Roof hook mounting

General information

The installation on pitched tiled roofs is still one of the most frequent kinds of installation for photovoltaic plants. Usually, so-called "roof hooks" or "rafter anchors" are used. An anchor plate usually serves for the fastening to the roof rafter with wood screws, a bar between the roof plates transmits the holding force outwards. On these bars, the load-bearing profiles for the modules are fastened. The geometry of the load transmission is usually considerably limited by the shape of the tile, thus an exact check is required especially if there are heavy loads. As most tiles are grooved above each other, they inevitably have to be cut to shape in most cases, but the tiles must not be weakened in an impermissible manner by these adaptions.

This documents compiles important information on choice of roof hooks, planning and mounting.

Generally it has to be stated that with most photovoltaic plants on roofs, not enough roof hooks are used and to make matters worse the roof hooks often are too weak. In many cases, it is completely ignored where and in what load conditions a specific plant is installed when the dimensioning is created. The damage cases regarding plants and roofs are still rather negligible, but they have already led to increased professionalism. This development is especially positive regarding the reduction of the risks for the installation companies. It should be considered that especially the mounting system that only represents 5 to 8% of the costs of the solar plant is crucial for the stability of the complete plant and thus can be the decisive factor whether or not there are damage cases (for example tile breakage, roof untightnesses, material damage, etc.).

1 Typical faults

A faultless mounting of the hooks is a crucial precondition for the quality and the durabilty of the complete plant and the roof. If grooved tiles are used, a cutting to shape of the tile is inevitable, but the tile definitely must not be weakened in an impermissible manner (see a negative example on the picture at the left). The consequences of faulty mounting are roof leakiness and the danger of tile breakage.

Further main causes of problems generally are wrong hook dimensionings without consideration of local wind and snow loads or faulty mounting without consideration of the minimum distance to the tile. A hook can only take loads and tranfer them into the substructure if it can deform elastically without touching the tile. In case of very heavy local snow loads, a seating-on of the hooks on the tiles may have to be tolerated, even if extra stable roof hook designs are used. In this case, substitute tiles made of sheet metal are recommendable in order to avoid consequential damage (please also see the section "structural dimensioning").

Dimensioning errors can often occur when cross rail system are applied: The increased number of rails of the cross rail construction does not lead to a direct improvement of stability. In most cases, the fastening grids respectively the rail distances are made too big, so that far fewer fastening points than required are installed. One-layer mounting systems often have more fastening points at comparatively low costs. In case of distributed loads (wind load, snow load), a sufficiently high areal density of fastening points is always the decisive factor.

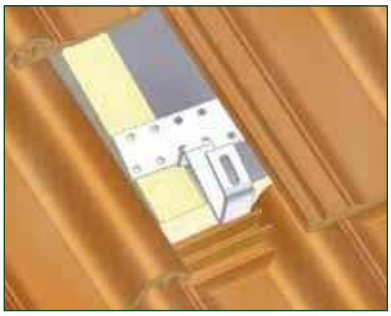
2 Roof forms and selection of suitable roof hooks

First of all, the roof hook used must be suitable for the roof covering. Besides special hooks for special roof forms (plain tile, Tegalit, Bitumen roof), roof hooks of the universal design "Frankfurter Pfanne" of different thicknesses are used for most pantile and grooved tile roofs. In case of doubt, a sampling inspection will show whether or not a roof hook is suitable for a specific roof. It has to be made sure that not only the type of tile, but also the type and the thickness of the battens are taken into account when the hook design is selected. In order to limit the variety of designs, usually all hooks are adapted to the lower tile forms. With higher tiles, underlay plates under the mounting plates may be required. Plywood plates or also aluminum underlays (bottom right picture) that are suitably combined regarding thickness can be used.
As the flat areas of the tiles mostly are not placed directly above the middle of the rafter, a wide mounting plate makes it possible to install the hook also laterally shifted.

