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Sončni energijski sistemi za strehe: zahteve za konstrukcijske povezave solarnih plošč

Solar energy systems for roofs: Requirements for structural connections to solar panels

Solare Energiesysteme für Dächer: Anforderungen an konstruktive Verbindungen zu Sonnenkollektoren

Systèmes d'énergie solaire pour les toits : Exigences relatives aux raccordements des panneaux solaires à la charpente

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This draft Technical Report is submitted to CEN members for Vote. It has been drawn up by the Technical Committee CEN/TC 128.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (FprCEN/TR 16999:2016) has been prepared by Technical Committee CEN/TC 128 “Roof covering products for discontinuous laying and products for wall cladding”, the secretariat of which is held by NBN in co-operation with CEN/TC250 “Structural Eurocodes”, CEN/TC254 “Flexible sheets for waterproofing”; CEN/TC312 “Thermal solar systems and components” and CLC/TC82 “Solar photovoltaic energy systems”.

This document is currently submitted to the vote on TR.

Introduction

The following is a summary of the requirements for structural design of the structural connection between solar energy panels and the roof structure as detailed in this Technical Report.

a) Type of solar panel: Thermal or photovoltaic solar panels which comply with the mechanical resistance requirements of EN 12975-1 (solar thermal collectors) or EN 61215 (solar PV panels).

b) Determining of the loads and load combinations: self-weight of the solar panels and relevant imposed snow and wind actions in accordance with EN 1991-1-1, EN 1991-1-3 and EN 1991-1-4. Referring to French Standard NF P78−116 and Dutch Standard NEN 7250for additional data on snow and wind loads on solar panels.

c) Determining the design loads for the solar panels: multiplication of each of the loads by their respective partial factor $\gamma_{G \text{ or }} \gamma_{Q}$ for the ultimate limit state, and separately for the serviceability limit state in accordance with EN 1990.

d) Identifying combinations of most unfavourable design loads which act together at the same time, for the ultimate and serviceability limit states. Modifying the loads by applying a load combination factor ψ to one of the two variable loads which act at the same time.

e) Determining of 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 European Standards:

— EN 1992 series to EN 1996 series, and EN 1999 series for the ultimate and serviceability limit states;

— For the serviceability limit state, determining of the resistance at the specified maximum deformation limiting the function of the connection;

or

— determine the resistance by serviceability and ultimate load tests.

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

Four examples of design calculations for different solar panel connections are given in Annex A.

1 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:

— weather tightness of the roof, solar panels and connections;

— electrical, thermal or mechanical characteristics of the solar panels;

— precautions against fire of the installation.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1990:2002/A1:2005, *Eurocode - Basis of structural design*

EN 1991 (all parts), *Eurocode 1 - Actions on structures*

EN 1992 (all parts), *Eurocode 2 - Design of concrete structures*

EN 1993 (all parts), *Eurocode 3 - Design of steel structures*

EN 1994 (all parts), *Eurocode 4 - Design of composite steel and concrete structures*

EN 1995 (all parts), *Eurocode 5 - Design of timber structures*

EN 1995-1-1:2004/A2:2014 *Eurocode 5 - Design of timber structures - Part 1-1: General - Common rules and rules for buildings*

EN 1996 (all parts), *Eurocode 6 - Design of masonry structures*

EN 1997 (all parts), *Eurocode 7 - Geotechnical design*

EN 1998 (all parts), *Eurocode 8: Design of structures for earthquake resistance*

EN 1998-1:2004/A1:2013, *Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings.*

EN 1999 (all parts), *Eurocode 9: Design of aluminium structures*

EN 1999-1-1:2007/A2:2013, *Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules*

NEN 7250:2014, *Zonne-energiesystemen - Integratie in daken en gevels - Bouwkundige aspecten*

3 Terms and definitions

For the purposes of this document, the terms and definitions for structural design given in EN 1990, the EN 1991 series, the EN 1992 series, the EN 1993 series, the EN 1994 series, the EN 1995 series, the EN 1996 series, the EN 1997 series, the EN 1998 series, and the EN 1999 series apply.

4 Symbols

For the purposes of this document, the symbols for structural design given in EN 1990, the EN 1991 series, the EN 1992 series, the EN 1993 series, the EN 1994 series, the EN 1995 series, the EN 1996 series, the EN 1997 series, the EN 1998 series, and the EN 1999 series apply.

5 Configuration of solar panel installation

The configuration of solar panel installations is classified by the method of mounting on the roof structure, as given in NEN 7250:2014, Clause 3.

6 Design responsibility

The designer should ensure that:

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

— Adequate supervision and quality control are provided in design offices, factories and on site.

