Report

ClickFit Mounting Structure

Calculation on resistance to snow load

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1 Order

1.1 Introduction

On 2 February 2013 Mr T.J. Smidt BSc of Esdec B.V. in has ordered BDA Dakadvies B.V. in writing to perform consulting works for the ClickFit Mounting Structure.

1.2 Aim of the order

The aim of the order is to determine the resistance to loads by snow and ice from the ClickFit Mounting Structure.

1.3 Procedure

The calculations have been performed by Mr G. Koers MSc of BDA Geveladvies B.V.
The strength of the ClickFit Mounting Structure regarding the resistance to snow loads is assessed according to NEN-EN 1991-1-3 +C1:2011 - Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads, including the National Annex.
The calculations on strength have only been performed for the fixing of roof hooks. Therefore the strength of the roof hook, the strength of the roof tile the strength of the batten and the strength of the nail connection (batten to lath) have been examined.

2 Conclusions

The strength of the roof hooks, the roof tiles, the battens and the nail connections is sufficient to absorb the loads (permanent load from the weight of the panel and the snow).
The starting point is that the distance from the panels to the ridge is not more than 2 meters.

3 Data

3.1 System data

The ClickFit Mounting Structure consists of a support rail on which PV panels are fixed with module clamps. The support rail is hooked up to the battens with roof hooks between roof tiles. Because of the variety of roof tile thicknesses the system comprises three bracket thicknesses. This thickness relates to the thickness of the batten together with the thickness of the roof tile. There are two types roof hooks, fixed and adjustable. This concerns the distance of the support rail to the roof tiles. Furthermore there are tools: rail extension sets, auxiliary assembly sets and end clamps. The roof hooks have been fabricated by sawing an extruded aluminium profile in lengths corresponding the width of the roof hooks. This makes it possible to model the roof hooks that fit exactly in the support rail, so no deformations are possible between roof hooks and support rail, except for sliding in longitudinal direction of the support rail. The roof hooks have been fixed to the support rail bending proof.

Rotation of the support rail is prevented by the PV panels that are fixed on top of it. The PV panels are mounted at least on two parallel support rails. The part of the roof hook above the roof tiles rests on the tiles. The maximum width of the roof hook is 63 mm.
The distance between the tile and the support rail is 70 mm (for some types of roof hooks adjustable).
The forces parallel to the plane are transmitted via the ridge of the tile to the battens. For each panel at least 3 roof hooks are applied. In case of two panels next to each other it is possible that in total 6 hooks are applied. The maximum width of the panels is 1,6 m.
A roof hook has a width of 30 mm and a thickness 5 mm. At the thinnest part near to the connection to the support rail the thickness of the hook is 4 mm.

4 Calculations

4.1 Snow load

The ClickFit Mounting Structure is applied on tiled roofs. These are pitched roofs having an angle of pitch between 15° and 60°.
The standard NEN-EN 1991-1-3 indicates that the snow load on the ground s_k depends on the country, the altitude of the site and the location. The snow load may vary between 0,7 (e.g. the Netherlands) and 9,5 kN.m^{-2} (Iceland).
The snow load (s) on a pitched roof is calculated as follows:

$$s = \mu_1 C_e C_t s_{Ad}$$

Where:
C_e is the exposure coefficient; in most cases this is set at 1.
C_t is the thermal coefficient and can be smaller than 1 but for safety reasons it is set at 1.
The value μ_1 depends on the angle of pitch of the roof. This value varies for angles of pitch from 0° up to 60° between, 0,8 and 0. If there are obstacles on the roof, 0,8 shall be taken.
The PV system is interpreted as being an obstacle, so $\mu_1 = 0,8$.
The snow load $s = 0,8 \times S_{ad}$.
For the Netherlands the maximum snow load $s = 0,8 \times 0,7 = 0,56$ kN.m^{-2}.
For the Netherlands according to article 6.2 of the National Annex no local circumstances have to be taken into account.
This could mean that it would not be necessary to examine the system on the resistance to snow loads.
For safety reasons however in this report this is done anyway and it is assumed that the standard snow load is present on the roof part above the panels up to the ridge. In the calculation it is assumed that the snow load can slide and consequently causes loads on the roof hooks.

By weight of the PV panel and the snow load the roof hook is loaded to the following bending moment:
$M_d = (\gamma . G_{panel} + \gamma . G_{snow})$ (distance moments zero point to clamping)
The maximum weight of a panel is 20 kg.