In order to cope with different structural loads, there are numerous roof hook forms with different thicknesses (for example the Schletter designs EcoG, EcoS, VAMax, VaMax2 are available for "Frankfurter Pfanne" tiles). This allows an adaption to the location. There are also adjustable versions of many roof hook types to even out roof unevenesses. But is has to be kept in mind that the adjustment range is limited for constructional reasons. In case of very uneven roofs, solutions that "follow the roof shape" can be preferable, as such roofs mostly are not absolutely dimensionally stable in most cases.

3 Roof hook mounting

The guidelines for roof hook mounting can be looked up in the respective mounting instructions. But the essential steps are also displayed in the following pictures. Generally, a modification of the tiles is unavoidable, but the tiles must not be weakended in an impermissible manner. When mounting the roof hooks, it has to be made sure by all means that there is a distance of ca. 5 mm between the roof hook and the tile below on all sides, so that the hooks can elastically deform under load.



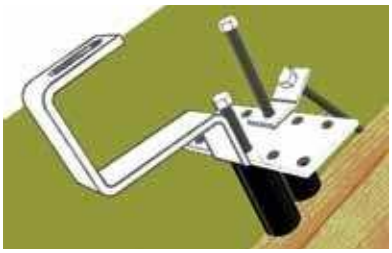
Mounting with aluminum underlay shims

4 Fastening screws

The structural calculations are always based on the assumption that there are at least 2 screws per roof hook (one screw in the upper row of holes and one screw in the lower row of holes. For better load distibution, these 2 screws should NOT be arranged directly above each other. This is also important in order to avoid too much stress on the wood.), a minimum penetration depth of 70mm is recommended. The minimum diameter of the screws is 8mm. Thus, a screw size of 80x80 is suitable for unboarded roofs; 8x120mm should be used for roofs with wood boarding and counterbattens. Galvanized screws may be used if the installation site is reliably dry and ventilated and if there is no aggressive atmosphere, otherwise, quality steel is recommended. Different screw designs can be used as far as there is an accordant design approval. Due to their design, normal Spax screws are not approved.

In order to safeguard load transmission, roof hooks should always be fastened to the supporting structure of the roof (rafters, purlins). It is not permissible to hinge the hook into the nailed batten, because the holding forces that have to be transmitted due to wind suction cannot be reliably verified in this case.

On roofs with on-roof insulation, hooks can usually be screwed to the rafter using long screws (for example Schletter Iso07 system). Depending on the roof structure (are there pressure stable roof battens or not?), the pressure force can be transferred by distance tubes. An additional inclined screw transmits the downhill-slope forces into the constrution (see picture on the right).



System Iso07

5 Structural dimensioning

In order to avoid damage caused by snow loads, a structurally sufficient dimensioning of the roof hooks has to be safeguarded by all means. Especially regarding the snow loads, there are very big differences in Germany between regions with normal loads (for example 0.55 to 0.75 kN/m²) and heavier loads (up to 5kN/m²). Only if the mounting system and the building that provides the substructure are optimally synchronized, there will be an economic and safe solution. Especially since the introduction of the new standardization (wind loads acc. to DIN 1055, part 4 (03/2005) and Eurocode 1 (06/2002), snow loads according to DIN 1055, part 5 (06/2005)), the regional load differences have considerably increased. In regions with heavy snow loads, roof hooks on every rafter are generally recommendable to safeguard a uniform loading of the roof. With heavy snow loads, substitute tiles made of sheet metal are generally recommendable, as the hook might touch the tiles (depending on the specific structural dimensioning).

Snow load distribution in Germany

Moreover, the required number of roof hooks per square meter of module area can be looked up in the structural dimensioning charts. The information required regarding local wind and snow loads is availabe as the postal code-based internet service "load determination" by the Schletter GmbH, for example. In the dimensioning of the number of roof hooks, the numbers for edge and border areas of the roof have to be increased, if necessary. For the first two rafters of the edge areas, one roof hook each is generally recommended in order to compensate the increased loading caused by wind turbulences.

