacing area A_x is set to zero ($A_x = 0$).

Now the mass m, the system has to be charged with, can be determined with pressure

$p = F/A$ $p = [Pa] = N/m^2$

and force

$F = m * g$ $F = [N] = kg\ m/s^2$ g = acceleration due to gravity $= 9{,}81\ m/s^2$

To calculate the force orthogonal to the surface of the system, the tilt angle ϕ of the system has to be taken into account (Fig. 2):

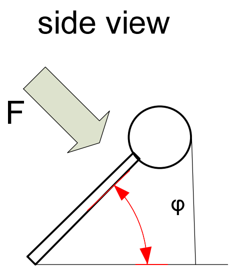


Figure 2: force orthogonal to surface of system

$m = p * A_{sys} / (g * \cos(\phi))$

This results in following equations for the different weight classes:

$m_1 = 250\ [Pa] * A_{sys}\ [m^2]/(9{,}81\ [m/s^2] * \cos(\phi))$

$m_2 = 500\ [Pa] * A_{sys}\ [m^2]/(9{,}81\ [m/s^2] * \cos(\phi))$

$m_3 = 750\ [Pa] * A_{sys}\ [m^2]/(9{,}81\ [m/s^2] * \cos(\phi))$

$m_4 = 1000\ [Pa] * A_{sys}\ [m^2]/(9{,}81\ [m/s^2] * \cos(\phi))$

Out of these masses, the number of sand sacks per weight class can be calculated.

The weight of each sand sack has to be checked.

$i = m_{1234}/m_S$ I = number of sand sacks

m_{1234}= load to charge the system with

m_S = mass of sand sack

Procedure

The system has to be mounted according to the manufacturer.

Tank should be filled with water during the test.

Before testing, the whole system has to be checked for damages on the rack, tank or collector.

Following steps should be conducted:

Calculate the weight load -number of sand sacks- for the 4 steps according to 5.7.4

The sand sacks for the first weight class (250 Pa) have to be distributed, starting with tank, **equally over the system** (Fig.2)

After charging the load wait **5 minutes** and check the mounting device/system for damage or deformation after. **Take picture** for protocol.

Put the missing sand sacks for the second weight class (500 Pa) on the system and repeat step c. The same for the third (750 Pa) and fourth (1000 Pa) weight class.

Figure 3: four steps from left: 250 Pa, 500 Pa, 750 Pa and 1000 Pa

Figure 4: Example of a non separable system, mechanical load test with sand sack

Figure 5 Example of a separable system mechanical load test with “stone load”.

Reporting requirements

After every weight class minimum one picture from the front and the side of the system has to be taken to notice and document possible damage on the system.

weight- class	**Area and weight determination**	**Charged load, number of sand sacks**	**Pictures**	**Notes/ Evaluation**
1	m_1 = 250 [Pa] * A_{sys} [m²]/(9,81 [m /s²] * cos (ϕ)) Asys = cos (ϕ)= m_1=			

…4	m_4 = 1000 [Pa] * A_{sys} [m^2]/(9,81 [m /s^2] * cos (φ)) Asys = cos (ϕ)= m_4 =			

6.2. Testing equipment and results

Because it is often not possible (because of constructional reasons) to bring the filled system in a horizontal position, the test has to be done including the mounting structure and somehow handling the sloped collecting area. This can be done with sand sacks to some extend. It is strongly recommended to go for a more repeatable and trustable testing methodology.

7. Transcript of the first telephone conference on December 2010:

If there would be classes of “load resistance” how would they be defined?

Giorgos: General requirement in the standard, extra load requirements not corresponding to the standard.

Uli: Classes to be defined in the standard, within these one can choose.

Minimum requirement needed. Maybe in the Scheme rules.

Peter: Why? Manufacturer chooses if he wants to sell in wind or snow areas.

Korbi: Classes combined for different forces? Heigh t of building, snow, wind free.

Stephan: Separated (+/-) classes could be helpful. Classes starting from “0”, without any test. Saying “Not checked”.

Stephan: Include mounting devices again.

Roof anchors----maybe not include them in judging

Mounted as if in real.

Uli:

Mounting equipment for different tiles should not be checked within EN ´75 in every version.

Korbi:

Different mounting situations should be tested.

Peter:

Does industry need this information? More and more standardized fixing/mounting equipment might be introduced.

Stephan:

Experiences are missing to include all the variations.

Uli:

EN´75 is maybe not the right place? CE marking?

Peter:

We should take responsibility for the box and the fixings. But where to draw the line? Roof tightness is maybe out of the reach of the collector manufacturer.

Calculation should be checked as well today?

Harmonization with PV, they are not testing the fixings as well.

Giorgos:

Difficult to test different situations, maybe not include the mounting equipment at all.

Peter: Shall we "translate" the load into area codes?

Stephan: maybe it´s not our core competence.

Uli: Steps of 250 are already class? If we test always up to breakage, we can give a limiting step/class.

Stephan: Not until breakage, but up to the whished class.

Summarizing:

Yes, keep positive and negative load in. Adopt to every technology in the scope of EN ´75.

Yes, include the mounting equipment (down to the roof anker), but only to provide realistic mounting situation and the test results only take into account the collector box and fixing to the mounting equipment.

Yes, introducing classes.

Manufacturer chooses up to which class should be tested (according to his calculations for his situation).

Version B

N/m²	*1000*	*2000*	*3000*	<
Classes	*A*	*B*	*C*	
+				
-				

Questions to discuss:

Should the wind and snow load as calculated in the EuroCodes DIN EN 1991 und DIN 1055 be reference for the Test?

No correlation in the standard. Has to be done by the installer/planer/manufacturer and give this information in appropriate way.

How should the manufacturer inform and make sure that the installer and /or the consumer is informed about the limits of the system?

->Certification matter, because it is clearly defined in the EN ´75 that this information has to be given. Many manufacturers do not know how to calculate this. -> no certificate?

How to represent the different mounting situations and the different resulting mechanical loads?

Uli: Mounting equipment is not examined right now. Scheme rules could mention, that only checked mounting situations can be taken into account.

Peter: SK data sheets only give small information. Only "roof integrated" yes/no. Calculation checking by the institute.

Stephan: Reporting shall include the equipment which was used.

Maria: Right now it is no limit up to which the test was performed / passed reported in the SK data sheet.

Stephan: ESTIF mandated already the EN´75 to be harmonized in regards to mechanical load. We even could refer to another standard and check on a confirmation letter. SK "proves" still consistence.

Korbi: Checking on the calculations is very difficult. Test shall include mounting "down" to the hook, to assure the mounting equipment and its interaction with the collectors frame are represented in the test results somehow. Different mounting equipment may be tested as well? Method still to develop, see also questions following further on.

K. Geimer:

IEC 61215 eine tolle Lösung für PV: "Mount the module on a rigid structure using the method prescribed by the manufacturer.
(If there are different possibilities, use the worst one, where the distance between the fixing points is at maximum.)"
In IEC 61646:

„NOTE 3: If different mounting methods for the module are permitted, the test is to be performed with different test configurations representing the range of envisaged mounting methods."

Should the mounting equipment be included in the test?

Yes, see above.

Should sloped forces be tested?

Stephan: It is a future topic, but more experiences needed. Procedure to develop and then to discuss again.

Peter: No proposal right now.

Korbi: ISE tries to work out on that.

How could one represent the influence of heat and cold to the mechanical strength and behaviour?

Stephan: Interesting, right now no possibility.

Peter: Especially when polymers are used.

Korbi: ISE will try to work on that.

[How is the influence of to another collector taken into account?]

Not for testing standard

What about dynamic loads induced by wind? Is there a responding frequency?

Uli: Dynamic loads by wind.

Korbi: ISE will do some test.

How to simulate live time? Load cycles!

Uli: How many cycles are reasonable?

Other topics:

ETC positive and negative load? Procedure and load calculation?

“not separable” systems? Procedure and load calculation?

CE marking, what does this really imply?

8. Decisions been taken in Stockholm:

- The testing for not separable Systems should be discussed and implemented in EN`76

- Note: There is a standard for mounting equipment under inquiry in Austria

- Include the fixings for realistic testing conditions

- Levels as defined in the table below.

One first very simple draft for classes could be:

N/m²	*1000*	*2400*	*5400*	*Exact limit*
Classes	*C*	*B*	*A*	
+				
-				

9. Literature

Korbinian Kramer, Jonas Budde, Rebecca Schwantes: Entwicklung einer Methodik zur Prüfung von Wind- und Schneelasten an solar-thermischen Kollektoren, DSTTP Technologie Konferenz, Berlin, 26.01.2010

Korbinian Kramer, Jonas Budde und Katharina Edelmann: MECHTEST – DEVELOPING A METHODOLOGY FOR TESTING THE MEACHANICAL SNOW AND WIND LOAD ON SOLAR THERMAL COLLECTORS, EuroSun 2010 Graz, 28. September - 01.Oktober

…

CEN/TC 128/WG 3
CEN/TC 128/WG 3 - Renewable energy systems for roofs
Email of secretary:
Secretariat: BSI (United Kingdom)

CEN-TC128-WG3-N0047 Draft CEN TR Renewable Energy on the roof(November2012)

Document type: Other committee document

Date of document: 2012-11-14

Expected action: INFO

Background:

Committee URL: http://cen.iso.org/livelink/livelink/open/centc128wg3

DRAFT November 2012

CEN/TC128/WG3: Proposed CEN Technical Report on solar energy systems for roofs: requirements for structural connections to solar panels

SUMMARY

a) Type of solar panel: Thermal or photovoltaic solar panels which comply with the mechanical resistance requirements of EN12575 (thermal modules) or EN61215 (PV modules).

b) Determine the loads and load combinations: self-weight of the solar panels and relevant imposed wind and snow actions.

c) Determine the design loads for the solar panels: multiply each of the loads by their respective partial factor γG ***or*** γ_Q ***for the ultimate limit state, and separately for the serviceability limit state.***

d) Identify one or more combinations of most unfavourable design loads which act together at the same time, for the ultimate and serviceability limit states. Modify the loads by applying a load combination factor ψ_0 ***for one of two or more variable loads which act at the same time.***

e) Determine the structural resistance of the connections between the solar panels and the roof structure in accordance with calculation methods of one or more of the following standards:

EN1992 to EN1996, and EN1999

for the ultimate and serviceability limit states. For the serviceability limit state, specify the maximum deformation limiting the function of the connection, e.g. water penetration or damage to roof components);

or

where the structural resistance cannot be determined by calculation methods, determine the resistance by load tests.

f) Verify the design by confirming that the factored structural resistance is not less than the critical combinations of factored actions for both limit states.