— The structure will be adequately maintained.

— The structure will be used according to the design assumptions.

— The building structure can safely support the solar panels according to Eurocode standards of design; building retrofitted with solar panels should also be checked.

7 Thermal solar collectors and PV solar panels

Thermal solar collectors and PV solar panels are collectively called solar panels in this Technical Report.

Thermal solar collectors should comply with EN 12975–1, according to the manufacturer's declared requirements.

PV solar panels should comply with the requirements of EN 61215 or EN 61646.

The structural resistance of the body of solar panels is not considered in this Technical Report. It is assumed that their structural resistance is adequate. Attention is drawn to high snow loads in certain areas of Central and Northern Europe (see EN 1991–1-3:2003/A1:2015, Annex C), acting together with downward wind loads, which should be compared with the structural resistance of solar panels determined by 'mechanical load tests' incorporating adequate safety factors.

8 Principles of limit state structural design

8.1 General

Structural design should be carried out according to the principles of limit states of EN 1990. The ultimate limit state and the serviceability limit state should both be considered, for relevant design situations.

For each limit state:

— the design value of an action is its characteristic value multiplied by the appropriate partial safety factor for the action;

— the design value of the resistance is its characteristic value divided by the appropriate partial safety factor for the material, which should be not less than the design value of the action.

8.2 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 (e.g. for mounting beams of solar panels);

— transient loads (e.g. during execution or repair);

— accidental actions (for exceptional conditions e.g. explosion, impact, disproportionate consequence of local failure);

— seismic actions (in seismic locations only).

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

8.3 Ultimate limit state

The ultimate limit state concerns 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.

8.4 Serviceability limit state

The serviceability limit state concerns the deformation, vibration or damage of the structure under normal use which affect its function, appearance, or discomfort to people.

9 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)

9.2.1 General

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 may be given in National Annexes to the standard.

9.2.2 Imposed loads

Imposed loads are in accordance with EN 1991-1-1.

9.2.3 Snow loads

9.2.3.1 General

Snow loads are in accordance with EN 1991-1-3 and the relevant National Annex. Supplementary information on increased snow load on solar panels at the eaves of pitched roofs in climatic conditions where melting, sliding and re-freezing of snow can occur, is given in NF P78-116.

9.2.3.2 Return period

The ground snow load value may be adjusted according to the return period adopted (see EN 1991-1-3:2003/A1:2015, Annex D), if specified by the National Annex. The return period may be based on the expected design life of the solar panel connections.

9.2.3.3 Sliding snow loads on pitched roofs

Sliding snow loads which act on the framework and connections of solar panels which project above the pitched roof surface should be determined according to EN 1991-1-3:2003/A1:2015, 6.4. They may occur at the same time as vertical snow loads and snow drift loads. Solar panel elements are not designed to resist sliding snow load.

To protect solar panels projecting above the roof surface from heavy sliding snow loads from a long length of pitched roof, snow guards 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.

9.2.4 Wind loads

9.2.4.1 General

The modelling of wind velocity and peak velocity pressure is given in EN 1991-1-4. For site-specific data on climatic information, wind speed distribution maps and altitudes, refer to the relevant National Annex to EN 1991-1-4.

The dynamic pressure of the wind should be derived in accordance with EN 1991-1-4 based on the peak velocity pressure. The characteristic wind load is the dynamic pressure modified by terrain, height and wind pressure coefficients according to the shape and orientation of the structure.

Pressure coefficients for roofs of certain building configurations are given in EN 1991-1-4. Information on pressure coefficients for various mounting configurations of solar panels on roofs and façades is given in NEN 7250.

The effect of wind loads on the roof surface with solar panels installed above it should be considered.

9.2.4.2 Return period

The wind speed may be adjusted according to the return period adopted (see EN 1991-1-4), which is normally assumed to be not less than 25 years, unless otherwise specified by the National Annex.

9.2.5 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 (including sliding snow for pitched roofs) + wind (downward);

— dead load + wind load (upward);

— loads induced by thermal action [for mounting beams].

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

9.2.6 Load combination factor ψ

Where the leading variable action occurs at the same time as other variable actions, the value of the other variable actions may be reduced by multiplying by combination factors ψ (See EN 1990 and design examples in A.1 and A.2).

9.2.7 Partial safety factors for actions

The design value of an action is the characteristic value multiplied by partial safety factor γ_G or γ_Q.

For the ultimate limit state:

— permanent actions: in favourable load combination γ_G = 1,0;

  — in equilibrium condition, e.g. dead load solely providing stability γ_G = 0,9;

  — in unfavourable load combination γ_G = 1,35;

— variable actions: γ_Q = 1,50.