Information about the roof hook arrangement

A pitched roof is structurally dimensioned as a unit, the service loads are evenly distributed and transmitted into the roof structure. When a PV-plant is installed, the bearing capacity for distributed loads must be maintained, as the roof has to bear the load of the PV-plant in addition to the snow load. Especially with high loads, roof hooks have to be fixed to every rafter, as every rafter has to bear part of the load after of mounting of the photovoltaic plant.
If there are heavy distributed loads, it is not reasonable to save costs by mounting extra stable hooks to only every second rafter.

Extra information on modular systems

The wide range of loads at different locations (for example snow loads of 0.6kN/m² on flat plains, up to 5kN/m² and more in higher regions), shows that a professional planning and dimensioning of a fastening system always must be based on the specific regional loads. Especially with pre-fabricated modular systems, this fact is often ignored. As a dimensioning of all systems based on the **worst case** and the maximum loads is economically not feasible, the selection and dimensioning has to be carried out considering the specific site of application.

System dimensioning

Especially the selection of roof hooks is decisive for the overall stability of the system, but it has to be made sure that all the components are suitable for the wind and snow loads at the installation location. Besides the rails, especially the modules are decisive. The warranties by the producer only apply, if the module is also approved for the loads at the respective location (please also consider the ➲ general information on module mounting).

6 "Seating-on" of the roof hook

It is a common error that the roof hook never touches the tile if the roof hooks are selected according to structural charts and the charts of the respective producer and according to the specific regional loads. However, considering the extreme snow loads that occur in individual regions, it is generally not even possible to avoid any contact between the tile and the hook. But it also has to be mentioned that the structural calculations in Germany include the maximum snow loads that statistically occur once in a period of 50 years.

Thus, the structural programs and charts of many producers "silently" tolerate the seating-on of the roof hook on the tile, but in most cases, the installer does not know that. Especially if there is an unfavorable roof hook arrangement, unpermissible load transmissions to the tiles below the hooks can arise that will inevitably lead to tile breakage under load.
In order to make all required data available to professional plant planners, the structural analyses that we create for our roof hooks cover both situations. So, the roof hooks can be looked up in the chart or calculated using a special programm considering "seating-on". But if a touching of the roof tile by the roof hook is supposed to be avoided even under extreme loads, the required values "without seating-on" can be looked up in the chart. Of course, in this case a higher number of roof hooks and maybe also a more stable type of rook hook is required. In this case, the roof hook only deforms elastically under load and returns to its original position when there is no load effect anymore.

Anlage 4: Tafel zur Ermittlung der erforderlichen Anzahl Dachhaken pro Flächeneinheit 1 m² - Elementneigung 30°

(ohne Aufsitzen)

Typenbezeichnung Dachhaken		Windzone 1: h<10 m (0,5 kN/m²)						Windzone 1: 10<h<18 m (0,65 kN/m²) Windzone 2: h<10 m (0,65 kN/m²)						Windzone 1: 18<h<25 m (0,75 kN/m²) Windzone 2: 10<h<18 m (0,80 kN/m²) Windzone 3: h<10 m (0,80 kN/m²)						Windzone 2: 18<h<25 m (1,10 kN/m²) Windzone 3: 10<h<25 m (1,10 kN/m²)					
		Bodenschneelasten = s_k kN/m²						Bodenschneelasten = s_k kN/m²						Bodenschneelasten = s_k kN/m²						Bodenschneelasten = s_k kN/m²					
		0,65	0,85	1,00	1,10	1,25	1,50	0,65	0,85	1,00	1,10	1,25	1,50	0,65	0,85	1,00	1,10	1,25	1,50	0,65	0,85	1,00	1,10	1,25	1,50
Rapid²⁺ 45	101001-000	0,90	1,10	1,25	1,35	1,50	1,75	0,92	1,12	1,27	1,37	1,52	1,77	0,94	1,14	1,29	1,39	1,54	1,79	1,32	1,32	1,33	1,43	1,58	1,83
Rapid²⁺ 45V	101001-001	1,13	1,38	1,56	1,69	1,87	2,18	1,17	1,41	1,60	1,72	1,91	2,21	1,20	1,45	1,63	1,76	1,94	2,25	1,27	1,52	1,70	1,82	2,01	2,32