Foreword

This Technical Report has been prepared by Technical Committee CEN/TC128 “Roof covering products for discontinuous laying”, the secretariat of which is held by NBN, in cooperation with:

CEN/TC250
CEN/TC254
CEN/TC312
CENELEC/TC82

1.0 Scope

This Technical Report provides guidance on the principles and requirements of structural design for the safety and serviceability of the structural connection between solar energy panels (thermal or photovoltaic) that are mounted on flat or pitched roofs.

This Technical Report does not include requirements for:

Solar panels which are made as part of roof covering products;
Weather tightness of the roof, solar panels and connections;
Electrical or thermal characteristics of the solar panels;
Precautions against fire of the installation.

2.0 References

EN1990	Eurocode: Basis of structural design	
EN1991	Eurocode 1:	Actions on structures:
		Part 1-1: General actions – Densities, self-weight, imposed loads for buildings;
		Part 1-3: General actions - Snow loads
		Part 1-4: General actions - Wind loads
		Part 1-5 Thermal actions
		Part 1-7 Accidental actions
EN1992	Eurocode 2:	Design of concrete structures
EN1993	Eurocode 3	Design of steel structures
EN1995	Eurocode 5:	Design of timber structures
EN1996	Eurocode 6:	Design of masonry structures
EN1998	Eurocode 8:	Design of structures for earthquake resistance
EN1999	Eurocode 9:	Design of aluminium structures
EN12975-2	Thermal solar systems and components	
EN61215	Crystalline silicon photovoltaic modules – Design qualification and approval	
EN61646	Thin-film terrestrial photovoltaic (PV) modules: Design qualification and type approval	
EN14437	Determination of the uplift resistance of installed clay or concrete tiles for roofing – roofing system test method.	

3.0 Types of solar panel installation on roofs

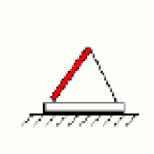


Figure 1a: Inclined installation on flat roof

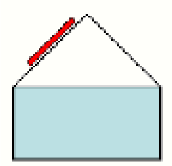


Figure 1b: Parallel installation on a pitched roof

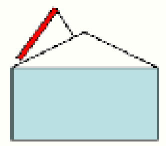


Figure 1c: Inclined installation on a pitched roof

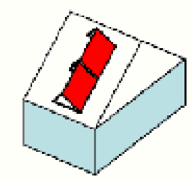


Figure 1d: Inclined installation perpendicular to the ridge of pitched roof

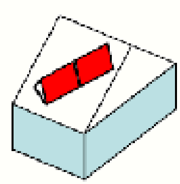


Figure 1e: Inclined installation oblique to the ridge of pitched roof

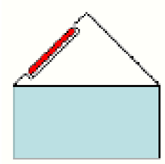


Figure 1f: Installation in the plane of the pitched roof covering

Figure 1. Types of solar panel installation *[from Austrian Standard M7778]*

4.0 Design responsibility

The designer should ensure that:

(1) The choice of the structural system and the design of the structural connections are made by appropriately qualified and experienced personnel.

(2) Adequate supervision and quality control are provided during execution of the work in design offices, factories and on site.

(3) The structure will be adequately maintained.

(4) The structure will be used according to the design assumptions.

(5) The building structure can safely support the solar panels according to Eurocode standards of design; building retrofitted with solar panels should be checked against the same standards.

5.0 Terms and definitions

The terms and definitions for structural design are in accordance with EN1990 to EN1999.

6.0 Symbols

The symbols for structural design are in accordance with EN1990 to EN1999

7.0 Types of solar panels

Solar thermal modules should comply with EN12975, according to the manufacturer’s declared requirements.

Solar PV modules shall comply with the requirements of EN61215.

8.0 Principles of limit states structural design

Structural design should be carried out according to the principles of limit states of EN1990. The ultimate limit state and the serviceability limit state should both be considered, applied to relevant design situations.

For each limit state, the design value is:

- the characteristic value of action(s) multiplied by the appropriate partial safety factor for each action,

which should be not less than:

- the characteristic value of resistance divided by the appropriate partial safety factor for the material.

8.1 Design situations

Design situations to be considered are actions which are:

Persistent (conditions of normal use, from dead loads, wind and snow loads, and other imposed loads);

Induced loads from thermal action due to temperature variation (for mounting beams of solar panels);

Transient loads (e.g. during execution or repair);

Accidental actions (exceptional conditions e.g. explosion, impact, consequence of local failure);

Seismic actions (in seismic locations only).

The most unfavourable combinations of actions which act together at the same tine should be considered in design. They include loads which are applied in different directions.

8.2 Ultimate limit states

The ultimate limit states concern the safety of people and/or the structure when failure of the structure occurs by excessive deformation, transformation into a mechanism or loss of stability.

8.3 Serviceability limit states

The serviceability limit states concern the deformation, vibration or damage of the structure under normal use which affect the appearance, discomfort to people or function (e.g. causing roof leakage or damage to the roof covering).

9.0 Determination of actions

9.1 Permanent actions (G)

The characteristic value of self weight of the solar panel and its structural connection should be taken as its mean value. Indirect actions, e.g. caused by irreversible deformation, are also classed as permanent actions.

9.2 Variable actions (Q)

Variable actions are imposed loads, wind and snow loads, and loads induced by thermal movement (e.g. for mounting beams)

The characteristic load values for snow and wind speeds may vary with location and given as Nationally Determined Parameters NDPs) in National Annexes to the standard.

9.2.1 Imposed loads

To be in accordance with EN1991-1-1.

9.2.2 Snow loads

To be in accordance with EN1991-1-3.

9.2.2.1 Return period

The ground snow load value may be adjusted according to the return period adopted (see EN1991-1-3 Annex D), if specified by the National Annex. The return period may be based on the expected design life of the solar panel connections, but should be assumed for this purpose to be not less than 5 years. .

9.2.2.1 Sliding snow loads on pitched roofs

Sliding snow loads of sliding snow which act on the solar panels projecting above the pitched roof surface should be determined according to EN1991-1-3 Section 6.4. They may occur at the same time as vertical snow loads and snow drift loads.

NOTE. To protect solar panels projecting above the roof surface from heavy sliding snow loads from a long length of pitched roof, snow guards of adequate strength are recommended to be installed up-slope of the solar panels. Where the projected height of the solar panels is greater than that of the snow guard, snow drift loads should be assumed to act on the difference in projected height.

9.2.3 Wind loads

The modelling of wind velocity and peak velocity pressure is given in EN1991-1-4. For site-specific data on climatic information, wind speed distribution maps and altitudes, refer to the relevant National Annexes to EN1991-1-4.

Wind loads acting on solar panel installations should be derived in accordance with EN1991-1-4 based on the peak velocity pressure, reference height and wind pressure coefficients.

Pressure coefficients for certain solar panel and building configurations which are not given in EN1991-1-4 may be obtained from NEN7250.

~~Wind pressure coefficient data in 9.2.3.2 and 9.2.3.2 are taken from Austrian Standard M7778. They refer to coefficients in the 'standard' [or central] roof area. For perimeter areas of roof, the coefficients should be increased by 25%.~~

NOTE. It may be assumed that solar panels installed on a roof do not cause an unfavourable change of wind loads on the roof surface.

~~9.2.3.1 Wind load pressure coefficients for solar panels above the plane of the roof (Figure1b)~~

a) ~~Clearance > 300mm: c_f = -0,7/ +1,0~~

b) ~~Clearance ≤ 300mm: c_f = -1,3/ +1,0~~

~~9.2.3.2 Wind load pressure coefficients for solar panels on inclined installations (Figures 1a, 1c, 1d, 1e)~~

a) ~~On flat roofs (≤ 5° pitch): c_f = -1,45~~

~~b) On pitched roofs, perpendicular to ridge): c_f = -1,6 +1,6~~

9.2.4 Critical load combinations

The following are load combinations which may act together at the same time on solar panels and their connections:

Dead load + imposed load;

Dead load + snow load (and with sliding snow load for pitched roofs) + wind load (+ or -), [+ loads induced by thermal action for mounting beams].

The most unfavourable load combinations in magnitude and load direction should be adopted for design.

9.2.5 Load combination factor ψ_0, ψ_1, ψ_2

Where the leading variable action is applied together with other variable actions, the value of the other variable actions may be reduced by multiplying by a combination factor ψ_0. (See EN1990).

Appropriate values of ψ_1 and ψ_2 load combination factors should be applied to frequent and quasi-permanent snow loads, or for snow loads considered to be accidental actions, where specified by the National Annex to EN1991-1-3.

9.2.6 Partial factors for actions

The design value is the characteristic value multiplied by partial factors γ_G or γ_Q.

For the ultimate limit state:

- permanent actions: in favourable load combination $\gamma_G = 1,0$;

  in equilibrium condition providing total stability $\gamma_G = 0,9$;

  in unfavourable load combination $\gamma_G = 1,35$

- variable actions: $\gamma_Q = 1,50$

For the serviceability limit state:

- permanent and variable actions, $\gamma_G = 1,0$; $\gamma_Q = 1,0$

9.2.7 Consequence of structural failure

Solar panels installed on buildings in normal conditions of use may be designated with a reduced consequence of failure than for the supporting structure (see EN1990 B1). The normal consequence class for solar panels should be CC1 (EN1990 Table B1) corresponding to Reliability Class RC1.

For RC1, a multiplying consequence factor $K_{FI} = 0,9$ should be applied to unfavourable actions.

For installations requiring consideration of higher risk, see EN1990 B3.