Upper panel at the most 2 meter from the ridge.
The snow load is 560 $N.m^{-2}$ calculated on the plane. Two meters pitched roof (45°) has a projected length of 71% of this.
The load component parallel to the roof is 71% of this.
For each roof hook a calculation value of the load is transmitted to the roof construction of:
$F_d = (200 \times 1,3 + 560 \times 1,5 \times 2) / 3 \times 0,71 \times 0,71 = 326$ N

Where the load factors are taken into account according to NEN-EN 1990 (table NB4).
The bending moment in the roof hook is:
$M_{d\ each\ bracket} = F_d \times 35 = 11410$ Nmm.

4.2 Strength ClickFit roof hooks

The roof hook is clamoed in the support rail.
The roof hooks have been made out of t aluminium with a tensile strength of 165 $N.mm^{-2}$.
The absorption moment is: $M_{absorption} = \sigma_e \times W = 165 \times \sigma_e = 1/6 \times 30 \times 4^2$ Nmm = 13200 Nmm.
This is higher than the moment that is generated by the loads (snow and panel weight): 11410 Nmm.
The strength of the roof hooks is sufficient to carry the weight of the panels including a snow load and with a maximum distance to the ridge of 2 m.
σ_e = yield strength.
W = section modulus.

4.3 Strength roof tiles

The reaction force of the roof hook needs to be transmitted to the battens via the ridge of the roof tile. The reaction force by permanent load and snow is 326 N.
Roof tiles have ridges with a ridge height of at least 10 mm and a total ridge width of 30 mm. In the ridge a compressive stress of 1,1 $N.mm^{-2}$ is present. The compressive strength of the sherd material of the roof tiles is more than 15 $N.mm^{-2}$. The roof tiles will not give way under the weight of the roof hooks.

4.4 Strenght battens

According to the requirements the minimum thickness of the battens is 21 mm. The wood measures of laths varies from 21 mm × 40 mm to 21 mm × 50 mm.
The battens have a maximum span of 600 mm. This means that the battens are supported by laths having a maximum distance of 600 mm centre to centre. The force from the roof hook acts parallel to the plane. The wood stress due to the force from the roof hook must be calculated by having the hook gripped in the middle of the span between two laths.
The bending moment in the lath is:
M_{lath} = ¼ × 326 × 600 Nmm = 48900 Nmm.
The bending stresses in the lath are: M_{lath} / W = 48900 (1/6 × 21 × 40^2) $N.mm^{-2}$ = 8,7 $N.mm^{-2}$.
Pinewood has a bending strength from 18 $N.mm^{-2}$ up to 22 $N.mm^{-2}$. The laths satisfy the strength requirements provided that the lath dimensions are at least 21 mm × 40 mm.

4.5 Verification nail at snow load

In most cases the battens are nailed on the laths.
The most unfavourable situation is that the roof hook has been applied directly next to the nail. Then the force (326 N) from the roof hook is transmitted directly to just 1 nail.

Calculation strength nails

Calculation pull out strength from a nail in axial direction perpendicular to the wood fibre
The pull out strength of nails is determined according to EN 1995-1-1: 2004/A1:2008 - Design of timber structures - Part 1-1: General - Common rules and rules for buildings, article 8.3.1.3: Nailed panel-to-timber connections.
The characteristic pull out strength $F_{v,Rk}$ of an axial loaded nail having a diameter smaller than 3 mm, is (the pull out value is determined according to article 8.40a):

$$F_{v,Rk} = f_{h,k} \times d \times t_1$$

$$f_{h,k} = 0{,}082 \times \rho_k \times d^{-0,3}$$

Where:

d is the diameter of the nails

t1 is the position depth

$f_{h,k}$ is the characteristic pull out strength with an angle α to the fibre direction

The mass ρ_k of preserved wood is 400 kg.m^{-3}. The diameter of the nails is 3 mm.
The minimum adhesion length of the nail is 30 mm.

$f_{h,k} = 0{,}082 \times 400 \times 3^{-0,3}$ N.mm^{-2} = 23,6 N.mm^{-2}.

$F_{ax,Rk} = 23{,}6 \times 3 \times 30$ N = 2123 N.

The typical snow load concerns the load type: short term load duration class 3 according to table 2.2.

k_{mod} (service class 3) = 0,7 according to table 3.1.

The calculation value for the pull out strength according to 2.4.1 is:

$Xd = k_{mod} * X_k / \gamma_m$

(γ_m = 1,3 for connections according to table 2.3).

Calculation value nail fron preserved wood (or heavier) is: 2123 × 0,7 / 1,3 N = <u>1143 N.</u>

The force that can be absorbed by the nail is substantially higher than the load from the roof hook due to panel weight and snow.

Gorinchem, 2013.06.25

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