Roof hook chart "without seating-on"

Anlage 4: Tafel zur Ermittlung der erforderlichen Anzahl Dachhaken pro Flächeneinheit 1 m² - Elementneigung 30°

(mit Aufsitzen)

Typenbezeichnung Dachhaken		Windzone 1: h<10 m (0,5 kN/m²)						Windzone 1: 10<h<18 m (0,65 kN/m²) Windzone 2: h<10 m (0,65 kN/m²)						Windzone 1: 18<h<25 m (0,75 kN/m²) Windzone 2: 10<h<18 m (0,80 kN/m²) Windzone 3: h<10 m (0,80 kN/m²)						Windzone 2: 18<h<25 m (1,10 kN/m²) Windzone 3: 10<h<25 m (1,10 kN/m²)					
		Bodenschneelasten = s_k kN/m²						Bodenschneelasten = s_k kN/m²						Bodenschneelasten = s_k kN/m²						Bodenschneelasten = s_k kN/m²					
		0,65	0,85	1,00	1,10	1,25	1,50	0,65	0,85	1,00	1,10	1,25	1,50	0,65	0,85	1,00	1,10	1,25	1,50	0,65	0,85	1,00	1,10	1,25	1,50
Rapid²⁺ 45	101001-000	1,18	1,43	1,62	1,75	1,94	2,26	1,21	1,47	1,66	1,79	1,98	2,30	1,25	1,50	1,69	1,82	2,01	2,33	1,32	1,57	1,76	1,89	2,08	2,40
Rapid²⁺ 45V	101001-001	0,92	1,12	1,27	1,37	1,53	1,78	0,94	1,14	1,29	1,40	1,55	1,80	0,96	1,16	1,32	1,42	1,57	1,83	1,00	1,21	1,36	1,46	1,62	1,87

Roof hook chart "with seating-on"

Menu item "seating-on" in the calculation program

System PP	109004-000	0,60	0,73	0,83	0,90	1,00	1,17	0,61	0,74	0,84	0,91	1,01	1,18	0,72	0,76	0,86	0,92	1,02	1,19	1,03	1,03	1,03	1,03	1,05	1,22
Mönch Nonne	109005-000	0,98	1,21	1,39	1,50	1,67	1,96	0,99	1,22	1,39	1,51	1,68	1,97	1,00	1,23	1,40	1,52	1,69	1,98	1,07	1,25	1,42	1,54	1,71	2,00

Die ausgewiesenen Werte gelten für als Dreifeldträger ausgeführte Montagesysteme. Die Windlasten gelten für Aufstellung im Binnenland unter regelmäßigen Bedingungen, Einordnung nach Windzone und Aufstellhöhe.
Bei Standorten in Küstennähe oder an exponierten Lagen (Kuppen und Wannen) sind größere Windlasten zu erwarten. Bei Anwendungsfällen außerhalb der Profiltafeln wird empfohlen, einen fachkundigen Planer hinzu zu ziehen.
Hinweis: Sofern mit Aufsitzen gerechnet wurde, wird der Einsatz von Blechpfannen empfohlen. Eine Distanz von 5 mm zwischen Dachhaken und Dachpfanne muss eingehalten werden.
Bei Dacheindeckung mit Biberschwanz wird grundsätzlich die Verwendung von Blechpfannen empfohlen.

Additional information in charts "with seating-on"

Of course, the selection of the number and the type of the roof hook is also an economic question. A potential "seating-on" of the roof hooks on the tile is often accepted by the installers, because there have been good experiences in practice. This is also partly justified by the DIN EN 1034 that pre-assumes a certain load-bearing capacity of new tiles. The final decision is left to the plant planner. Warranties by the manufacturers of fastening sytems are only valid if the specific guidelines are observed.
In practice, it has to be considered that aged tiles often only have a considerably reduced load-bearing capacity. With concrete tiles, the risk of breakage is higher when they are new, as concrete has a very slow hardening behaviour.