10.0 Structural resistance of connections

10.1 Configuration and type of connectors

Connectors directly supporting the solar thermal or PV panels should be not more structurally unfavourable in number, position, strength and stiffness, than those which comply with the mechanical load tests in EN12975 (solar thermal panels) or EN61215 (PV panels).

10.2 Design by calculation

The structural resistance should be determined by calculation in accordance with one or more Eurocodes EN1992 to EN1996 and EN1999, for both the ultimate and serviceability limit states, to support adequately the most unfavourable load combinations.

The design resistance is the characteristic strength at the ultimate limit state, or at the serviceability limit state, divided by a material partial factor γ_M, whichever is less. .·

Values for γ_M are specified in the relevant Eurocode for structural materials EN1992 to EN1996 and EN1999.

10.3 Design assisted by testing

Where the structural resistance of the connection or part of the connection cannot be determined by normal calculation methods, it may be determined by testing

In accordance with EN1990 Annex D, design may be based on a combination of tests and calculations.

Testing to determine the resistance of the structure or part of the structure may be carried out, for example, in the following circumstances if:

- adequate calculation models are not available;

- a large number of components are to be used;

- it is necessary to confirm, by control checks, assumptions made in the design

Test specimens should be specified or obtained by sampling in such a way as to represent the conditions of the real structure, and to obtain a statistically representative sample.

The rate of loading should where possible reflect actual conditions. Where the material of the structure has significant time dependent effects on strength and deformation (e.g. timber – see EN1995-1-1), the test results should be modified to take this effect into account. Tests should be continued until failure occurs, recording load increments and deflections.

The characteristic strength should be the 5% characteristic value based statistically on the Normal Distribution of a population of test results (EN1990 Table D1). The minimum population of tests results should be 3.

The design resistance value for the ultimate load condition is the characteristic value divided by $\gamma_M > 1,0$. Values of γ_M vary according to the type of structural material (See relevant Eurocode 1991 to 1999).

The strength at the limit of serviceability should also be the 5% characteristic value. The design resistance is the characteristic value divided by $\gamma_M = 1,0$.

The minimum design resistance is the lesser of the ultimate load and serviceability conditions.

Where separate tests are carried out on loads each acting in different directions, the combined characteristic value for the loads acting together may be obtained vectorally.

For a test method to determine the wind uplift resistance, see EN14437.

11.0 Design for accidental action

Solar panel installations can normally be considered to be of low consequence of failure and would not induce progressive collapse of the building to which they are attached, therefore no special measures are required against accidental actions.

In exceptional conditions of high consequence of failure, EN1991-1-7 provides design advice.

12.0 Design for seismic action

Design for seismic action should be in accordance with EN1998 and is required only in earthquake areas as indicated in relevant National Annexes to EN1998, or in national building regulations, which specify seismic zones and reference ground acceleration values.

National seismic design requirements and standards should also be adopted.

The design should validate both seismic and non-seismic design situations.
.

Solar panels connected to the roof structure should normally be regarded as ‘non-structural elements’ or ’appendages’ of buildings as defined in EN1998.

Unless otherwise specified, the effect of seismic action may be determined by applying to the non-structural element a horizontal force Fa, defined in EN1998 as:

$$Fa = (Sa.Wa.\gamma a)/qa$$

where Fa is the horizontal seismic force, acting at the centre of mass of the non-structural elements in the most unfavourable direction;
Wa is the weight of the element;
Sa is the seismic coefficient for non-structural elements, defined as
$Sa = \alpha S\{3(1+z/H)/(1+(1-Ta/T1)2)-0,5\}$, but $Sa \geq \alpha S$
γa is the importance factor of the element, taken as 1,0;
qa is the behaviour factor of the element, taken as 1,0;
α is the ratio of the design ground acceleration on type A ground, ag, to the acceleration of gravity g;
S is the soil factor;
Ta is the fundamental vibration period of the non-structural element;
Ti is the fundamental vibration period of the building in the relevant direction;
Z is the height of the non-structural element above the level of application of the seismic action (foundation or top of a rigid basement);
H is the building height measured from the foundation or from top of a rigid basement

13.0 Bibliography

Austrian Standard ÖNORM M 7778 (24 June 2010) “Montageplanung und Montage von Solarpanelen (thermische Kollektoren und Fotovoltaikmodule)”

Dutch Standard NEN7250 (in preparation): Solar energy systems – Integration in roofs and facades – Building aspects.

Annex A. Design examples

Annex A1 - Design of a solar fixing hook for solar PV panels parallel to and above the roof covering

A1.1 Description of the system:

A solar roof hook which is used to anchor solar panels above an outer covering of roof tiles as shown in Figure 1B of this TR. The roof hook is screwed to the rafters of the roof via its base plate and the hook then penetrates through the outer covering of roof tiles via the headlap of those tiles. In order to facilitate this, the weather bars of the roof tiles are hand modified so that the roof hook passes through the tile array without increasing the gapping of the roof tiles and hence without influencing the weather-tightness of the roof. If necessary a durable foam rubber strip is added around the hook to ensure adequate weather-tightness of the penetration.

Generic examples are shown in Figure A1.1. The top section of the hook clamps to a mounting rail system which in turn secures the solar panels. A minimum of two mounting rails are required per solar panel and several hooks may be required per panel.

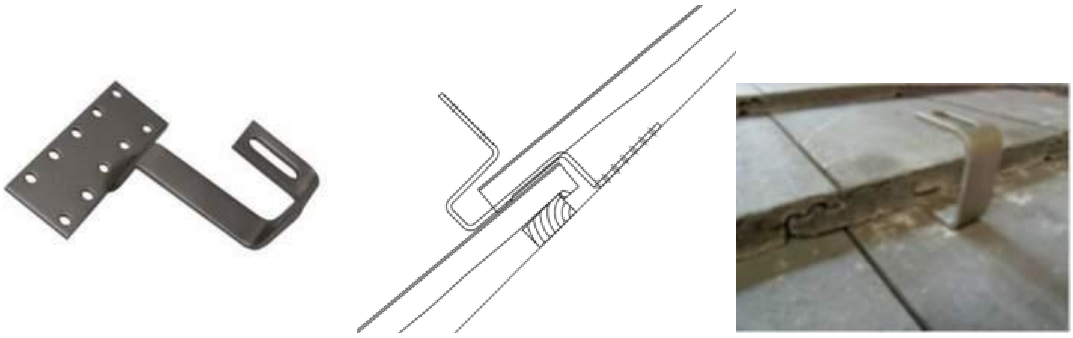


Figure A1.1 Generic solar roof hook designs

It is necessary to check the design of the hooks and their fixing into the roof to determine how many hooks are required per solar panel in order to prevent failure on the roof under load. Failure may be classified as actual failure of one or more parts of the system (ultimate limit state) or serviceability failure (serviceability limit state) such that the system is no longer fit for purpose. Examples of serviceability failure are: i) breakage of roof tiles and ii) a significant permanent deflection of the roof tiles such that the weather-tightness of the roof is compromised.

This example considers a roof with rafter pitch of 30°, with the solar panels fixed above the roof, parallel to the rafters and with a clearance of ≤ 300mm between the panels and the roof covering.

A1.2 Climate zone

The solar roof hooks are to be used in the German market.

A1.3 Loads

(a) Dead loads

Example solar panels and support rails have been chosen. The panels have an individual area of 1.386 m^2. The combined self-weight of the panels and rails is 18.5 kg/m^2.

(b) Imposed load

An imposed point load of Qk = 1.0kN will be considered. (Section 9.2.1)

This design load simulates the weight of a person working on the panels. Since it is not customary to walk on solar panels this is considered to be an accidental load. Furthermore this load is unlikely to occur in combination with significant snow or wind loads. It is will therefore be considered to act only in conjunction with the dead weight of the system. The imposed load must be applied at the most severe position.

(c) Wind & Snow loads

The once in 50 year wind & snow loads must be derived for the site or region in Germany using data from the Euro-Codes for wind and snow, together with the relevant National Annexes.

The relevant Euro-Codes are:

EN 1991-1-3: 2003, Eurocode 1 – Actions on structures – Part 1-3: General Actions – **Snow Loads (National Annex: DIN EN1991-1-3/NA)**

EN 1991-1-4: 2003, Eurocode 1 – Actions on structures – Part 1-4: General Actions – **Wind Loads (National Annex: DIN EN1991-1-3/NA)**

Initially these are used to calculate the design wind pressure, q, and the characteristic snow load, $S_{k.}$ The following values have been derived for the purposes of this example and cover a range of areas in Germany, including the North Sea coast where wind loads are highest but snow loads are modest and also including the southern parts of Germany where snow loads can be high, whilst wind loads are lower.

WIND			**SNOW**		
Zone	**Building height**	**q_p (N/m²)**	**Zone**	**Altitude**	**S_k (kN/m²)**
Zone 3 incl coast	≤ 10m	1050	Zone 2	≤ 250	0.85
Zone 2, inland	**≤ 18m**	**800**	**Zone 2**	**≤ 400**	**1.21**
Zone 2, inland	≤ 10m	650	Zone 2a	≤ 1000	5.68

Table A1.1 Example values of design wind pressure & characteristic snow load

In the example calculations which follow the second of these conditions will be used (shown in bold, q_p = 800 N/m^2, S_k = 1.21 kN/m^2). In practice a range of conditions would be calculated.

i) Calculation of the wind load acting on the panels

q_p = once in 50 year wind pressure based on a short duration gust at 10m height over flat open ground. Other ground roughness values, distances for the sea, building heights or the presence of topography will influence this value.

The (unfactored) wind load acting on the panel, normal to the surface is calculated as follows:

Wind load = F = q_p x C_f x A

C_f = force coefficient or net pressure coefficient. Negative values signify a force acting upward normal to the roof. Positive values signify a force acting downward normal to the roof.

A = area of the panel (m^2) = 1.386 m^2 in this example

Values of C_f are given in paragraph 9.2.3. The values and the resulting wind loads are shown in Table A1.2

.