Where design is assisted by wind tunnel testing using an appropriate model of the structure and of the natural wind (see EN 1991–1-4), the value of γ_Q for wind action may be taken as 1,35.

For the serviceability limit state:

— permanent and variable actions, γ_G = 1,0; γ_Q = 1,0.

9.2.8 Consequence of structural failure

Where permitted nationally, solar panels installed on buildings in normal conditions of use may be designated with a consequence class CC1 (EN 1990:2002/A1:2005, Table B.1) corresponding to Reliability Class RC1.

For RC1, a multiplying consequence factor K_{FI} = 0,9 should be applied to unfavourable actions (ultimate limit state only).

For installations requiring consideration of higher risk, see EN 1990:2002/A1:2005, B.3.

10 Structural resistance of connections

10.1 Configuration and type of connectors

The arrangement in number, position and spacing of connectors to solar panels should be not less favourable than the arrangement adopted in the mechanical load test for the body of the solar panel.

10.2 Design by calculation

The structural resistance should be determined by calculation in accordance with one or more Eurocodes the EN 1992 series, the EN 1993 series, the EN 1994 series, the EN 1995 series, the EN 1996 series and the EN 1999 series, for both the ultimate and serviceability limit states, to support adequately the most unfavourable load combinations.

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

Values of γ_M at the ultimate limit state are specified in the relevant Eurocode for structural materials: the EN 1992 series, the EN 1993 series, the EN 1994 series, the EN 1995 series, the EN 1996 series and the EN 1999 series (see design examples C1 and C2). The value of γ_M for the serviceability limit state is 1,0.

10.3 Design assisted by testing

In accordance with EN 1990:2002/A1:2005, 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 EN 1995-1-1), the test results should be modified to take into account the difference in load durations between testing and the design conditions. 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 (EN 1990:2002/A1:2005, 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: EN 1990, the EN 1991 series, the EN 1992 series, the EN 1993 series, the EN 1994 series, the EN 1995 series, the EN 1996 series, the EN 1997 series, the EN 1998 series, or the EN 1999 series).

The design resistance at the limit of serviceability should also be the 5 % characteristic value.

The design resistance at the limit of serviceability is the characteristic value divided by $\gamma_M = 1,0$.

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

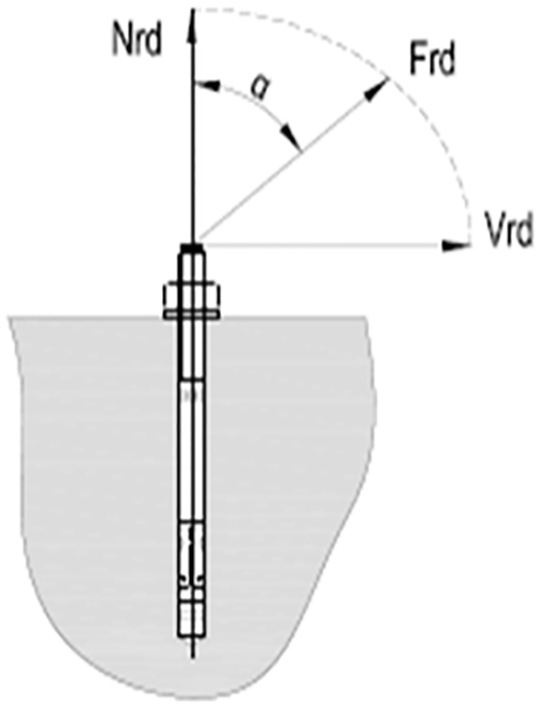

Figure 1 — Resultant value for the load

Where separate tests are carried out on two loads each acting in different directions, the resultant value for the loads acting together may be obtained vectorally by Formula (1):

$$F_{rd} = \frac{1}{\sqrt{(\cos[\alpha / V_{rd}])^2 + (\sin[\alpha / N_{rd}])^2}} \qquad (1)$$

where

- N_{rd} is the design resistance of the anchor point acting normal to the roof;
- V_{rd} is the design resistance of the anchor point acting parallel to the roof;
- F_{rd} is the resultant design resistance acting at an angle α.

For a test method to determine the wind uplift resistance, see NEN 7250:2014, 11.2.

11 Design for accidental action

Solar panel installations normally would not induce progressive collapse of the building to which they are attached, therefore no special measures are required against accidental actions for the structural connections.

In exceptional conditions of high consequence of failure, EN 1991-1-7 provides design advice.

12 Design for seismic action

Design for seismic action should be in accordance with the EN 1998 series and is required only in earthquake areas as indicated in relevant National Annexes to the EN 1998 series, or in national building regulations.