EN 1304:2005 (D)

4.4.2 Bending load-bearing capacity

The bending load bearing criteria are not applicable to special form tiles.

The tests are regarded as satisfying, if the tiles do not break under a minimum load acc. to EN 538:

- 600 N for plain tiles;
- 900 N for grooved tiles with a flat visible surface;
- 1000 N for Spanish tiles;
- 1200 N for all other kinds of tiles.

Load-bearing capacity of form tiles according to DIN EN 1304

Especially in areas with heavy snow loads, the seating-on of the roof hooks on the tiles can only be tolerated if consequential damage to the roof definitely can be ruled out. This can usully be made sure by mounting substitute tiles made of sheet metal beneath the roof hooks. Using suitable battens and planks as underlay components, it has to be made sure that this “tile” is not unsupported, but can rest solidly on the roof structure. With such heavy loads, it is also required to mount a sufficient number of roof hooks in order to transmit the loads evenly into the roof structure.

The following pictures show an example mounting of a sheet metal tile.






7 Roof hook material

Still different kinds of materials with different properties are used for roof hooks:

Galvanized steel

Galvanized steel of suitable quality is quite suitable to be used as a roof hook, but it has to be taken into account that, according to the standards, only hot-dip galvanized steel is approved for this kind of exterior application.

Aluminium

When it is suitably shaped, aluminium can be optimized rather well for the loads that actually occur. But due to the roof tile covering, the bar widths are always limited, which is a problem.

High-grade steel 1.4301 or higher quality

High-grade steel 1.4301 (also V2A) has very good production characteristics (good weldability, tough, elastic, bendable) and also good use properties, especially due to its good corrosion behaviour. A significant structural property is the tolerant load and breakage behavior. Whereas an aluminum hook is defined very close to its breakage level when the structural analysis is carried out correctly, a quality steel roof hook has a considerably higher load-bearing capacity until it reaches its breakage limit compared to other materials. These big load-bearing capacities can become decisive especially regarding the wind resistance if it comes to climatic changes in the future.
Only high-grade steel 1.4301 is generally approved by the building authorities (Z-30.3-6).

High-grade steel 1.4016 or similar materials

This High-grade steel is often used for roof hooks due to its low price. But as this material is "poorly weldable", poorly bendable", "not suitable for exterior applications" (taken from: “material characteristics VA”) , it is only condionally usable for roof hooks.
There is no general approval by the building authorities.

8 Water-tightness of the roof

In this document, it has already been mentioned several times that the installer of the plant generally has to bear a rather high risk due to the numerous different technical aspects (PV-plant, roof, AC-installation, lightning protection, etc.) and is liable for damage in many respects. In this context, we again would like to mention the water-tightness of the roof. When roof hooks are installed, many potential weak spots are created that can cause problems especially on low pitch roofs. Thus, you must not forget that tile producers only guarantee a limited water-tightness of roofs with low pitches. The following example data by a renowned tile producer are supposed to help to detect problems:

Grooved tiles
- are recommended for roof pitches of 30 degrees or more.
- are only recommended in special cases (tight sarking membrane, glued if necessary) for roof pitches of 24 degrees or more

Flat roof tile MZ3
- are usually recommended for roof pitches of 22 degrees or more.
- are only recommended in special cases (tight sarking membrane, glued if necessary) for roof pitches of 16 degrees or more

Plain tiles
- like grooved tiles

Frankfurter concrete tile
- like MZ3

With very flat roofs, it is recommendable for the installer to point out potential water-tightness problems in the contract.

9 Summary

Even though photovoltaic plants have been installed on a large scale for many years now, especially in the area of mounting and roof modification there are still many aspects that are not handled with sufficient professionalism.
Intense communication between the producers of the different solar plant components (modules, mounting systems, etc.) and a permanent information transfer to the installers in the form of documentations, workshops, etc. will help to serve the market in the long run and to promote the transition to renewable sources of energy.

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