	Uplift Loads		Down loads	
	Local area	General area	Local area	General area
C_f values for a clearance ≤ 300mm	- 1.63	- 1.3	+1.25	+1.0
F / A (Pa)	1300	1040	1000	800
F (N)	-1802	-1442	1386	1109

Table A1.2 Values of C_f & the calculated wind loads

Local area = areas around the edges of the roof and around obstacles in the roof. Local areas experience larger wind loads than the remainder of the roof. The local areas of the roof are defined in EN1991-1-4.

General area = those areas of the roof not classified as local areas.

The remainder of this example will consider only the Local Areas of the roof. In reality the General Areas would also be considered where these represent a large section of the roof.

ii) Snow loads

S_k is a characteristic value & must be multiplied by several factors taken from the Euro-Code and its National Annex. The result is then the once in 50 year snow load acting as if the roof was horizontal.

$S\ (kN/m^2) = \mu_i \times C_e \times C_t \times S_k$

μ_i = shape coefficient & depends on the roof geometry & pitch. (eg; for a normal duo-pitch roof at 30° μ_i=0.8, at 60° μ_i=0).

C_e = topography factor (take as 1.0 for 'normal' topography.) For sheltered sites C_e = 1.2, for windswept sites C_e = 0.8. In this example C_e = 1.0

These values give:

$S_{\mu=0.8}$= 0.968 kN/m^2

The snow load acting on a solar panel, assuming it to be horizontal, is then:

$S_L = S_{\mu=0.8} \times A$ = 1342 N

iii) Summary of loads acting on a single panel, in directions normal to the roof and down the roof:

These are derived by multiplying the loads by sin30° or cos30°, as appropriate.

	Force vertical to the roof		Force down the roof	
	Based on wind uplift	Based on wind download	Based on wind uplift	Based on wind download
Imposed load (N)	To be calculated	To be calculated	To be calculated	To be calculated
Dead load (N)	218	218	126	126
Snow load (N)	1162	1162	671	671
Wind load (N)	-1464	1126	0	0

Table B1.3 Loads acting on a single panel (N)

The sign conventions for loads vertical to the roof: +ve is downwards, -ve is upwards.

A1.4 Factored load combinations for the ultimate limit state

Based on Section 9.2.4 - 6 and Tables A1.1 & A1.2 of EN1990:2002 the following load cases are considered. These include the appropriate load combination factors and load side partial safety factors. (Check KFI also applies to self-weight in uplift situation – load case 5).

Load Case 0: 0.9 x [1.35 x Dead Load + 1.35 x Imposed load]

Load Case 1: 0.9 x [1.35† x Dead Load + 1.50 x Snow Load]

† The partial safety factor for dead load (a permanent action) is:

1.35 when the dead load acts in the same direction as variable actions (snow & downward wind loads).
1.0 when the permanent load relieves the variable load (for example wind uplift)

Load Case 2: 0.9 x [$1.35^{\dagger}$ x Dead Load + 1.50 x Wind Load]

Load Case 3: 0.9 x [$1.35^{\dagger}$ x Dead Load + 1.50 (Wind Load + 0.5 Snow Load)]

Load Case 4: 0.9 x [$1.35^{\dagger}$ x Dead Load + 1.50 (Snow Load + 0.6 Wind Load)]

Load Case 5: 0.9 x [1.0 x Dead Load + 1.50 x Wind Suction]

Note: Thermal effects still to be added in – loads created by thermal contraction of rails installed in the height of summer – contraction can be significant in severe winters. Load case 1 becomes:

Load case 1: 0.9 [1.35 x (Dead Load) + 1.50 x (ψ1 x Snow Load + ψ2 x Thermal Load)]

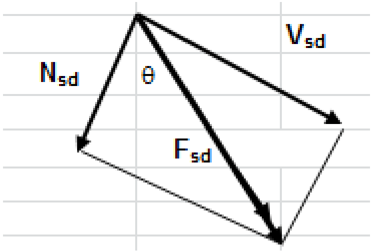
We must consider: $\psi_1 = 1.0$ with $\psi_2 = 0.6$
and also:
$\psi_1 = 0.5$ (for site altitudes, H, ≤ 1000m), with $\psi_2 = 1.0$

The factor of 0.9 appearing in each load case is the K_{FI} factor described in Section 9.2.7.

These loads occur in orthogonal pairs and can be combined into a single effective combined load by vector addition. These resulting values of F_{sd} are later compared against effective resistance values derived by measurement.

N_{Sd} = force on the anchor point acting normal to the roof
V_{sd} = force on the anchor point acting parallel to the roof
F_{sd} = resultant force, acting at an angle θ

$F_{sd} = \surd(V_{sd}^{2} + N_{sd}^{2})$
$\tan \theta = V_{sd} / N_{sd}$



The values are summarised below and have been derived for each load case:

Load case	Wind load acting upwards normal to roof					Wind load acting downwards normal to roof				
Load case	N_{sd} (N)	V_{sd} (N)	**F_{sd} (N)**	**θ°**	Dominant load	N_{sd} (N)	V_{sd} (N)	**F_{sd} (N)**	**θ°**	Dominant load
LC 1	1833	1059	**2117**	**30°**	Normal down	1833	1059	**2117**	**30**	Normal down
LC 2	-2237	113	**2240**	**-2.9°**	Normal up	2136	153	**2142**	**4.1**	Normal down
LC 3	-1452	566	**1559**	**-21.3°**	Normal up	2920	606	**2983**	**11.7**	Normal down
LC 4	305	1019	**1064**	**73.3°**	Parallel down	2956	1059	**3140**	**19.7**	Normal down
LC 5	-2256	102	**2259**	**-2.6°**	Normal up	2048	102	**2050**	**2.8**	Normal down

Table A1.4 Resultant force acting on the solar hooks – ultimate limit state calculations

A1.5 Factored load combinations for the serviceability limit state

The load cases are the same as those in Section B1.4 except that all partial safety factors and K_{FI} take the value of 1.0.

Load Case 0: Dead Load + Imposed load

Load Case 1: Dead Load + Snow Load

Load Case 2: Dead Load + Wind Load

Load Case 3: Dead Load + (Wind Load + 0.5 Snow Load)]

Load Case 4: Dead Load + (Snow Load + 0.6 Wind Load)]

Load Case 5: Dead Load + Wind Suction

These are analysed in the same manner as the design loads for limit state failure.

Load case	Wind load acting upwards normal to roof					Wind load acting downwards normal to roof				
Load case	N_{sd} (N)	V_{sd} (N)	**F_{sd} (N)**	**θ°**	Dominant load	N_{sd} (N)	V_{sd} (N)	**F_{sd} (N)**	**θ°**	Dominant load
LC 1	1380	797	**1593**	**30.0**	Normal down	1380	797	**1593**	**30.0**	Normal down
LC 2	-1584	126	**1589**	**-4.5**	Normal up	1604	126	**1609**	**4.5**	Normal down
LC 3	-1003	461	**1104**	**-24.7**	Normal up	2185	461	**2233**	**11.9**	Normal down
LC 4	479	797	**930**	**59.0**	Parallel down	2073	797	**2221**	**21.0**	Normal down
LC 5	-1584	126	**1589**	**-4.5**	Normal up	1604	126	**1609**	**2.5**	Normal down

Table A1.5 Resultant force acting on the solar hooks – serviceability limit state calculations

A1.6 Structural resistance

The design resistance of the solar hooks must be measured by load tests to determine the failure loads in each direction in which loads are expected to act, for instance (see Figure A1.2):

- Downwards normal to the roof (a)
- Upwards normal to the roof (c)
- Down the roof (ridge to eaves b)
- Up the roof (eaves to ridge d)
- Across the roof (e)

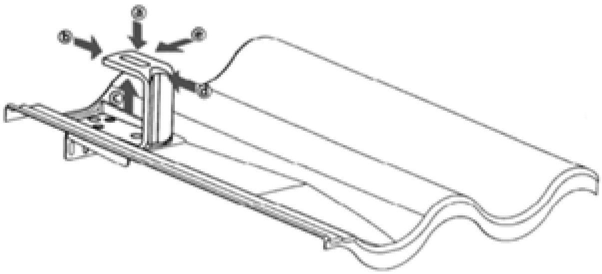


Figure B1.2 Measurement directions

Note: This figure is to be changed to a sketch of a more generic solar roof hook.

During the measurements all modes of failure must be measured, including both serviceability failures and ultimate failure. Serviceability failures usually occur before ultimate failures.

Example serviceability failures are:

– Breaking of tiles

– Permanent deflection of the solar hooks such that the tiles have a permanent deflection which will threaten the weather-tightness of the roof (permanent deflection of the roof covering greater than a critical value for leakage eg; 3mm)

– Large displacement of the tiles even if they go back into place afterwards (> 75mm)

Example ultimate failures are:

- Breaking of the fixings into the roof
- Breaking of the hook or other anchor type

The test must apply the loads realistically to the roof hook. This may be done by including the mounting to the rails or panel.

Characteristic Resistance

Each load direction should be tested a minimum of 3 three times, thereby allowing statistical analysis to be carried out to derive the characteristic resistance, R_k, for each failure mode in each direction.

The characteristic resistance is the 95% confidence limit calculated from the mean value (R_x) and the standard deviation (S_f) of the individual measured failure resistances, R_i

$$R_x = \sum_{1}^{n} R_i / n$$

$$s_f = \left[\sum (R_i^2 - R_x^2) / n - 1 \right]^{0.5}$$

$$R_k = R_x - k_n \cdot s_f$$

n = number of measurements of individual failure loads

The value of k_n depends upon the number of measurements, Table A1.5 :

No. of test results, n	Corresponding value of k_n
3	3.37
5	2.33
7	2.06

Table A1.5 Statistical factor used for deriving the characteristic resistance

Safety factors & design resistance

The design resistance loads in each direction are derived from the characteristic resistance values for each failure mode by dividing by the appropriate material safety factor, γ_m, Section 9.2.6.

The safety factors to be applied to the measured resistances of the anchor point are deduced from the relevant Eurocode:

- For failure in steel or metal components - EN1993-1-1: Design of steel structures.
- For failure in timber – EN1995-1-1: Design of timber structures: General rules & rules for buildings.

a) Ultimate Limit State (the system actually fails):

- For failure in a metal component the safety factor is, $\gamma_m = 1.1$
- For failure in the timber component the safety factor is more complicated:
  For snow as the dominant load: Safety factor, $\gamma_m = 1.625$
  For wind as the dominant load: Safety factor, $\gamma_m = 1.44$
- For thermal actions as the dominant load, $\gamma_m = 1.44$

These values have taken into account the influence of load duration and other parameters in-line with EN1995-1-1 Table 2.2 and clause 2.3.1.

b) Serviceability Limit State

For serviceability failure the safety factor, $\gamma_m = 1.0$

Design structural resistance values:

Example design resistance values are shown for serviceability and ultimate failure and shown in Tables A1.6 & A1.7 – values still to be entered

	Mean (N)	Standard Deviation (N)	Characteristic Value (N)	Safety factor γ_m	Design resistance (N)
Load 'Normal Up' to Roof				1.0	
Load 'Normal Down' to Roof				1.0	
Load ‘Parallel Up’ the roof				1.0	
Load 'Parallel Down' the Roof				1.0	
Load 'Parallel to the side				1.0	

Table A1.6 Example design resistance values for serviceability failures

	Mean (N)	Standard Deviation (N)	Characteristic Value (N)	Safety factor γ_m	Design resistance (N)
Load 'Normal Up' to Roof					
Load 'Normal Down' to Roof					
Load ‘Parallel Up’ the roof					
Load 'Parallel Down' the Roof					
Load 'Parallel to the side					

Table A1.7 Example design resistance values for ultimate failures

A1.7 Design verification – derivation of the number of hooks required

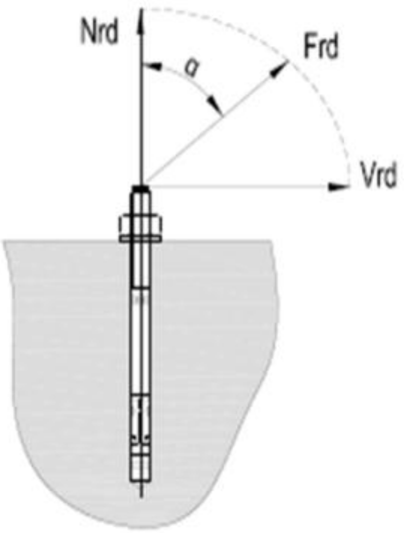
/Determination of the number of anchor points

The determination of the required number of solar hooks follows the procedure in the Austrian standard, ÖNORM 7778: 2011, “Assembly planning and assembly of thermal solar collectors and photovoltaic modules”.

In order for the fixing resistance to be adequate, sufficient solar roof hooks must be used to ensure that the total effective resistance per panel exceeds the design loads given in Tables B1.4 (ultimate limit state) and Table B1.5 (serviceability limit state). Tables B1.4 & B1.5 give the resultant design loads, F_{sd} and the angle θ at which it acts. These values are given for each load case for both the ultimate limit state and the serviceability limit state.

Tables A1.6 & A1.7 give the design resistance values for each load direction, again for both the ultimate limit state and serviceability limit state. Using these values the effective resistance, F_{rd}, may be calculated along the line of action of each of the resultant design loads, F_{sd}. The average number of solar hooks required per panel is the found by dividing F_{sd} by F_{rd}.

The sketch below is to be changed to one more clearly depicting a solar roof hook.



$$F_{Rd} = \left[\left(\frac{\cos \alpha}{N_{Rd}} \right)^{1,5} + \left(\frac{\sin \alpha}{V_{Rd}} \right)^{1,5} \right]^{-\frac{2}{3}}$$

N_{Rd} = design resistance of the anchor point acting normal to the roof
V_{Rd} = design resistance of the anchor point acting parallel to the roof
F_{Rd} = resultant design resistance acting at an angle α

Number of fixings per solar panel = $F_{sd}(\alpha)$ / $F_{rd}(\alpha)$. The values shown are the minimum for the design cases considered.

Load case	Wind load acting upwards normal to roof				Wind load acting downwards normal to the roof			
Load case	**F_{sd} (N)**	**θ°**	**Frd (N)**	**No. of solar hooks required**	**F_{sd} (N)**	**θ°**	**Frd (N)**	**No. of solar hooks required**
LC 1	**2117**	**30°**			**2117**	**30**		
LC 2	**2240**	**-2.9°**			**2142**	**4.1**		
LC 3	**1559**	**-21.3°**			**2983**	**11.7**		

LC 4	**1064**	**73.3°**			**3140**	**19.7**		
LC 5	**2259**	**-2.6°**			**2050**	**2.8**		

Table A1.8 Minimum number of solar hooks required per panel – Ultimate limit state

Load case	Wind load acting upwards normal to roof				Wind load acting downwards normal to the roof			
Load case	**F_{sd} (N)**	**θ°**	**Frd (N)**	**No. of solar hooks required**	**F_{sd} (N)**	**θ°**	**Frd (N)**	**No. of solar hooks required**
LC 1	**1593**	**30°**			**1593**	**30**		
LC 2	**1589**	**-2.9°**			**1609**	**4.1**		
LC 3	**1104**	**-21.3°**			**2233**	**11.7**		
LC 4	**930**	**73.3°**			**2221**	**19.7**		
LC 5	**1589**	**-2.6°**			**1609**	**2.8**		

Table A1.9 Minimum number of solar hooks required per panel – Serviceability limit state

Dr Nigel Cherry

Annex A2 Tests and calculations for verifying the fastening system of thermal solar collector and photovoltaic modules

1 INTRODUCTION / OBJECTIVE OF THE DOCUMENT

This document presents the tests and calculation that are requested and checked by the CSTB in order to verify the mechanical resistance of the thermal solar and photovoltaic systems.

It aims to be an example and a discussion basis for the CEN/TC 128/WG 3.

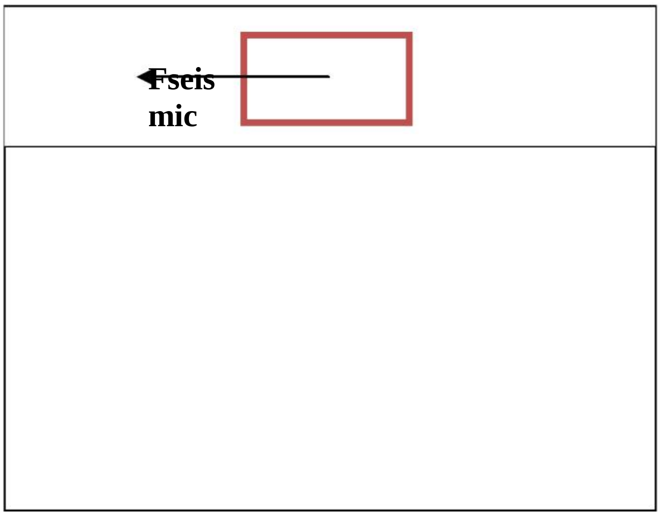
We would like to show you that, depending on the systems, the critical element can be different and in this way, we ask our customers to prove the mechanical resistance by experimental tests and calculations.

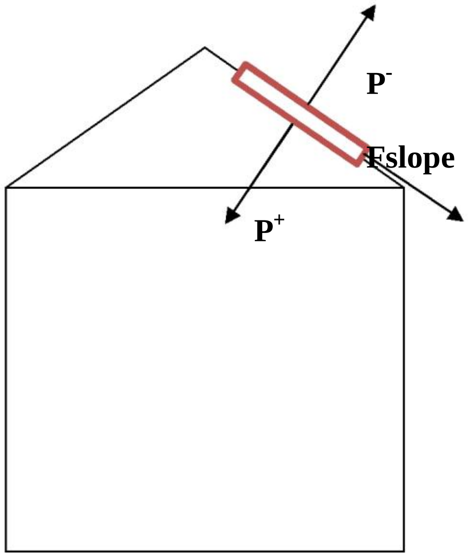
We are aware that the method presented in this document can be improved in order to be more in accordance with the Eurocodes, but we think that it presents an economic advantage (mixing between tests and calculations) and a security aspect.

In this document, the collectors end panels are integrated into the roof.

The objective is to determine the maximum loads for a mounting configuration at ultimate limit state:

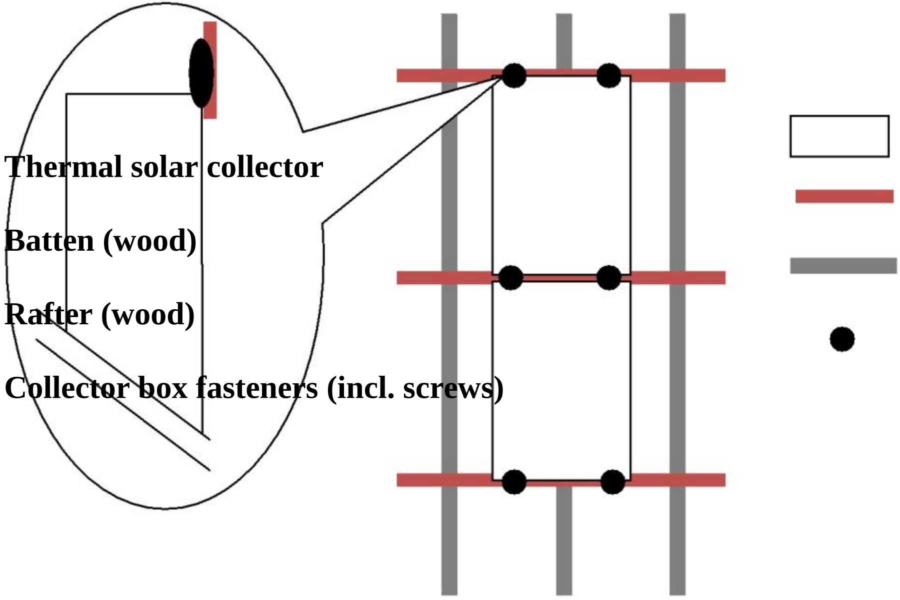
- The negative pressure on the collector / panel : P^-
- The positive pressure on the collector / panel : P^+
- The force in the direction of the slope of the roof (mainly linked to snow, gravity and seismic actions) : F_{slope}
- The force perpendicular to the slope of the roof (mainly linked to the seismic actions) : $F_{seismic}$





2 THERMAL SOLAR COLLECTOR

System design



Example of installation:

The collectors are designed to be installed on a wooden roof structure (rafters). The system is composed of:

2 solar collectors

Collector box fasteners (with wooden screws : 4 screws per fastener) o Additional “heavy” battens (EN 338 class : C24)

The fasteners are the mechanical link between the collector box and the battens. The battens are screwed in the rafters.

The system is designed to be installed on a wooden roof structure (typical distance between rafters: 600 mm).

The collector gross area is 2.5 m²

2.1 DETERMINATION OF P^- AND P^+

2.1.1 TEST OF THE GLOBAL MOUNTING SYSTEM

The system is installed on a simulated wooden roof structure and tested according to a procedure similar to the EN 12179 “Curtain walling - Resistance to wind load”:

A “reference pressure” is determined before test

o Positive pressure test:

- **System is tested at 25%, 50%, 75% and 100% of the reference pressure**
- **Frontal displacement and frontal deflections are recorded**

Negative pressure test:

- **System is tested at 25%, 50%, 75% and 100% of the reference pressure**
- **Frontal displacement and frontal deflections are recorded**

Increased negative load test:

- **System is tested at 150% of the reference pressure**
- **Pressure is then increased until failure**

In this case, the failure mode was:

- **Breakage of glass bead,**
- **Failure of the gluing between glass and collector box.**

Result of this step:

The maximum resistance of (collector + fastener) is the value of the failure with the application of a

security factor (depending on the failure mode). This value resistance $F_{max,12179}$ is an ultimate state resistance.

2.1.2 TEST OF THE ASSEMBLY SCREWS / FASTENERS

Calculations according to Eurocodes are possible but concern only the screws. Because we work on the assembly between fasteners and the batten, we prefer to test it according to the method given in NF P 30-310:

- **12 samples are tested in a tensile testing machine – the failure tension is registered F**
- **The resistance is : P_k = Fm -2s**

Were: $\Sigma -$ **and** $\sqrt{\Sigma(\quad)}$

Result of this step:

The resistance of the assembly at the ultimate limit state is obtained with the P_k and γ_m to take into account the material properties of the support.

2.1.3 CALCULATION OF THE BATTENS

The battens have to be calculated according to Eurocodes 5 to determine its limit states (service and ultimate), for the actual size of the installation, in the worst case.

The service limit state has to be checked.

The resultant on each rafter should also be calculated.

2.1.4 TEST OF THE SCREWS BETWEEN BATTENS AND RAFTERS

These screws can be calculated with Eurocodes or tested in the same way as described in 2.2.2.

2.1.5 DIMENSIONING OF THE RAFTER

The rafter (and the wooden roof structure) is outside from the solar installation. If necessary, it can be calculated using the resultant calculated at 2.2.4.

2.1.6 VALUE OF P^- AND P^+

For each part of the mounting system, it is possible to calculate the equivalent maximum pressure on the collector:

- Global pressure on collector:
- Resistance of fasteners:

In this case: it assumed that the 2 fasteners in the middle are charged with half of the pressure on each collector

- …

The value of P^- is the lower equivalent pressure for the weakest element.

Considering the state of the art and the general implementation of the solar thermal collectors, it is assumed that the system is more resistant to positive pressure than to negative pressure.

So: At least $P^+ = P^-$

2.2 DETERMINATION OF F_{SLOPE}

Resistance to slippage is mostly a result of the resistance of screws and battens.

They all can be tested in the same way than in 2.2.2 with the method explained in the NF P 30-316. F_{slope} is the maximum force in the ultimate limit state

2.3 DETERMINATION OF $F_{SEISMIC}$

In this case, no Fseismic was considered.

2.4 THE USE OF THE RESULTS

In order to use the results above, the calculations are:

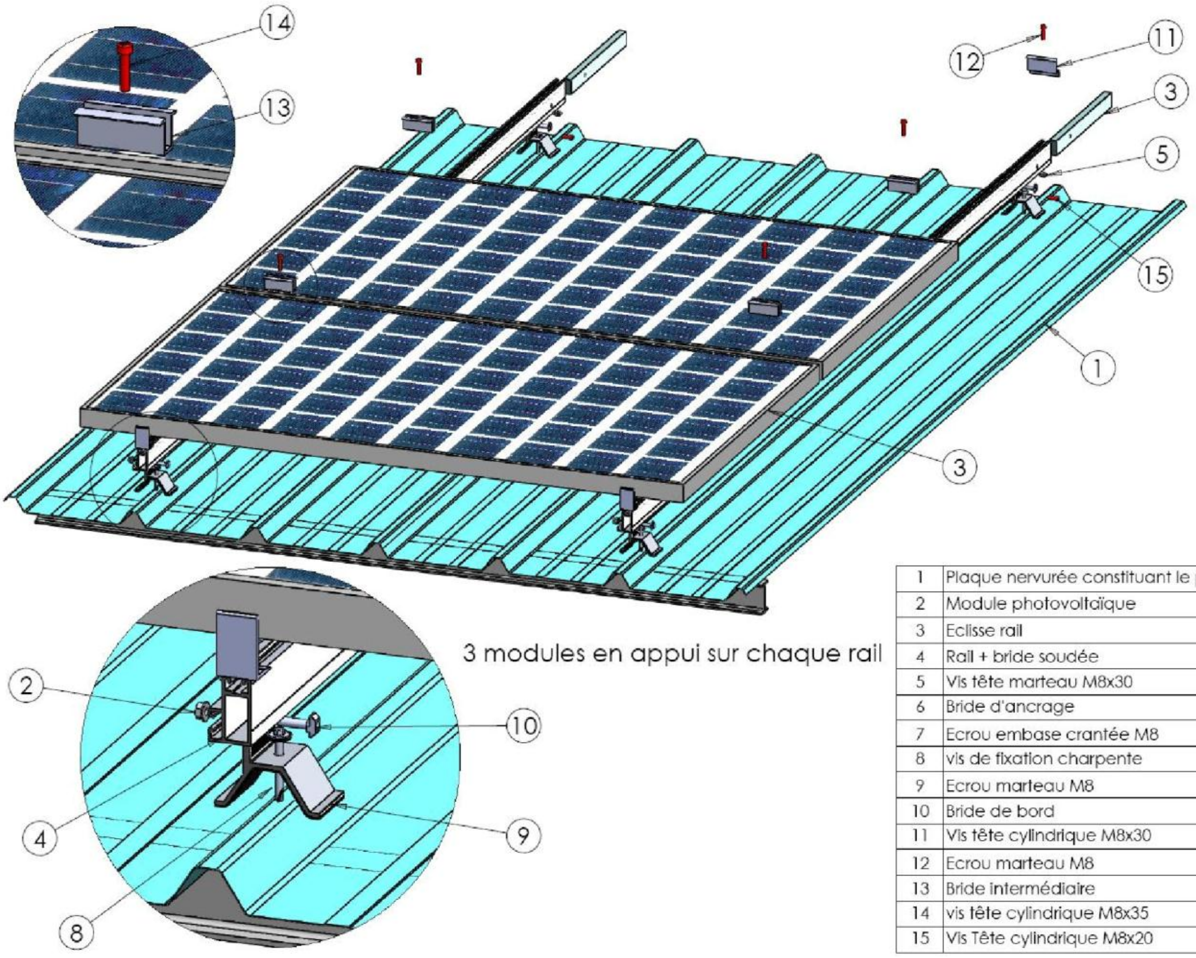
- Calculate each load case – in ultimate limit state (according to Eurocode 0 and Eurocode 1)

- **Project actions onto the axis perpendicular to the collector**
- **Verify whether the actions are lower than the maximum forces determined before.**

3 PHOTOVOLTAIC SYSTEMS

3.1 SYSTEM DESIGN

For example, we will study the case of photovoltaic modules, mounted with clamps on two parallel profiles (in the direction of the roof's slope). These profiles are fixed, through the metallic sheet, on the metallic purlins with specific pieces with screws.



1	Plaque nervurée constituant le plafond étanche
2	Module photovoltaïque
3	Eclisse rail
4	Rail + bride soudée
5	Vis tête marteau M8x30
6	Bride d'ancrage
7	Ecrou embase crantée M8
8	vis de fixation charpente
9	Ecrou marteau M8
10	Bride de bord
11	Vis tête cylindrique M8x30
12	Ecrou marteau M8
13	Bride intermédiaire
14	vis tête cylindrique M8x35
15	Vis Tête cylindrique M8x20

3.2 DETERMINATION OF P^- AND P^+

To determine the maximal P- and P+ that can be supported by the whole system, we have to characterize each assembly:

- **Modules with clamps,**
- **Clamps with profiles,**

- **Profiles with the fixing pieces,**
- **Fixing pieces with the purlins.**

3.2.1 TESTING OF THE GLOBAL MOUNTING SYSTEM

The first step is to test the whole system with its most unfavourable implementation.

However, for photovoltaic systems, the testing can't be sufficient in most cases because the implementation isn't always the same (*same elements, same distance between elements, etc.*), or because the test specimen can't be representative of the most unfavourable configuration for all the elements of the system.

Consequently, the test is majorly used to evaluate the mechanical comportment of the assembly "modules with clamps" because it's very difficult to evaluate it by calculation.

As said before (§2.1.1), the system is tested according to a procedure similar to the EN 12179 until a failure of the test specimen in depression (ultimate limit state): it leads to a value of $F_{failure}^{-}$.

In this case, the test was made especially to test the mechanical resistance of the assembly "modules + clamps" because of numerous configurations of the other elements. The test specimen was representative of the max dimension of modules cantilevered on the profiles.

The failure in depression occurred with the escaping of the module from the clamps. The maximum resistance of the assembly "module + clamps" is the value of the failure $F_{failure}^{-}$ with a safety coefficient for the failure mode. It leads to an ultimate limit state F_{max}^{-}.

For the value of F_{max}^{+}, because of the conception of the photovoltaic modules, an experimental test is needed to prove the intrinsic mechanical resistance of the module: for example, by the same test similar to the EN 12179 in positive pressure until the failure of the specimen. Otherwise, a major safety coefficient can be used on the value of the failure in depression but it's less favourable.

3.2.2 CALCULATIONS OF THE PROFILES

Because the test methods can't verify the constraints and the bending considering the elastic resistance of the profiles, calculations according to Eurocodes are necessary to verify these elements.

The profiles have to be calculated for the real dimensions and implementation, in the most unfavourable way for the ultimate and service limit states to determine the force that leads to their maximal resistance.

Considering the ultimate limit state, it leads to $F_{profile.}$

In this example, $F_{profile}$ was < to F_{max}^{-}, so the maximum value that can be supported by the system has to be $F_{profile}$.

3.2.3 DESIGN OF THE FIXING PIECES

Because the test specimen wasn't representative of the most unfavourable way for the fixing pieces, traction tests were made on these elements: 12 samples were tested and the resistance at the ultimate state is given with the average minus two standard deviations and a safety coefficient γ_m.

In this case, the mechanical resistance of the fixing pieces was much greater than $F_{profile}$.

3.2.4 TEST OF THE SCREWS

As described in §2.1.2, the screws for the fixation of the profiles on the fixing pieces and the screws for the fixation of the fixing pieces on the purlins have also to be tested and verified considering the repartition of the efforts on the system.

3.2.5 VALUE OF P+ AND P-

The value of P^+ and P^- is given by the worst value of each element.

In this case, $P^- = F_{profile}$.

Note : All this verification is made on ultimate limit state. For the service limit state, we consider that it's given by the mechanical test of the NF EN 61215 where photovoltaic modules are tested to withstand 2 400 Pa or 5 400 Pa. Generally, the verification on service limit state is always inferior to these values, so it doesn't make any problem. Otherwise, the system would have to be limited to 2 400 Pa or 5 400 Pa.

3.3 DETERMINATION OF F_{SLOPE}

In this example, the system has to provide two dispositions to avoid the slippage:

- **One disposition on the level of the modules,**
- **One disposition on the level of the profiles.**

The first one is given, for this example, by the geometry of the last fixing piece and by resistance of the screw linked to the profile.

The second one is given by the resistance of the screws that link the profiles to the purlins. In this way, these screws have to be tested with the method explained in the NF P 30-316.

Considering their density and the forces P^+ and P^- that occur, a calculation must determine if the resistance is sufficient. If it's not the case, the screws must be changed to obtain a better resistance or the values of P+ and P- have to be lower.

Note : in this example, the shearing resistance of the screws that fix the profiles isn't sufficient. The screws must also be verified to flexion, in the same principles.

3.4 DETERMINATION OF $F_{SISMIQUE}$

In this case, no $F_{seismic}$ was considered.

3.5 THE USE OF THE RESULTS

In order to use the results above, the calculations are:

- **Calculate each load case – in ultimate limit state (according to Eurocode 0 and Eurocode 1)**
- **Project actions onto the axis perpendicular to the modules.**
- **Verify whether the actions are lower than the maximum forces determined before.**

Annex A3 Solar thermal panel on flat roof stabilised with dead weight

A3.1 Type

Solar thermal panels 2400mmm x 1200mm at an inclination of 45^o, mounted on triangular aluminium frames at 1200mm centres supported on a flat roof surface (without parapets) and stabilised with concrete blocks against sliding and uplift from wind pressures.

A3.2 Climate zone

Central Europe

A3.3 Loads

(a) Dead loads

Weight of solar thermal panel 0.4kN
Weight of supporting frame is ignored for this example.

(b) Imposed wind load at roof height Z

Peak velocity pressure for design, $q_P(Z)$ = 1,0kN/m^2
Overall wind pressure coefficients*:
For 'standard' (or 'central') roof areas -1,45 or +1,1
** based on ÖN M7778*

A3.4 Ultimate load case for uplift and sliding (for standard roof areas)

Imposed load (downward): 0

Ultimate partial factor for dead load (permanent action) $\gamma_G = 0,9$ (equilibrium condition)

Factored dead load of solar panel: W = 0,9x0,4 = 0,36kN

Ultimate partial factor for wind load (variable action) $\gamma_Q = 1,50$

Consequence factor $K_{FI} = 0,9$

Solar panel area 2,0x1,2 = 2,4m^2

Factored ultimate wind load on solar panel P = -1,50x0,9x2,4x1,45x1,0 = 4,70kN acting normal to solar panel surface

Vertical component Pv = 4,70sin45 = 3,32kN

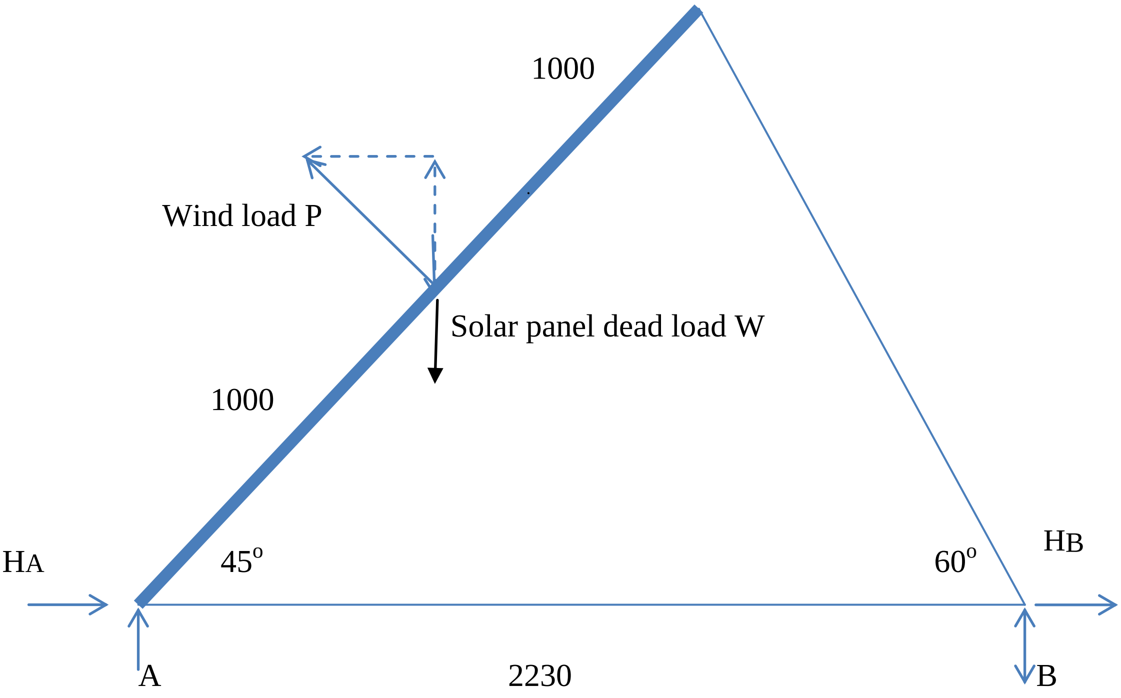
Horizontal component Ph = 4,70cos45 = 3,32kN

A3.5 Serviceability load cases

Not relevant for this example.

A3.6 Ultimate resistance to uplift and sliding

Equilibrium diagram



Vertical or horizontal distance A to centre point of actions = 1000cos45 = 707mm
Inclined distance from A to centre point of actions 1000mm

Determine support reactions VA and VB by taking moments:

Moments around B:
3,32 x 0,707 – 3,32x(2.23 – 0,707) + 0,36x(2.23 – 0,707) – VA x 2,23 = 0
Reaction VA = -0,97kN (uplift)

Moments around A:
-4,70x1,00 + 0,36x0,707 - VB x 2,23 = 0
Reaction VB = - 1,99kN (uplift)

If ultimate sliding force H is shared equally between A and B: HA = HB = 05.P.sin45 = 1.66kN
Weight of concrete holding-down blocks = C kN

The concrete blocks provide resistance to wind uplift and sufficient net downward load (dead weight minus uplift) to provide sliding resistance. For this example the coefficient of friction between the surface of the supporting frame and roof covering is assumed to be 0,3.
Required resistance to sliding at A = (CA – 0,97)x0,3 = 1,66; CA = 6,50kN
Required resistance to sliding at B = (CB – 1,99)x0,3 = 1.6kN; CB = 7,52kN
To allow for wind acting in opposite directions provide CA for both supports.

For concrete blocks 250x250x250, the dead load is 0.35kN each.

Number of blocks required at each support A or B = 7.52/0,35 ≈ 22

The footprint of a solar panel's supporting frame is 1,2x2,23 = 2,68m^2
The average load intensity from the concrete blocks on the roof is 2x22x0,35/2.68 = 5,74kN/m^2

This load is several times higher than normal roof imposed loads, showing that holding-down dead weights are not suitable to be used on roofs to stabilise solar panels against wind uplift and sliding, unless the roof structure is specially designed for this condition. If holding down tension connections to the roof structure are used, precautions should be taken to avoid water leakage through roof penetrations.

If the resistance to sliding is provided by connections, and dead weight is used only to resist wind uplift, the number of concrete blocks required at each support is 1,99/0,35 ≈ 6. In this case the average load intensity from the concrete blocks on the roof is 2x6x0,35/2,68 = 1,57kN/m^2. To check to maximum roof load case, the design snow load should be added. The average roof load from using concrete blocks can be reduced by increasing the footprint area of the supporting frame.

Note that the wind uplift loads are increased by 25% for solar panels installed in the 'local' or 'perimeter' areas of the roof, as defined in ÖN 7778.

DRAFT 2: 01.06.2012

Annex A4 Example of the earthquake resistant design of solar PV panels

A4.1 Description of the system

Below mentioned assumptions have been taken from Annex B1 (Draft 1:12 January 2012)
- The roof has a rafter pitch of 30°, with the solar panels fixed above the roof, parallel to the rafters.
- The combined self-weight of the panels and rails is 18,5 kg/m2.
- The panels have an individual area of 1,386 m2.

Other assumptions have been made as follows:
*Location: Turkey, Second seismic zone
*Moderate earthquake intensity: a seismic action with a 10% probability of exceedance in 50 years **[EN 1998-1:2004, 3.2.1 (3)]**

A4.2 Calculation of the seismic load acting on the panels

The horizontal seismic load acting at the centre of mass of the panel is calculated as follows:
Seismic load = $F_a = (S_a.W_a.\gamma_a)/q_a$ ... (1) **[4.24, EN 1998-1:2004 , 4.3.5.2]**
W_a = the weight of the panel.
γ_a = importance factor of the panel, which ranges from 1.5 for important and/or hazardous elements to 1.0 for all other elements, as defined at EN 1998-1:2004 **4.3.5.3.** In this example, γ_a has been taken as 1.0 for solar panels.
q_a = behaviour factor for non-structural elements equal to either 1.0 or 2.0 depending on their behaviour during earthquake. Behaviour factor, q_a, has been taken for solar panels as 1.0 , regarding to the **Table 4.4** at EN 1998-1:2004 , chapter **4.3.5.4.**
So the equation (1) can be approximated as
$\mathbf{F_a = (S_a.W_a)}$ ... (2)

$\mathbf{S_a}$ is the seismic coefficient for non-structural elements, defined as
$S_a = \alpha.S\ [3(1+z/H)/(1+(1-T_a/T_1)^2)-0{,}5]$ but $Sa \geq \alpha S$ … (3) **[4.25, EN 1998-1:2004 , 4.3.5.2]**
S is the **soil factor = 1**, regarding to the Table 3.2 at EN 1998-1:2004 , chapter **3.2.2.2.**
$\mathbf{T_a}$ is the fundamental vibration period of the non-structural element.
$\mathbf{T_i}$ is the fundamental vibration period of the building in the relevant direction.
-->Equation (3) takes into account the relative flexibility of non-structural element as compared to that of its supporting structure. Since the non-structural elements are generally rigid as compared to the supporting structures, that is $\mathbf{T_a/T_1 \sim =0.0}$
Z is the height of the element measured from the foundation or top of a rigid basement.
H is the building height measured from the foundation or from top of a rigid basement.
-->For the non-structural elements attached at the roof is **z=H**
So the equation (1) can be approximated as
$\mathbf{S_a \sim = \alpha.\ [2{,}5]}$ ... (4)
α is the ratio of the design ground acceleration on type A ground, ag, to the acceleration of gravity g.
$\alpha = a_g / g$
Design ground acceleration on type A ground was formulated as follows;
$\mathbf{a_g = \gamma_I . a_{gR}}$ ... (4)

a_{gR} =reference peak ground acceleration on type A ground. In chapter 3.2.1 (2), at the “Note”, it is pointed out that “The reference peak ground acceleration on type A ground, a_{gR}, for use in a country or parts of the country, may be derived from zonation maps found in its National Annex.”
γ_I =importance factor, which is equal to 1.0 , assigned to the seismic action with a 10% probability of exceedance in 50 years, which is pointed out in chapter 3.2.1. (3)
In the example, the location was assumed as Turkey , second seismic zone. Therefore for α , Turkish Seismic Code has been utilised.

Seismic Zone	**A_0**
1	0.40
2	0.30
3	0.20
4	0.10

Table A4.1 Effective Ground Acceleration Coefficient (Ao) in Turkish seismic code, Chapter 2.4.1 Table 2.2

$\alpha = A_0$ (for second zone) = 0,30
S_a~ = 0,75
$F_a = (S_a.W_a)$
F_a = 0,75 . (18,5 . 1,386) = 19,23 N (horizontal seismic load on a single panel)
Dead Load = m . a = [18,5 kg/m2 . 1,386 m2 . 9,81N/kg] =252 N

A4.3 Seismic load and other loads acting on a single panel

Seismic loads can impact in both directions horizontally, which must be checked first individually, and then the most unfavourable direction must be taken into account.
The loads in the table are derived by multiplying the loads by sin30° or cos30°, as appropriate.

Loads	Force normal to the roof	Force parallel to the roof
Dead Load (N)	218	126
Seismic Load (N)	±9,62	±16,65
Snow Load (N) (derived from AnnexB1)	1162	671

Table A4.2 Loads acting on a single panel (N)

A4.4 Load Combination

Since the wind load and seismic load are lateral loads, and the probability of simultaneously occurrence of both of these loads is low, in this example, they are not considered to act in the same time. For both loads, the calculations must be carried out separately and the most unfavourable load shall be considered.
Based on the Section 3.2.4 and 4.2.4. of EN 1998-1:2004; Section 6.4.3.4 and Table A1.1 & A1.3of EN 1990:2002 the following load cases are considered.
LC1: [1.0 x Seismic load + 1.0 x Dead load]

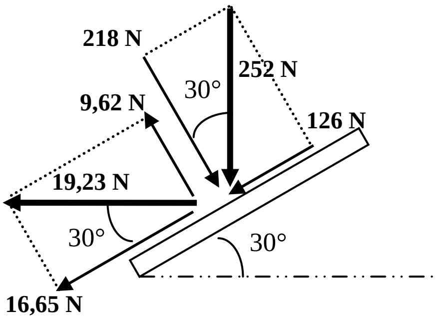


Figure A4.1 Seismic and dead load acting on a single panel (N) (LC1)
LC2: [1.0 x Seismic load + 1.0 x Dead load + 0.2 x Snow Load]

Load case	N_{Ed} (N)	V_{Ed} (N)	F_{Ed} (N)	θ	Dominant Load
LC1	209	143	253	34°	Normal down
LC2	442	277	522	32°	Normal down

Table A4.3 Resultant force acting on the solar hooks

COMMENT !!! *Loads derived from the seismic calculations are generally inconsiderable. Therefore, first of all, the other loads and load combinations acting on the panel must be checked. Then, if necessary, seismic calculations can be added.*

Press Release

Freiburg
November 23, 2012
No. 24/12
Page 1

Fraunhofer ISE Inaugurates New Test Stand for Solar Thermal Collectors

Comprehensive Stress Tests under Different Climates

On 23 November 2012, the Fraunhofer Institute for Solar Energy Systems ISE officially put its new test stand for solar thermal collectors into operation. With this test stand, the scientists aim to simulate mechanical loads under extreme climate conditions e. g. wind or snow loads, analyzing their effects on the solar collectors. Fraunhofer ISE and PSE AG, both located in Freiburg, jointly developed this special mechanical load test stand housed in a climate chamber. The test results shall serve as input for new test procedures and improve the quality and safety standards for solar thermal collectors over the long term. Now with the newly created experimental possibilities, new materials, material savings and optimizations can be analyzed under real-like conditions in order to save costs on collectors and mounting elements.

With the new test stand, Fraunhofer ISE is able to investigate complex questions about the mechanical stability of solar thermal collectors, including their mounting system for roof and façade applications. The test stand can handle collectors up to a maximum of nine square meters and loads up to seven tons push and pull. Another notable feature is that the mechanical load tests can be carried out under extreme temperatures from -40 °C to +60 °C. Additionally, it is possible for the first time to simulate cyclical as well as asymmetric loads, like varying amounts of accumulated snow on the collector, and also how the loads are realistically created through the piling up of snow and ice.” We see a large potential in the new system,” says Korbinian Kramer, Group Leader of Test Center and Quality Assurance at Fraunhofer ISE. “The new test stand enables a more detailed investigation of the connecting techniques and mounting

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system under different temperatures and realistic load cases. This is a decisive advantage over the established test procedures in which the loads are merely applied perpendicularly and at room temperature.”

During the joint development and the manufacture of the new test stand by PSE AG, there were many challenges to overcome. ”The requirements for the test stand were very complex: for example, high flexibility with regard to possible loads and at the same time very large mechanical loads. We employed a lot of technical ingenuity in order to implement all the degrees of freedom necessary for the load tests,” explains Frank Luginsland, Department Head of Technology at PSE AG.

Based on a detailed analysis of the loads, the scientists at Fraunhofer ISE develop a test method which is generally applicable for the different types of collector constructions, compact systems and mountings under different climatic conditions. In the medium-term, this leads to the further development and improvement of solar thermal components. This new test method is offered to manufacturers who want to verify the safety and quality of their product with little effort from their side. Through such tests, both material savings and optimization can be achieved which lead to reduced costs in the installation of large solar systems. The work and the test stand are supported through “MechTest”, a project sponsored from the Federal Ministry for the Environment, Conservation and Nuclear Safety (BMU).

About Fraunhofer ISE

With a staff of 1200, the Fraunhofer Institute for Solar Energy Systems ISE, based in Freiburg, is the largest solar energy research institute in Europe. Fraunhofer ISE is committed to promoting energy supply systems which are sustainable, economic, safe and socially just. It creates the technological foundations for supplying energy efficiently and on an environmentally sound basis in industrialized, threshold and developing countries. To this end, the institute develops materials, components, systems and processes for a total of eight different business areas: Energy-Efficient Buildings, Applied Optics and Functional Surfaces, Solar Thermal Technology, Silicon Photovoltaics, Photovoltaic Modules and Systems, Alternative Photovoltaic Technology, Renewable Power Supply and Hydrogen Technology. Fraunhofer ISE also has numerous accredited test facilities.

About PSE AG

PSE AG provides highly specialized solar testing systems and solar consulting expertise to customers around the world. PSE Solar Test Stands are used by test labs and manufacturers for performance and durability measurements and certification to international standards. PSE Solar Consulting conducts rural electrification consulting and manages international research projects. PSE Conference Management organizes major scientific solar conferences. PSE AG was established in 1999 as a spin-off company of the Fraunhofer Institute for Solar Energy Systems ISE and currently has a staff of 65.

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New mechanical load test stand at Fraunhofer ISE. To investigate the stability and safety of solar thermal collectors under wind and snow loads, the test stand is housed in a climate chamber. ©Fraunhofer ISE

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